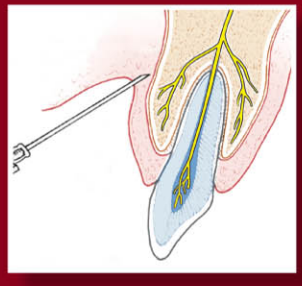
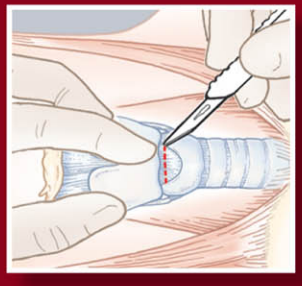
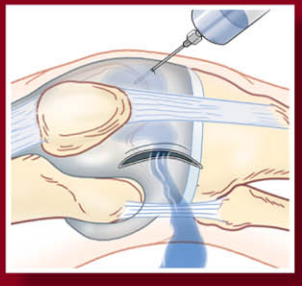
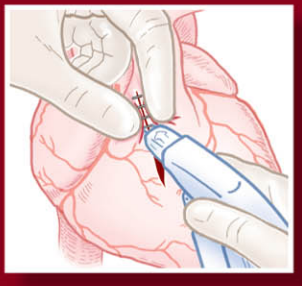


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Eric F. Reichman

Second Edition

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Emergency Medicine Procedures

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Emergency Medicine Procedures

Second Edition

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To my wife, Kristi. Thanks for your patience with the semi-permanent card table and computer in the living room, and the mess with all the papers and files. Thanks for your support and understanding. Thanks to Joey, Jake, Rocky, and Phoebe for entertaining me each day.

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Preface

The scope of Emergency Medicine is extremely broad and covers the neonate through the geriatric, surgical, and medical, and encompasses all organ systems. Emergency Medicine is rapidly evolving to reflect our increasing experience, knowledge, and research. Procedural skills must supplement our cognitive skills. Achieving proficiency in procedural skills is essential for the daily practice of Emergency Medicine. We have produced a clear, complete, and easy-to-understand textbook of Emergency Medicine procedures. This text will provide all practitioners, from the medical student to the seasoned Emergentologist, with a single procedural reference on which to base clinical practices and technical skills.

The primary purpose of this text is to provide a detailed and step-by-step approach to procedures performed in the Emergency Department. It is expressly about procedures. While well referenced, it is not meant to be a comprehensive reference but an easy-to-use and clinically useful procedure book that should be in every Emergency Department. The contents and information are complete. It is organized and written for ease of access and usability. The detail is sufficient to allow the reader to gain a thorough understanding of each procedure. When available, alternative techniques or hints are presented. Each chapter provides the reader with clear and specific guidelines for performing the procedure. Although some may use this text as a library reference, its real place is in the Emergency Department where the procedures are performed. Despite its size, we hope that this book will find its way to the bedside to be used by medical students, residents, and practicing clinicians.

This book will satisfy the needs of physicians with a variety of backgrounds and training. While this text is primarily written for Emergentologists, many other practitioners will find this a valuable reference. This book is written for those who care for people with acute illness or injury. Medical students and residents will find this an authoritative work on procedural skills. Medical students, residents, nurse practitioners, physician's assistants, and practitioners with limited experiences will find all the information in each chapter to learn the complete procedure. Family Physicians, Internists, and Pediatricians will find this text useful to review procedures infrequently performed in the clinic, office, or urgent care center. Intensivists and Surgeons involved in the care of acutely ill patients will also find this book a wonderful resource. The experienced clinician can get a quick refresher on the procedure while enhancing their knowledge and skills. Physicians actively involved in the education of medical students and residents will find this text an easy-to-understand and well-illustrated source of didactic material.

The text has 16 sections containing 195 chapters. The contents are organized into sections, each representing an organ system, an area of the body, or a surgical specialty. Each chapter is devoted to a single procedure. This should allow quick access to complete information. The chapters have a similar format to allow information to be retrieved as quickly and as efficiently as possible. There are often several acceptable methods to perform a procedure. While alternative techniques are described in many chapters, we have not exhaustively included all alternative techniques. Key information, cautions, and important facts are highlighted throughout the text in bold type.

Each chapter, with a few exceptions, has a standard format. The relevant anatomy and pathophysiology are discussed followed by the indications and contraindications for the procedure. A list is provided of the necessary equipment. The patient preparation, including consent, anesthesia, and analgesia, is addressed. The procedure is then described in a step-by-step format. Cautions are placed where problems commonly occur. Alternative techniques and helpful hints for each procedure are presented. The aftercare and follow-up are discussed. Any potential complications are described, including the methods to reduce and care for the complications. Finally, a summary contains a review of any critical or important information.

This book covers a wide variety of procedures. We have made an effort to think of most procedures that may be performed in a rural or urban Emergency Department and have incorporated it into this text. This includes procedures performed routinely or rarely. It also includes procedures that are often performed in the acute care, clinic, and office setting. Some of the procedures in this book may be performed frequently in the daily practice of Emergency Medicine, such as laceration repair or endotracheal intubation. Other procedures, such as a cricothyroidotomy, are seldom to rarely performed but critical to the practice of Emergency Medicine. While many of the procedures are well known to the Emergentologist, some are uncommon and may not be known to the reader. This provides an opportunity to acquire new information that may be converted, with proper practice and training, into a useful skill. A few of the procedures are performed only by Surgeons. They are included to promote understanding by those who may later see the patients in the Emergency Department and have to provide emergent care for a complication. This edition has added chapters to cover additional procedures, especially the Respiratory section. A few chapters of seldom used procedures have been eliminated.

We have drawn on a wide variety of authors. The majority of authors are residency-trained, board-certified, and practicing Emergentologists. We have the honor of having many contributors from outside the field of Emergency Medicine, who are experts in their own specialty. The authors do have biases because of differences in education, experience, and training. We have tried to base all recommendations on sound clinical and scientific data. However, we have not excluded personal experience or preferences when appropriate. In these cases, the authors also present alternative techniques.

Hopefully, this book has grown and changed with this second edition. Suggestions from you, the reader, would be most appreciated. Let us know what additional procedures should be included or excluded in the future.

Eric F. Reichman, PhD, MD

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SECTION 1

Introductory Chapters

1 Informed Consent for Procedures in the Emergency Department

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This chapter is designed as a practical reference for the Emergency Physician (EP). It focuses on the unique challenges of informed consent in the Emergency Department (ED). It presents a practical guide for the informed consent process, reviews the exceptions, and offers suggestions on difficult scenarios of informed consent in the ED.

INFORMED CONSENT

The right of a patient to make decisions about their body, including the refusal of recommended procedures and treatment, is an important concept in medical practice with foundations in law and medical ethics. **Informed consent is the process of communication that demonstrates a physician's respect for a patient's right to make autonomous decisions about their healthcare. Informed consent is both an ethical practice and a legal requirement for all procedures and treatments.**

UNIQUE CHALLENGES OF INFORMED CONSENT IN THE ED

Each practice environment presents its own challenges to the process of obtaining informed consent. Physicians frequently fail to fulfill all the requirements of obtaining informed consent.[1] The ED presents significant challenges, which, despite assumptions to the contrary, results in a greater need to spend time delivering information and engaging patients in their care decisions to the fullest extent possible (**Table 1-1**). Time pressure and acuity are the most critical factors that influence the care paradigm in the ED. Care provided in the ED spans the full continuum of care (nonacute care is increasingly sought in the ED) and addresses the full spectrum of society (patients from diverse health literacy, language origins, socioeconomic backgrounds, and other recognized vulnerable populations—elderly, children, prisoners). Emergency Physicians need to be prepared to address the broad clinical needs of diverse patients under pressure without the historical physician–patient relationship. Systemic constraints exacerbate this challenged professional context as patients have no choice in the treating physician or the treating facility, which is often dictated by EMS protocols. Tension may arise when a patient's wishes conflict with greater societal or institutional needs for efficiency and protocol compliance independent of the patient's preferences and needs. Examples include a trauma activation or a public health emergency. Increasing space constraints and crowding found in most EDs create a lack of privacy that can impede the free exchange of sensitive information. Procedural interventions in the ED are often concurrently diagnostic and therapeutic, further complicating informed decisions.

TABLE 1-1 Challenges for the Emergency Physician to Spend Time Engaged in Conversation with a Patient

Time pressure
Little privacy
Pace of care challenges lay person decisions
No prior relationship
Lack of facility choice
Public health- or system-imposed constraints

The torrent of complex medical information physicians provide patients is overwhelming in the most controlled settings, and is only made worse in the high emotion and high stress environment of the ED. Emergency Physicians often make rapid decisions with limited information on a daily basis. Many of our colleagues in other specialties may not share this skill, and our expectations of patients must be equally, if not more, tolerant. The absence of an ongoing physician–patient relationship offers no basis on which to build trust, elicit values, and draw preference knowledge. Lack of a prior relationship tests the EP's ability to establish an immediate rapport with the patient, and renders the patients' ability to express their values most important.

When there is uncertainty about a patient's preferences or a potential refusal, there may not be time to ponder the intricacies of medical ethics in the ED or to satisfy all the requirements of searching for the best surrogate decision maker. Many EPs will default to doing as much as possible in these difficult situations,[2] but there is often enough time to make a considered decision before acting in the most aggressive fashion. While some say that it is easier to withdraw care once the clinical picture becomes clearer, this aggressive course of action must be balanced with the knowledge that EPs may be performing a painful or unwanted procedure on a patient who has previously made their wishes clear. Traditionally, informed consent was often bypassed under the presumption that a patient would want aggressive treatment. The scope of ED care and societal norms have shifted in recent years. Informed consent for procedures in the ED needs to reflect the current standards of practice.

LEGAL FOUNDATION FOR INFORMED CONSENT

Consent originates in the legal doctrine of battery (touching of the body without permission). The notion of protecting a patient from the bodily trespass of a procedural invasion was framed by Justice Cardozo in 1914, "[e]very human being of adult years and sound mind has a right to determine what shall be done with his own body; and a surgeon who performs an operation without his patient's consent commits an assault, for which he is liable in damages…."[3] By 1957, the notion of consent shifted from mere permission to an authorization following "the full disclosure of facts necessary to an informed consent."[4] Emerging at the same time as the bioethics movement's shift away from paternalistic medicine toward a patient's rights focus in medicine was *Canterbury v Spence*.[5] This case resulted in **an appeals court establishing a physician's duty to disclose the risks and benefits of a procedure and its alternatives and introduced the reasonable patient standard. The reasonable patient standard is what a reasonable patient would**

need to know to make an informed choice shifting away from the professional standard, what most physicians deemed necessary. Today, the standard for disclosure varies by state.[6] As a result of the informed consent "duty," the legal and risk management function of informed consent (consent process that meets institutional and/or legal parameters for formal recognition referred to as **'effective consent'**) overshadows the ethically driven process of informed consent (consent as communication process that demonstrates respect for a patient's autonomy referred to as **'autonomous authorization'**). Often conflated under the "informed consent," these two aspects serve distinct functions. Both are necessary for valid informed consent and are addressed separately throughout this chapter.[7]

LEGAL FOUNDATION OF THE EMERGENCY EXCEPTION

The exception presuming permission to treat in an emergency has equally deep roots. Justice Cardozo's opinion continues, "[t]his is true except in cases of emergency where the patient is unconscious and where it is necessary to operate before consent can be obtained."[3] In *Canterbury v Spence*, "the emergency exception" is included as a privilege from the duty to disclose when "the patient is unconscious or otherwise incapable of consenting, and harm from a failure to treat is imminent and outweighs any harm threatened by the proposed treatments." It also states that a "physician should, as current law dictates, attempt to secure a relative's consent if possible." **In the emergency context one may presume permission: (1) to do what is necessary when (a) there is imminent harm from nontreatment and (b) harm from nontreatment outweighs the harm from the proposed intervention; (2) where the patient is unconscious or unable to participate in care decisions; and (3) the patient's preferences are not known and no surrogate is immediately available to provide authorization.**[8]

ETHICAL FOUNDATION FOR INFORMED CONSENT

In an era of patients' rights and shared decision making, robust informed consent reflects a process of communication that secures that a patient "gives an informed consent to an intervention if (and perhaps only if) one is competent to act, receives a thorough disclosure, comprehends the disclosure, acts voluntarily, and consents to the intervention."[9]

It is not uncommon to encounter the challenge of a patient refusing a recommended procedure or intervention in a healthcare environment where there is an expectation for more active patient participation in healthcare decisions. Central to a strong patient–physician relationship is the desire to promote patient well-being and simultaneously respect patient autonomy. Conflict between EPs and patients may arise when views of what is in a patient's best interest differ. Emergency Physicians with the greatest integrity come to work with the intention to act in the best interests of patients, and do so with a focus on the prevention and eradication of disease in order to preserve life and improve disability. After an EP has fully informed a capable patient about an intervention in an understandable way, the patient may consent or refuse the recommendation. An initial refusal of recommended treatment should begin a critical conversation that confirms all the elements of an informed refusal. Ultimately, this informed refusal process will respect patient autonomy by accepting a patient's view of well-being and may require honoring a refusal of the EP's recommendation.[10]

EMERGENCY PHYSICIAN'S ROLE AND GOALS IN INFORMED CONSENT PROCESS

The EP's role in the informed consent process is to provide patients the information needed to make their own decisions. It is important not to overwhelm a patient with too much information or complex clinical decisions. Including patients in appropriate care decisions, such as the informed consent process for a procedural intervention, is an ethically important goal.

TABLE 1-2 The Goals of Emergency Physicians in the Informed Consent Process

Support patients to make their own decision
Give information (more than we think we need to give)
Make information accessible
Offer guidance in weighing information
Allow autonomous authorization (patient may consent or refuse)

Emergency Physicians must pay particular attention to the informed consent process to accomplish the goal of respect for autonomy (**Table 1-2**). Foremost, EPs need to provide more information to the patient than they think is needed. Research indicates that patients need more information than physicians think they need in order to feel "informed" in the decision-making process.[11] The need for a procedure seems obvious to the EP and the balance of the considerations clearly tips in the favor of "do it." Emergency Physicians must slow down to fully explain the rationale for their recommendation with the patient and to offer the patient information that allows their meaningful consideration of the recommendation allowing them to reach their own decisions. A good guideline is to offer more time and information for procedures carrying greater risk.[12] **Emergency Physicians must make an effort to work against the features of the ED (Table 1-1 and presumption of consent) and allow patients who are capable of engaging in their care decisions to express autonomous authorization.** This is achieved by giving patients sufficient information, in an understandable way, and by honoring their decisions.

COMPONENTS OF THE INFORMED CONSENT AND INFORMED REFUSAL PROCESS

Informed consent is the communication process that both demonstrates and protects a patient's self-determination by providing a patient with decision-making capacity with sufficient, understandable information and allowing the patient to make a voluntary, knowledgeable decision. There are five requirements that must be satisfied.[13] These include the patient having decision-making capacity, the EP providing sufficient information, the patient understanding the information, the patient giving consent in a voluntary fashion without coercion, and the patient communicating their decision (**Table 1-3**).

DECISION-MAKING CAPACITY

While the terms "competence" and "decision-making capacity" are frequently used interchangeably, their strict meanings are different.

TABLE 1-3 Requirements of the Informed Consent Process[13]

1	Does the patient have the decision-making capacity to make this decision?
2	Has there been disclosure of relevant procedural information (including risks/benefits for intervention, alternatives, and nonintervention)?
3	Has the information been presented in a way that is understandable to the patient?
4	Has the information been presented in a way that allows the patient to make his or her own decision voluntarily while still being informed of the physician's recommendation?
5	Has the patient communicated a decision?
6	Does an exception apply?

Competence is a legal term with broader applications related to financial matters and the determination of personal choices. **Decision-making capacity is a clinical term that speaks to the specific capacity to make a particular clinical decision.** Many people who are legally "incompetent" retain healthcare decision-making capacity. If the patient does not have decision-making capacity, informed consent cannot be obtained and it must be obtained from a surrogate decision maker, or the patient may fall into an exception from informed consent.

DETERMINING DECISION-MAKING CAPACITY

The determination that a patient has decision-making capacity is at the core of informed consent. By default, EPs assume that a patient has capacity and confirm this through routine dialogue with the individual. There are six elements that should be confirmed when there is a question about a patient's capacity to make an informed decision about procedures or treatment.[14] The patient must be able to: understand and process the options, weigh the benefits and risks, apply a set of values and goals to the decision, arrive at a decision, communicate a choice, and demonstrate capacity to make the decision (**Table 1-4**).

Determination of capacity is a clinical decision based on the judgment of the EP regarding the patient's actual level of functioning and appreciation of the ramifications of the clinical situation. The degree of capacity needed to understand risks and benefits of suturing a finger laceration differs from a cardiac catheterization. As such, a patient may be able to understand one choice, but not another. An Alzheimer patient (who is pleasant, oriented to place and year) may be unable to appreciate the consequences of a decision. While this patient may have capacity for some tasks, they may lack the capacity to consent for a specific procedure such as a lumbar puncture.

The EP needs to assess the ability for the individual to weigh the risks in light of their own values. An example would be the ramifications of a fracture reduction on the dominant hand. A construction worker or musician may make a decision different than an individual whose livelihood does not depend on perfect hand function.

A recognized element of decision-making capacity is whether the patient's decision is consistent over time. This is not necessarily applicable specifically to the ED. A possible heuristic is whether the decision is consistent with the person's narrative and values as expressed consistently over time in life choices. The decision-specific nature of capacity acknowledges that the level of capacity needed depends on the complexity of the decision, with greater capacity needed for decisions with graver consequences. The degree of capacity needed to consent does not necessary equal the degree of capacity needed to refuse a recommended intervention.[10] Informed refusal will be discussed later in this chapter.

Decision-making capacity is a dynamic process and changes depending on the patient's evolving condition and task in question. The ED patient may be able to participate to a greater or lesser extent depending on fluctuations in their condition and alterations of their sensorium from the administration of medications. Efforts should be made whenever possible to enhance the patient's decision-making capacity (reduce pain medication temporarily or visit patients at optimal times) in order to engage them to the fullest extent possible in their care.

TABLE 1-4 Elements to Determine if a Patient has Decision-Making Capacity

1	The patient is able to understand and process the options presented
2	The patient is able to weigh the relative benefits, burdens, and risks of the options
3	The patient is able to apply a set of values and goals to the decision
4	The patient is able to arrive at a decision that is consistent over time
5	The patient is able to communicate a choice
6	The patient demonstrates capacity appropriate and sufficient to make this decision

Emancipated minor and adolescent laws vary from state to state.[9] It is important to note that emancipated minors are legally recognized as adults and responsible for their own finances and care. They are able to provide fully informed consent. It is important for EPs to know their local laws where minors who are not emancipated may give consent for sensitive conditions or procedures such as those of a reproductive nature or substance abuse.

Informed consent may not be possible with some populations, such as young children and elderly with dementia. It is still possible to inform these patients of the procedure and to engage their assent. Unlike consent, assent is not determinative. It does offer the possibility of the individual participating in their care.[15]

PATIENTS LACKING DECISION-MAKING CAPACITY

It is not possible to obtain informed consent when a patient lacks decision-making capacity. Necessary treatment may be provided to patients who lack decision-making capacity without obtaining the patient's informed consent. However, EPs should make every effort to learn the patient's previously stated preferences for treatment (e.g., written advance directive or communication with a primary care provider). Efforts should be made to obtain consent from a surrogate decision maker if prior preferences are not available. A surrogate decision maker is a person entrusted with making healthcare decisions because they know the patient best and can bring the patient's values and goals into the clinical decision process. This role can be challenging for even the most capable decision makers. It is not uncommon for surrogates to have a role conflict between applying their own values and/or wishes and those of the patient.

Emergency Physicians must pay attention to the language used when asking a surrogate decision maker for consent. Frame the discussion with phrases asking what the patient would want in the situation such as "How would your father view this situation?" or "What would your father's preference be based on his values?" Avoid general phrases such as "What should we do?", "What do you want us to do?", or "What do you think he would want?" If the decision seems to stem from a role conflict, an EP can ask the surrogate "Why do you think he would choose that?" No prior conversation covers every clinical scenario perfectly and the gravity of the decision can frequently be overwhelming for the surrogate.[10]

The choice of a surrogate decision maker may be quite obvious in some cases such as the parent or legal guardian of a child. The choice can be more complex in other cases. Who may serve as a surrogate and their scope of authority varies by state. What if the appropriate surrogate is in question and there is no statutory guidance? A useful guide is that the surrogate's authority arises from a close relationship to the patient that affords accurate and informed communication of the patient's values. Challenges in resolving conflict between potential surrogates (e.g., siblings with different opinions regarding parental care) should be referred to an ethics committee or other institutional mechanisms to offer guidance unless emergent conditions make that impractical.

INFORMATION TRANSMITTAL

The EP must relate sufficient information about the procedure to the patient. This raises the questions of what information to present and how much to present. **Relevant information includes the risks and benefits of the procedure, any alternatives to the proposed course of action, and the consequences of nonaction.** The question remains how much information needs to be disclosed to

patients, particularly in light of the potential that legal action may be taken if an EP does not obtain informed consent properly.[16]

There are two standards that are commonly used, and these standards vary by state. The traditional "professional standard" requires the EP to provide information based on what the profession's standard of practice would deem necessary to disclose for a patient to be informed. The more common "reasonable person standard" requires the EP to include all the information that a reasonable patient would want to know in order to make a knowledgeable decision. Information that should be communicated includes: the patient's current medical condition and how will it progress if no treatment is given, the treatment alternatives, the risks and benefits of each potential treatment and their probabilities, and the financial costs of each if those estimates exist. Finally, the EP should provide a personal recommendation as to the best alternative.[17]

UNDERSTANDABLE PRESENTATION OF INFORMATION

Information must be given in a way that is understandable. The patient must be able to adequately weigh the benefits, burdens, and risks of the treatment in the context of their own beliefs, life, values, and goals. The obvious differential in knowledge and understanding between patients and EPs may be exacerbated by language barriers, literacy, numeracy, and low educational levels.[18] Such barriers may be overcome by: speaking at a level easy for the patient to comprehend, being sensitive to patients who may be unable to read, and being sensitive of patients who may not be highly educated. Understanding is bidirectional and necessitates that EPs confirm that the patient understands what they are told.[19] Communicating numbers, such as risk and probabilities, is the most complex task asked of EPs.[20] Frame numbers in multiple ways and present outcomes in both positive and negative contexts to enhance informed consent.[20] For example, "3 out of 4 children have no side effect but one in four will have nightmares from this medication."

Language barriers are frequent in the ED and pose significant concern in obtaining and documenting informed consent.[21] Understanding languages is situational. Although some EPs may have additional language (non-English) proficiency, it is imperative to know when to call an interpreter. Limited language skills allow the EP to extract critical clinical information. Patients may need more information than the EP's skills allow. Calling an interpreter may be essential for meeting a minimum standard of care.[22]

VOLUNTARY NATURE OF THE DECISION

Forced treatment where any real choice is removed from the patient being involved in the decision-making process violates the doctrine of informed consent. Any form of coercion based on threats or intolerable consequences, such as the withholding of pain medication, would fall into this category. Emergency Physicians cannot manipulate patient decisions by withholding or distorting information that the EP believes may sway the patient toward a preferred course. Persuasion is permissible, and it is an obligation as trained professionals to synthesize the information and recommend a course of action. An appropriate recommendation includes laying out the risks, benefits, and reasoning behind one's recommendation as well as explaining the reasoning for not selecting an alternate approach. Emergency Physicians can also utilize the resources of the patient's family or significant others to provide arguments in favor of a particular course of treatment. The EP must be careful to avoid overwhelming the patient as the goal should be a shared solution by consensus and not forcing the patient to surrender to the wants of others.[23] Strategies to approach a patient's refusal are discussed in depth later in this chapter.

EFFECTIVE INFORMED CONSENT AND REFUSAL

There is a difference between the autonomous authorization informed consent (information and dialogue) and the effective informed consent (to meet legal and institutional requirements). **The EP should document the discussion of the benefits, burdens, risks, and alternatives addressed in the discussion with the patient in order for an autonomous authorization to be recognized as effective and, thus, the entire informed consent valid.** Local institutional policies should be referenced to confirm an effective informed consent or refusal.[7]

Some hospitals have patients sign "blanket" consent forms agreeing to all emergency tests and treatments on their registration in the ED. Such consent forms provide no information regarding specific individual procedures. These forms are not acceptable because they fail to respect patient autonomy. Blanket consent forms cannot substitute for the usual informed consent process for procedures in the ED, where a dialogue with the patient is required.[24]

EXCEPTIONS TO THE INFORMED CONSENT PROCESS

THE EMERGENCY EXCEPTION

Society's overriding assumption is that a person would want lifesaving treatment in an emergency situation. Consent to treatment is generally presumed under specific emergency circumstances where intervention is necessary to save life or limb, the harm of nontreatment is greater than the harm of the intervention, a patient is unable to participate in care decisions, and patient preferences are not known with no surrogate available. This emergency exception is not absolute. This is particularly true when there is clear evidence that the patient's wishes are contrary to the intervention being considered, such as a prehospital advance directive or wallet card stating no blood transfusions.

Some EPs believe that any patient in the ED qualifies for an emergency exception by virtue of the fact that they are in the ED. This is not true. Location by itself can be used neither to justify the emergency exception nor to infer an "implied consent" for broad ED care. Rather, the emergency exception may be invoked only when the patient will be harmed by the delay necessary to obtain informed consent.[25] EPs should ask themselves a few brief questions to determine if a patient meets the criteria for an emergency exception to informed consent (**Table 1-5**).

THERAPEUTIC PRIVILEGE

The therapeutic privilege is a disfavored concept but recognized exception. It excuses EPs from the duty to disclose in the limited circumstances where disclosure might create harm to the patient and interrupt the treatment process. This privilege is rarely invoked as it could almost negate the entire informed consent process.

TABLE 1-5 Questions to Justify an Emergency Exception

1	Will failure to treat quickly result in serious harm to the patient?
2	If their condition worsens, will the patient die or suffer serious harm before definitive care can be delivered?
3	Would most capable and reasonable people want treatment for this type of injury?
4	Is the patient unable to participate in care decisions?
5	Are the patient's preferences known or knowable in a timely way from a surrogate?
6	Is there any evidence that the patient would refuse this specific treatment?
7	Would failure to treat result in greater harm than the proposed intervention?

Therapeutic privilege may be applied when direct disclosure to a patient would create harm, generally recognized as occurring in some psychiatric conditions and for some cultural groups.[26]

WAIVER OF INFORMED CONSENT

While EPs have a duty to disclose information, patients may differ in how they approach their participation in care decisions. Some patients may prefer that another person, such as a close family member, receive healthcare information and make treatment decisions on their behalf (delegated autonomy). This may be due to personal preference or cultural variation. The delegation of the decision making must be confirmed with the patient and not assumed based on cultural norms. The delegation reflects a patient's right to waive informed consent. Their choice to delegate that right to another person demonstrates an autonomous choice that should be honored.[27]

Some patients may interrupt the informed consent process after only partial information is disclosed and elect to follow the EP's recommendation. If the EP confirms the patient's acceptance of the consequences of consent with only partial information, the EP may accept this as consent via waiver of the informed consent process.[25] The EP may accept a waiver of consent if, like other decisions, the patient has capacity, understands that they are giving up an important right, and has made the request voluntarily. Emergency Physicians who are uncomfortable with this responsibility may ask the patient to designate another person to assume this role.

IMPLIED CONSENT

Implied consent is also a disfavored concept. It may be considered to "apply" in the very limited circumstances when an EP is undertaking a clinical activity with a well-known risk/benefit profile.[28] The most favored implied consent example is when a patient extends his or her arm for a blood draw. The volitional act of extending the arm is deemed as implied consent to the blood draw and its risks (pain and possible bruising). The assumption of "implied consent" poses a dangerous trap for EPs, since what an EP considers routine and well-known risks may differ greatly from what the patient knows. This is particularly true in the ED where there is little trust and no knowledge of the patient's health literacy.

Emergency Medicine research shows at least 50% of patients wanted time spent on "detailed" information, including a review of the risks of only 1% chance of occurrence. For example, while lumbar punctures are clinically safe and pose little risk, patients perceive this as an invasive procedure that requires more information for informed consent.[11] It is important to note that implied consent is not sufficient when informed consent is required or possible.[10]

UNREPRESENTED PATIENTS/PATIENT ALONE

A patient who is unable to participate in care decisions and has no surrogate decision makers is known as the "unrepresented patient" or the "patient alone." These highly vulnerable patients have no social networks to assist the care team in navigating consent and care decisions, and attention to clinical decision making for this patient population is growing.[29] Statutory guidance on decision making for this patient population varies by region. Institutional policies should be reviewed to determine whether a policy exists for decision making for the "unrepresented patient." In the absence of such a policy, consultation with the ethics service is recommended and efforts should be made to develop a consistent and transparent approach to care decisions for this vulnerable population.[27]

INFORMED REFUSAL

Emergency Physicians often begin with the presumption that patients possess decision-making capacity to both consent and refuse procedures. It is notable that in practice, EPs may question a patient's capacity more readily when they disagree with recommendations.

UNDERSTAND THE REASONS FOR REFUSAL

A refusal for recommended intervention should be the beginning of an important conversation with the patient. On first encounter, a refusal of a recommendation may seem a rebuff or potential time challenge. Approach a refusal with openness and curiosity. Help the patient not feel cornered into following the recommendation while confirming their informed refusal. A refusal is an opportunity to learn how to practice persuasive reasoning. During the barrage of information disclosure, a patient might have misheard numbers or the proposed procedure may resemble a prior negative experience. Take time to listen to the patient's concerns and reasons for refusal. This can help navigate the informed refusal process.

CONFIRM THE ADEQUACY OF INFORMATION WITH AN EMPHASIS ON UNDERSTANDABILITY

With the patient's reasons for refusal in mind, EPs should reflect these reasons back to the patient so that they feel they have been heard. It is important for EPs to acknowledge the patient's perspective, even if they disagree with the reasons. This allows the patient to engage in listening as the EP provides additional information to support the recommendation. Normalizing an "irrational concern" allows the patient to feel "OK" and still follow the EP's recommendation. For example, "I can understand that your sister's complication from procedural sedation several years ago would give you some concerns about this recommendation. And I want to reassure you that today we take these additional steps…." Tailor the revised recommendation to address the concerns of the patient and focus on making sure that the information provided is simple, direct, and understandable.

ADDRESS BARRIERS TO UNDERSTANDING

Significant efforts should be undertaken to enhance the patient's ability to understand the information when a refusal occurs. **A professional interpreter must be utilized to compensate for any communication barriers to the patient's understanding in an informed refusal process.** The EP should revisit all the information from the initial discussion of information that occurred with an informal interpreter (e.g., family member or healthcare provider). Residual misinformation can prolong a patient's refusal. Starting from the beginning of the clinical communication, even if it takes more time, can often remedy the situation. Use language or pictures tailored to a patient's lower educational or functional level when necessary.[19] Anxiety and pain may contribute as a barrier to understanding and should be addressed as quickly as possible.

CONFIRM CAPACITY TO REFUSE RECOMMENDATIONS

Is decision-making capacity a potential issue? The EP must take steps to mitigate any factors leading to impaired decision making so that the patient may participate in their care to the fullest extent possible.

In the past, it was thought that patients with certain diagnoses by default lacked decision-making capacity. Many clinicians now recognize that patients with severe mental illness, early dementia,

TABLE 1-6 Red Flag Scenarios that Require Additional Assessments of the Patient's Decision-Making Capacity

Refusal of recommended treatment
Patients readily consenting to invasive or risky treatment
Abrupt change in mental status
Chronic psychiatric or neurologic conditions
Cultural and language barriers
Limited education
Anxiety or untreated pain
Extremes of age

TABLE 1-7 Mnemonic for Documentation of Decision-Making Capacity Assessments

"U *and* I GLAD"
U—understanding of the procedure/discussion
I—impairing conditions
G—goals and values
L—logic used to decide
A—actual functioning
D—danger or risks of decision

and some organic brain syndromes are at risk for impaired decision making but may possess decision-making capacity for selected procedures and treatments.[14] However, there are certain Red Flag scenarios when an EP should scrutinize a patient's decision-making capacity with greater depth (**Table 1-6**). Actions or decisions with greater consequences require a more intense evaluation of the patient's capacity. A more careful evaluation of capacity is indicated when the patient's choice seems unreasonable or if the patient is unwilling to discuss their thought process. Chronic psychiatric and neurologic conditions remain a risk for, but should not be equated with, impaired decision making. Cultural, educational, and language barriers certainly impact a patients' decision making. High levels of anxiety, whether from untreated pain or the inevitable stress of the ED, are known to impair decision making as well.[30]

Many providers outside the ED setting will utilize psychiatric consultations to assist with the evaluation of a patient's decision-making capacity. The utility of such a consultation in the ED is frequently limited by time and consultant availability. Consultations in the ED may prove useful when evaluating a thought or delusional disorder that may impede understanding.

EFFECTIVE AUTHORIZATION: DOCUMENTATION OF INFORMED REFUSAL

Honoring a refusal of emergency treatment that would be beneficial or may result in decompensation or death is never easy. Use of the standard hospital "Against Medical Advice" form can create an adversarial relationship that an EP may find damaging to future patient interactions and the subsequent treatment plan. However, anecdotal reports include cases where patients reconsidered their decision when presented with such a document. It is important to document refusal of care, not only for medicolegal protection but also to confirm that clear communication with the patient had occurred.

Documentation recommendations when a patient refuses treatment should include the following elements: the patient has refused the recommended procedure, test, or treatment; the patient's reasons for refusal; the consequences of the refusal were explained to the patient including the alternatives, if any, being offered or performed in lieu of the recommended procedure. Documentation should also include statements that show the patient understood and continued to refuse the specific procedure or treatment and has the capacity to do so. Document that the patient's wishes are being honored against medical advice. It would be preferable if the EP could have the patient read this documentation followed by the patient signing the medical record below this documentation in acknowledgment.

Additional documentation is required when an EP recognizes a "Red Flag" scenario for impaired decision making or has other reasons for concern (**Table 1-7**). These are essential items that must be documented in these cases. Document the patient's medical condition and the procedure or treatment that is suggested, including the urgency and necessity. Document the patient's current decision-making abilities with a description of the impediments to capacity and the actions taken by the provider to maximize capacity. Additional documentation should include the availability of family or other surrogate decision makers and any relevant discussions.

Documentation will vary by institution and local laws. Being familiar with the appropriate measures to make an informed consent or refusal is effective and is a critical part of the informed consent/refusal process in the ED.[31]

2 Aseptic Technique

John S. Rose

INTRODUCTION

The proper use and an understanding of aseptic technique are critical for the care of patients in the Emergency Department (ED). Aseptic technique dovetails with prescribed universal precautions and is central to our practice. Knowledge of proper aseptic technique ensures that procedures performed in the ED provide maximal protection for both the patient and the physician while keeping the risk of contamination as low as possible.[1–15]

Wound infection and sepsis are the two major complications resulting from poor and improper aseptic technique. Other complications that may contribute to the patient's morbidity and mortality include increased length and cost of hospital stay, patient discomfort, scarring, and even death. With this is mind, it is clear that aseptic technique is warranted except in the most dire circumstances.

Numerous terms are used to describe the establishment and maintenance of a "sterile" environment. These include aseptic, sterile technique, and disinfection, to name a few. Many people often, and incorrectly, interchange these terms. The proper definitions of the terms used to describe aseptic technique or associated with it can be found in **Table 2-1.**

ANATOMY AND PATHOPHYSIOLOGY

The skin and hair are colonized with various organisms. The stratum corneum layer of the epidermis is colonized with a polymicrobial flora. This includes *Staphylococcus aureus, Staphylococcus epidermidis,* various *Streptococcus* species, viruses, yeasts, and molds. Many of these organisms are nonpathogenic, even when placed in environments considered appropriate for infection. *S. aureus* is the most common cause of wound infections. It can result in an infection when introduced into deeper skin layers. Some species, such as *S. epidermidis,* are pathologic only when inoculated into deeper layers of the skin and soft tissue. For most infections, a significant

TABLE 2-1 Definitions of Terms Used to Describe Aseptic Technique or Associated Processes

Term	Definition
Aseptic	Freedom from infection. Prevention of contact with microorganisms. Involves the use of sterile technique and skin disinfection
Clean technique	The practice of using nonsterile equipment to perform procedures. This is considered as part of the universal body fluid precautions
Disinfection	The cleaning of an area to make it free of pathogenic organisms and microbes
Sterile field	The zone in which strict sterile technique is maintained. Generally consists of an area 3 to 10 times larger than the area of the primary procedure
Sterile technique	The practice of utilizing sterile equipment and procedures to maintain an aseptic environment
Super aseptic	Ultrahigh state of an aseptic environment. Usually, this is achievable only in the operating room

inoculation is required to create a critical level for microbial growth to occur. **Aseptic technique decreases bacterial exposure and reduces the level of potentially pathologic organisms.**

INDICATIONS

The role of aseptic technique in the ED is primarily for invasive procedures. Despite this, invasive procedures require varying degrees of aseptic technique. Placement of a small peripheral intravenous catheter may require no more than a brief wiping of the skin. In contrast, a diagnostic peritoneal lavage requires operating room–level disinfection and strict sterile technique.

Routine and adequate provider disinfection involves careful hand washing, the use of clean and disinfected personal diagnostic equipment (e.g., stethoscopes), and wearing appropriately cleaned coats and clothing. This is critical in preventing iatrogenic infections in the ED. Aseptic technique in the ED can be referred to as clinical aseptic technique, since it is virtually impossible to achieve an operating room level of asepsis. Clinical aseptic technique involves the combining of adequate disinfection with sterile techniques and protocols at the bedside.

CONTRAINDICATIONS

There are very few contraindications to the maintenance of adequate clinical aseptic technique. One exception would be that extreme clinical circumstance in which time simply does not allow proper aseptic technique, as in an emergent thoracotomy. Even in such situations, however, the physician can still use sterile gloves and a quick application of an aseptic solution.

Always inquire about allergies and sensitivities to latex and antiseptic solutions. This information will affect the equipment that is chosen to properly prepare the patient.[8] Most, if not all, hospitals have a latex-free cart that contains equipment for use with latex-allergic patients. Do not use povidone iodine solution in patients allergic to iodine. Alternative agents include chlorhexidine and hexachlorophene preparations.

EQUIPMENT

- Povidone iodine solution
- Chlorhexidine gluconate (chlorhexidine)– or hexachlorophene-based solutions
- Seventy percent isopropyl alcohol
- Sterile 4 × 4 gauze squares or applicator sticks
- Sterile gloves
- Face mask and eye protection
- Sterile drapes or towels
- Adequate lighting
- Sterile gowns
- Bedside procedure table

PATIENT PREPARATION

Inform the patient of what the procedure entails before performing any procedure in the ED. This should include an explanation of sterile technique and a request that the patient not touch the drapes or sterile equipment. Obtain any required informed consent (Chapter 1) before the patient is draped. The only exception to this is if an emergent and lifesaving procedure must be immediately performed.

Place the patient in the most comfortable position possible. Patient discomfort frequently results in movement and the potential loss of the sterile field. Utilize sedation and/or analgesia (Chapters 123-129) as necessary to facilitate proper patient positioning. The physician must also be comfortably positioned if possible and have adequate lighting.

TECHNIQUES

Aseptic technique can be divided into skin disinfection and sterile technique. Skin disinfection removes any microorganisms found on the skin and decreases potential contamination during the procedure. Sterile technique is performed for the same reason. There are different levels of aseptic technique, ranging from full aseptic technique (mask, gown, gloves, and drapes) to simple sterile gloves. The physician must use their judgment to determine which level is most appropriate to the task at hand.[8]

SKIN DISINFECTION

Disinfection involves the application and scrubbing of a disinfectant preparation onto the skin. Simple procedures, such as injections or venipunctures, may require little disinfection. Wipe the skin with gauze that has been impregnated with 70% isopropyl alcohol for simple procedures. The alcohol has an antibacterial effect. The mere force of wiping the skin reduces bacterial counts. No disinfection is used for simple venipunctures in some countries. More comprehensive skin preparation involves the use of a disinfectant agent such as povidone iodine or chlorhexidine solution.

Povidone iodine, 2% iodine tincture, and chlorhexidine are the most commonly used skin antiseptic solutions. Povidone iodine solution is highly germicidal for gram-positive and gram-negative bacteria, viruses, fungi, protozoa, and yeasts.[7] It rapidly reduces bacterial counts on the skin surface and these effects last up to 3 hours.[7,11] Allow the iodine solution to dry and then wipe it from the skin with 70% alcohol prior to beginning the procedure. The iodine solutions work by oxidation and cross-linking of sulfhydryl groups, killing bacteria as the solution dries. Isopropyl alcohol can be applied to the skin and scrubbed vigorously for 2 minutes to achieve disinfection, although this may cause skin irritation. Chlorhexidine or hexachlorophene preparations may be routinely used or as substitutes in iodine allergic or sensitive patients. These agents provide good bactericidal activity against gram-positive bacteria but somewhat less activity against gram-negative organisms.[8]

Chlorhexidine-based solutions are being used more commonly and are replacing the iodine-based solutions. Chlorhexidine

provides much longer antimicrobial activity (up to 48 hours) and is more gentle on the skin than iodine.[11–15] Chlorhexidine destroys cell membranes of gram-positive and gram-negative bacteria while precipitating the intracellular contents. Some preparations contain 70% isopropyl alcohol, further enhancing the antimicrobial activity.[12–14] The use of chlorhexidine solutions is proving to be superior to iodine solutions.[14,15]

Use a skin disinfectant for procedures other than simple venipuncture. Place the disinfectant solution onto either a sterile sponge or sterile gauze if it is not supplied inside a single-use applicator. Historically, the application of disinfectant to the skin is in a circular motion, beginning with the central area of the procedure and working out toward the periphery of the sterile field (**Figure 2-1**). There is no evidence to support this application method. It has been suggested that scrubbing in a back-and-forth motion creates friction to dislodge microbes and may be preferable to the traditional circular application.[9,10] The back-and-forth motion drives the disinfectant solution into skin crevices and deeper layers, thus killing more bacteria and hopefully preventing infections.

Regardless of the disinfectant solution used, repeat the application process three or four times using a new sponge, gauze square, or applicator each time.[8] This technique ensures that the central area where the procedure is to be performed is the most sterile area of the field. The area of disinfection must be much larger than the primary area of the procedure, as the number of organisms increases toward the periphery of the prepped area.

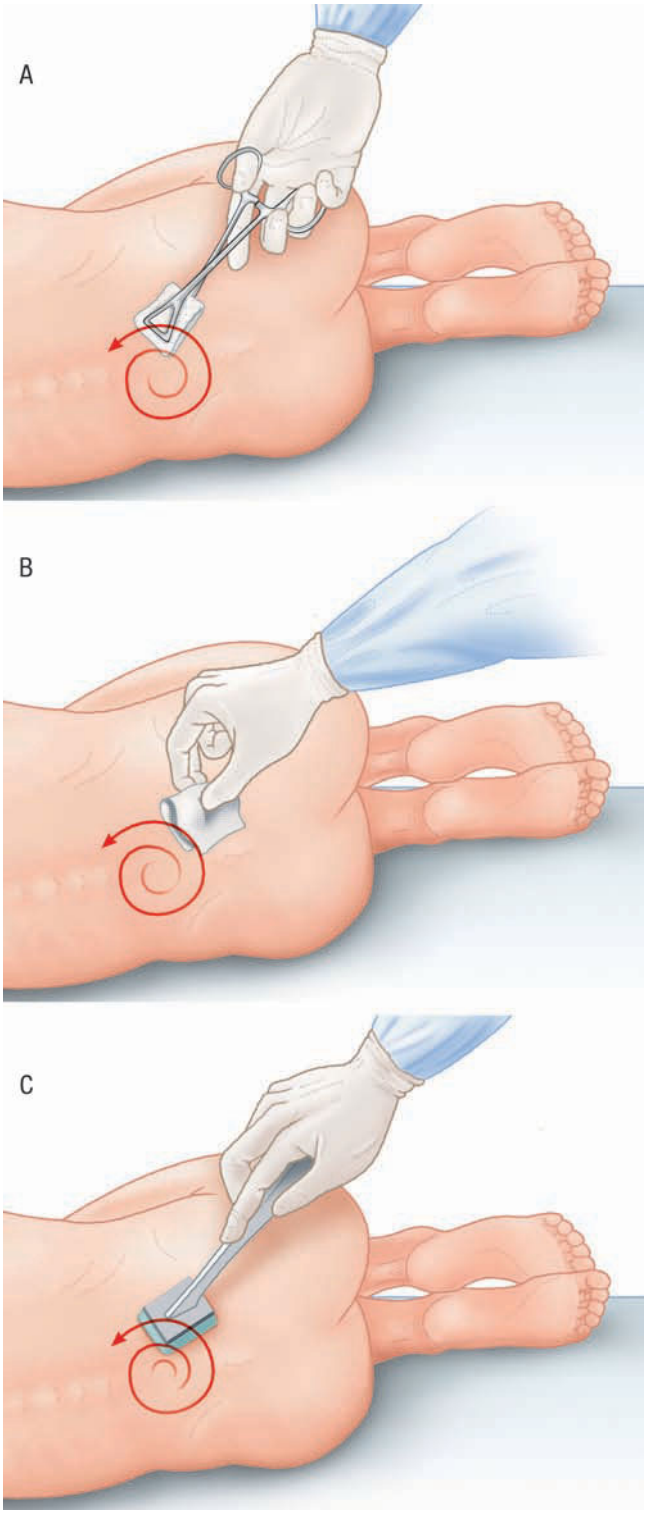


FIGURE 2-1. Preparation of the skin. Disinfectant solution is applied in a concentric circular pattern starting from the procedure site and working outward. Apply the disinfectant solution with sterile gauze held in a clamp (**A**), with sterile gauze held in a sterile gloved hand (**B**), or with a sponge on a stick (**C**).

STERILE TECHNIQUE

General sterile technique is described, followed by specific details for each step of the procedure. Strict sterile technique is virtually impossible in the ED. **However, make every effort to maintain a sterile field in order to minimize infection.** Assemble all equipment necessary and place it on a small procedure stand. **Do not use the patient or their bed to set up supplies or equipment.** Patient movement and their irregular body surfaces can result in items falling, breaking, becoming contaminated, or iatrogenic needle sticks. Avoid having different components scattered around the procedure area. Open all sterile items, using proper sterile protocol, so as to have them available once the physician has donned sterile gloves. Use anesthetic solution containers with removable caps. This allows the physician to draw up anesthetic without having an assistant and minimizes the risk of occupational needle exposure. Perform a thorough hand washing before the procedure.

Apply sterile gloves. Place sterile drapes or towels to form a field wide enough to allow for a comfortable work space. Drape the area near the patient closest to the bedside procedure table. This will minimize inadvertent contamination in moving from the table to the patient. Make a small flat sterile area near the procedure site to allow for placement of important items that must be immediately available. Open all caps, position stopcocks, and prepare all devices prior to starting the procedure. The likelihood of contamination increases if devices are not adequately prepared, thus requiring manipulation during the critical portion of a procedure. **Adhere to universal precautions guidelines.** Use eye and face protection during the procedure. This should be applied before donning gowns and gloves.

OPENING A STERILE PACK

Always make sure that the outer wrapping is intact, the sterility expiration date has not passed, and the sterility indicator tape is the appropriate color before opening a sterile pack.[2] Wash your hands and then remove the outer wrap if applicable. Remove the sterility indicator tape (**Figure 2-2A**). Place the sterile pack on a dry and level surface with the outermost flap facing away from you (**Figure 2-2B**). Grasp the corners of the outermost flap (**Figure 2-2B**). Hold your arms to the sides of the pack to avoid reaching over the sterile area. Lift the flap up and away from you (**Figure 2-2B**). Open the side flaps by grasping the folded corner with a thumb and index finger



FIGURE 2-2. Opening a sterile pack. **A.** Remove the sterility indicator tape. **B.** Grasp the edges of the outermost flap and open it away from you. **C.** Open the side flaps. **D.** Open the remaining flap toward you. **E.** The open pack.

and pulling the flap to the side (**Figure 2-2C**). Open the bottom flap (**Figure 2-2D**). Grasp and open the bottom flap while stepping back to prevent contaminating the wrap on your clothing (**Figure 2-2E**). **Make sure that your arms and clothes do not contaminate the contents of the pack when opening the flaps.** Repeat the procedure if the pack has an inner wrap.

PLACING STERILE SUPPLIES ON A STERILE FIELD

Sterile supplies are generally packaged in either a hard (hard pack) or a soft peel-back (soft pack) container. The general principle of opening these is the same, although there are subtle differences. Hold the hard peel-back container in the nondominant hand with

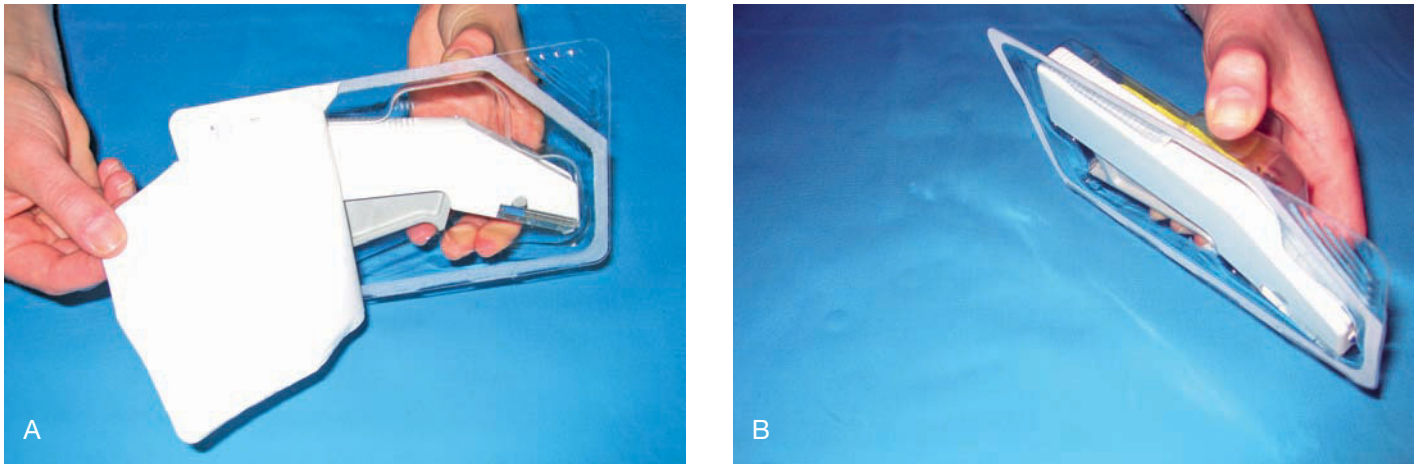


FIGURE 2-3. Opening a hard peel-back container. **A.** Grasp the container with the flap facing the sterile field. Remove the flap. **B.** Drop the contents of the hard container onto the sterile field.

the flap facing the sterile field (**Figure 2-3A**). Pull the flap toward you with the dominant hand so that the open end of the pack will be facing the field (**Figure 2-3A**). Hold the container 15 to 20 cm above the sterile field. This ensures that if the contents fall, it will be onto the sterile field where they are wanted. Drop the contents of the sterile pack onto the sterile field, taking care not to contaminate the field with the container itself (**Figure 2-3B**).

Gloves and syringes are wrapped in soft packs. Grasp both sides of the unsealed edge of the soft pack and pull them apart slightly (**Figure 2-4A**). Hold the open end facing the sterile field (away from you). Continue to open the soft pack. Fold the sides of the sterile packing back and over your hands to keep the contents sterile (**Figure 2-4B**). Gently drop the contents of the soft pack onto the sterile field.

APPLICATION OF A MASK

Surgical masks serve a dual role in the performance of aseptic technique. Masks have been shown to decrease contamination of the sterile field that may result from aerosolized droplets from the mouth and nose. Masks protect the caregiver's mucous membranes from exposure and possible splashing during the procedure. Wear a mask with an eye shield during high-risk procedures.

Apply the mask before donning gloves and other sterile equipment. Depending on the type and style of the mask, secure it by placing the elastic straps around the ears, placing the elastic straps around the head, or tying the mask securely to the face with ties around the head and neck. Pinch the metal nose clip securely to the bridge of the nose for a tighter fit and to minimize the gap between the mask and the nose.

HAND WASHING

A physician must thoroughly wash their hands despite the fact that sterile gloves are worn for all sterile procedures. Good hand washing technique should not be overlooked. A full surgical scrub is neither necessary nor feasible in the ED.

Rinse your hands in warm water prior to applying antiseptic soap. Apply soap, lather your hands, and rub them together vigorously for approximately 10 seconds. Wash each wrist with the opposite hand. Interlace the fingers of both hands and slide them back and forth to clean the web spaces. Clean around the nails with the fingertips and nails of the opposite hand. Completely rinse each hand from the fingers downward. Repeat the procedure a second time if your hands were grossly contaminated. Dry your hands with a disposable towel. Turn off the faucet, using the towel with which you dried your

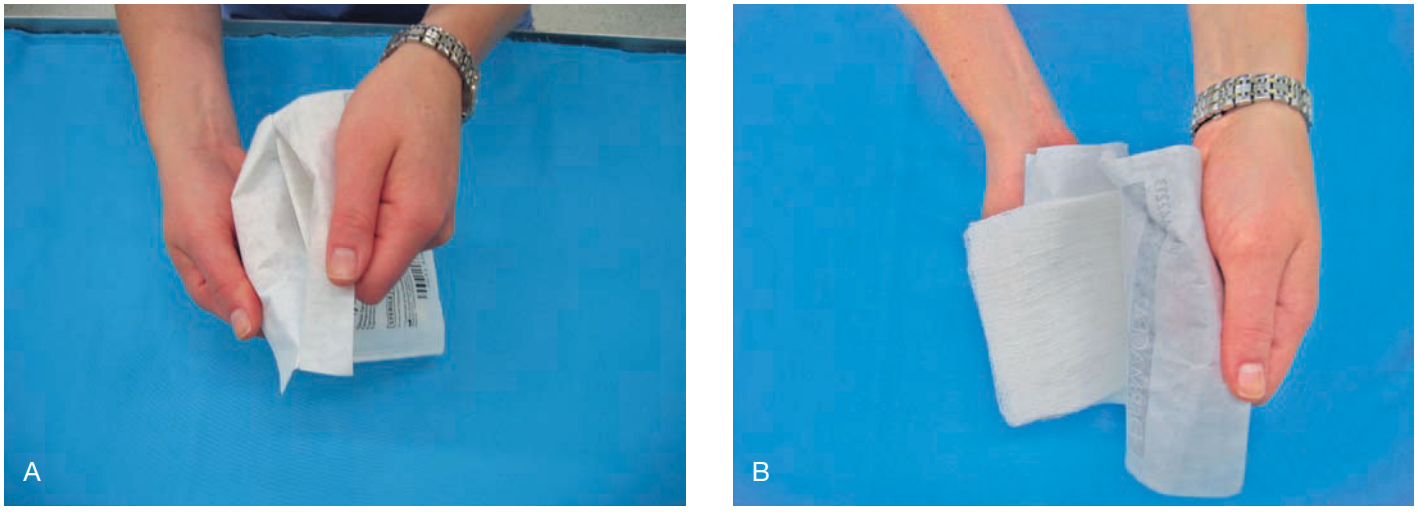


FIGURE 2-4. Opening a soft peel-back container. **A.** Grasp both sides of the unsealed edge and pull them apart. **B.** Face the pack toward the sterile field. Continue to open the edges until the contents fall onto the sterile field.

hands. Do not touch the faucet with clean hands. Otherwise they will become contaminated again.

APPLICATION OF A CLEAN GOWN

A clean (nonsterile) gown is often used as an additional barrier to contamination of both the field and the provider's clothing. Simply place your arms into the sleeves and pull on the gown with the opening toward the back. Secure the gown at the back of the neck and the lower back by tying the strings.

APPLICATION OF A STERILE GOWN

A sterile gown is worn for procedures requiring a stricter sterile technique (i.e., central venous access, diagnostic peritoneal lavage). To open a sterile gown, use the procedure previously described to open a sterile soft pack. Grasp and pick up the gown just below the neckline, touching only the inner surface of the gown. Hold the gown up and let it unfold with the inside facing you. Do not allow the gown to touch any nonsterile surfaces. Insert your arms into the sleeves until the gown is in place. Have an assistant grasp the back of the gown, pull it completely on, and tie the strings securely.

APPLICATION OF STERILE GLOVES

Wash your hands thoroughly before putting on sterile gloves. Apply a clean gown at this point if it will be worn during the procedure. Open the outer wrap of the sterile gloves and remove the inner wrap (**Figure 2-5A**). Place the inner wrap on a clean surface with the gloves' wrists facing toward you. Unfold the inner wrap, touching only the outside edges (**Figure 2-5B**). Open the inner wrap according to the procedure for opening a sterile pack (**Figure 2-5C**). Apply a sterile gown at this point if it will be worn during the procedure. Use the dominant hand to grab the opposite glove at the inner edge of its folded cuff (**Figure 2-5D**). Slip the nondominant hand into the glove, being careful not to touch the outer surface of the glove (**Figure 2-5E**). Pull the glove further onto the nondominant hand using the inner edge of the cuff (**Figure 2-5F**). Place the fingers of the gloved nondominant hand into the folded cuff of the other glove (**Figure 2-5G**). Slip the dominant hand into the glove (**Figure 2-5H**). Pull this glove over the dominant hand using the cuff (**Figure 2-5I**). Carefully unfold the cuff of each glove, taking care not to touch the fingers and palms of the gloves to nonsterile skin. Adjust each glove to ensure a snug fit over the fingers and hand.

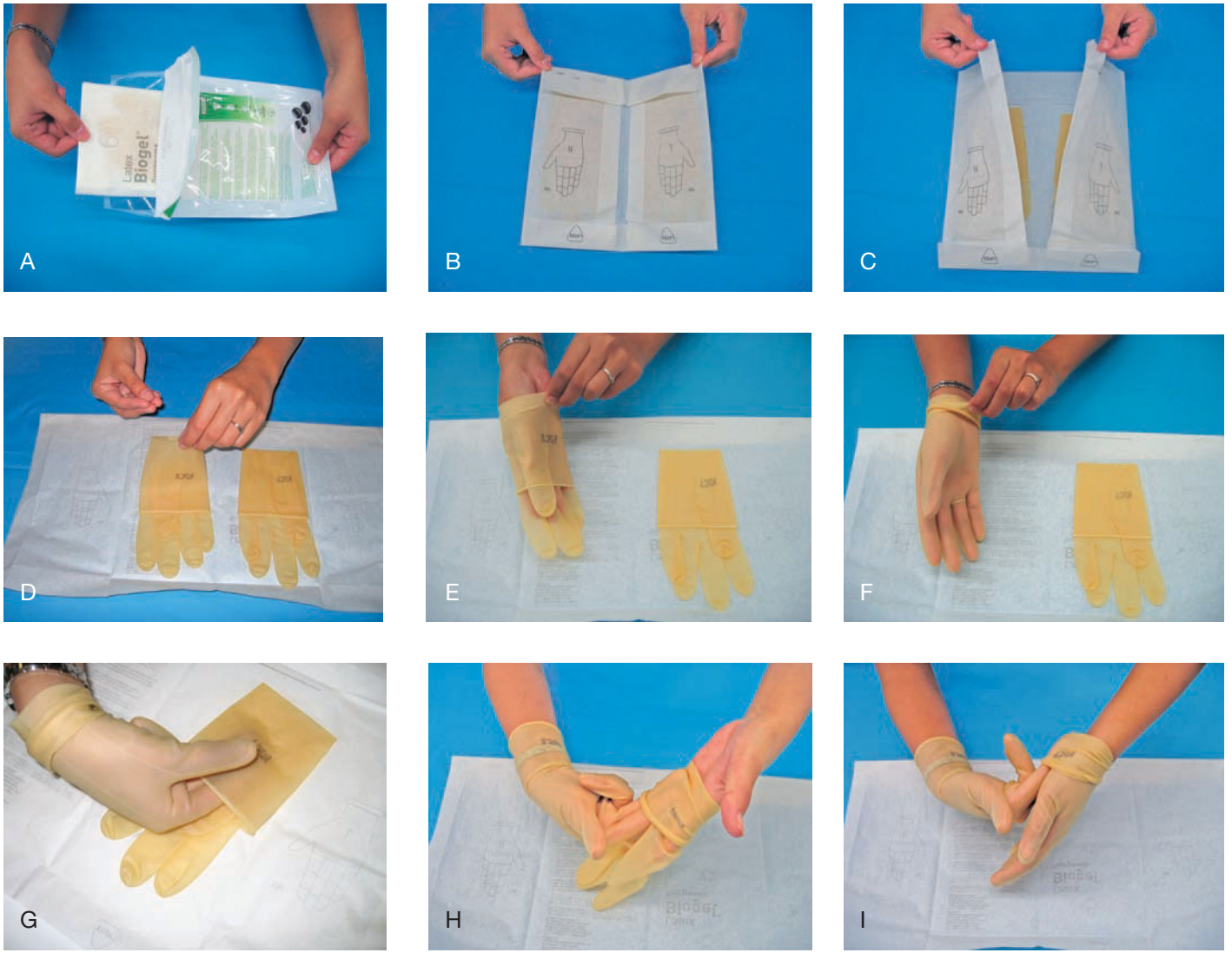


FIGURE 2-5. Application of sterile gloves. **A.** Open the outer wrap and remove the inner wrap. **B.** Unfold the inner wrap. **C.** Completely open the inner wrap. **D.** Grasp the cuff of a glove. **E.** Slip the glove onto the hand. **F.** Pull the glove onto the hand. **G.** Slip the gloved hand into the folded cuff of the second glove. **H.** Slip the glove onto the hand. **I.** Pull the glove onto the hand.



FIGURE 2-6. Removal of protective clothing. **A.** Untie the gown. **B.** Remove the gown by turning it inside out. **C.** Roll up the gown with the contaminated side facing inward. **D.** Remove the glove from the nondominant hand. **E.** Remove the glove from the dominant hand. Remove the face mask and wash your hands.

REMOVAL OF PROTECTIVE CLOTHING

Remove protective clothing in a systematic manner in order to protect yourself and others from the contaminants on your gown and gloves (**Figure 2-6**). Place all removed garments into appropriate waste containers. The first step is to untie the gown (**Figure 2-6A**). Have an assistant untie the neck strings of the gown or pull on both shoulders of the gown to break the neck strings. Untie the waist strings. Take off the gown by turning it inside out as it is removed (**Figure 2-6B**). Roll up the gown with the contaminated surface facing inward and away from you (**Figure 2-6C**). Dispose of the gown. Remove the gloves by turning them inside out, making sure that you do not touch the outside (contaminated) surface with your ungloved hands. Use the dominant hand to grasp the cuff of the glove on the nondominant hand (**Figure 2-6D**). Pull the glove inside out as you remove it and throw it away. Place the ungloved fingers of the nondominant hand into the inside edge of the gloved dominant hand and remove it by pulling the glove inside out (**Figure 2-6E**). Dispose of the glove. Remove the mask by untying its ties or removing the elastic straps from behind your ears. Dispose of the mask. Finally, wash your hands.

COMPLICATIONS

Properly performed aseptic technique has very few complications. The primary risk is in patients with sensitivities or allergies to latex or the disinfectant preparations. Although povidone iodine preparations are much less irritating than tincture of iodine, it is a good policy to clean all disinfectant off the patient at the end of the procedure so as to minimize any skin irritation. This is especially true of small children. Use alternate products for those patients with histories of allergies. **The main complication of improper aseptic technique is infection at the site of the procedure.[8] This only serves to underscore the need to perform aseptic technique properly.**

SUMMARY

Aseptic technique is an important component of all invasive procedures performed in the ED. Adequate skin disinfection and the proper use of sterile technique will greatly decrease the risk of iatrogenic infections. Aseptic technique allows a degree of protection for the caregiver as well as the patient.

3 Basic Principles of Ultrasonography

Gregory M. Press

INTRODUCTION

Emergency Physicians (EPs) have performed bedside ultrasound (US) for more than three decades. Today, US is ubiquitous in our specialty. Each year new physicians learn the skill, fresh evidence is brought to light supporting the practice, and novel indications are explored. Technological advances have delivered smaller machines with improved image quality that are less expensive than ever before. Several US manufacturers have developed machines targeted to Emergency Medicine (EM), taking into consideration our specific indications and less-than-forgiving work environment. US training is an important component of Emergency Medicine residency programs and a required core competency procedure of the Accreditation Council for Graduate Medical Education Residency Review Committee.[1] There are numerous opportunities for supplementary training in emergency US, ranging from local courses to established fellowship training programs.

Safety considerations have also contributed to the acceptance of bedside US. Sonography is noninvasive, safe in pregnancy, and does not require contrast agents that risk kidney failure, subcutaneous extravasation, and allergic reactions.[2] With increasing concern in the medical community over the long-term effects of ionizing radiation, US is recognized as an attractive alternative.[3] Additionally, the U.S. Department of Health and Human Services' Agency for Healthcare Research and Quality has highlighted US guidance for central line insertion as 1 of their top 10 recommended practices.[4]

The intent of this chapter is to provide an introduction to bedside US for the EP. The physician-sonographer should have a general understanding of the physics underlying the properties of an US wave. "Knobology" is a colloquial term used to describe the study of the buttons, dials, switches, and, of course, knobs, on the console of an US machine. It is important that all users have a good sense of their machine's operational functions. Typical machines and transducers used in the ED will be described.

THE PARADIGM OF BEDSIDE US

Bedside US is a relatively new paradigm in clinical medicine. Traditional radiology US involves a break in the patient–physician encounter. The multistep process involves the EP evaluating the patient and determining that an US is warranted, the radiologic technologist performing the study in an US suite, the radiologist reviewing the images and generating a report, and the EP ultimately correlating that information back to the patient (**Figure 3-1**).

Bedside US crafts a direct and immediate relationship between patient and EP (**Figure 3-1**). The technology is placed in the EP's hand for both image acquisition and interpretation. The EP can immediately synthesize US findings with clinical and laboratory data to paint a more complete diagnostic picture. A patient's condition can change on a moment's notice in the ED, and, fittingly, US is a dynamic tool that can be used swiftly and serially throughout a patient's course.

In the early years of emergency US, EPs often used large tank-like machines that were not conducive to a fast-paced work environment. The evolution of US has delivered small portable machines that produce high-quality images. Many US devices are the size of laptop computers that fit on maneuverable carts. "Pocket-sized" machines, not much larger than mobile phones, are being introduced and offer even greater portability (Signostics, Palo Alto, CA; GE Corporation, Fairfield, CT). The notion of the "sono-stethoscope" promises devices as small, easy to use, and available as the stethoscope, but with the superior insight of sonography. This device speaks to a true paradigm shift in clinical medicine.

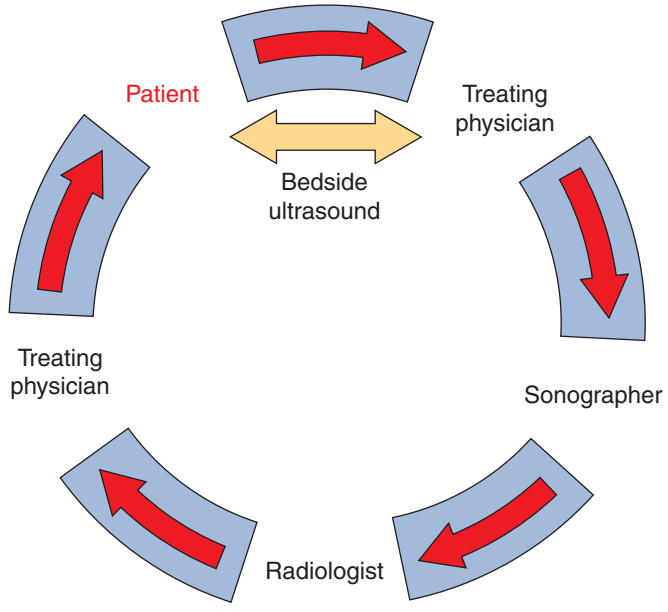


FIGURE 3-1. The paradigm of bedside US. The workflow of traditional US utilizing the radiology department (blue circle with red arrows) is a multistep process that may take hours to days to complete. Bedside US (double yellow arrow) establishes an immediate and direct interaction between patient and physician. (Courtesy of Christopher Moore, MD, RDMS, RDCS.)

INDICATIONS

The primary indications of emergency US have traditionally included: cardiac US for the presence of pericardial fluid and for cardiac activity; abdominal US for the identification of free peritoneal fluid; aortic US for abdominal aneurysms; biliary US for the detection of gallstones and cholecystitis; renal US for hydronephrosis and nephrolithiasis; and pelvic US for the identification of an intrauterine pregnancy and the exclusion of an ectopic pregnancy (**Table 3-1**). Basic emergency US has operated on the binary premise that emergencies are to be included or excluded by this diagnostic tool. As the field has developed, the boundaries between primary and secondary indications have blurred, and the yes/no equation for the evaluation of emergencies has matured.

TABLE 3-1 The Indications for Emergency Ultrasonography

Primary indications	Secondary indications	Procedural indications
Abdominal	Abscess	Arthrocentesis
Aorta	Deep vein thrombosis	Foreign body localization
Biliary	Gastrointestinal	Lumbar puncture
Cardiac	Genital	Nerve blocks
First trimester pregnancy	Lung	Paracentesis
Renal	Musculoskeletal	Pericardiocentesis
	Ocular	Thoracentesis
	Shock	Transvenous pacer placement
	Other	Vascular access
		Other

The list of indications for present-day emergency US is long and continually expanding (**Table 3-1**). Other common indications include the evaluation for deep vein thrombosis. Lung US can be used to diagnose pneumothorax, pleural fluid, and interstitial lung diseases. US evaluation for abscesses, primarily subcutaneous but also peritonsillar, deep-space, and abdominal is common. Ocular US can be used to identify a retinal detachment, lens dislocation, vitreous hemorrhage, foreign bodies, and optic nerve sheath assessment for increased intracranial pressure. Patients in shock or hypotensive may be evaluated by US of the inferior vena cava and internal jugular veins to estimate central venous pressure. Gastrointestinal US is used for the identification of appendicitis, pyloric stenosis, and other conditions. Male and female genitourinary US is used to assess for testicular and ovarian torsion, intrauterine pregnancy, and ectopic pregnancy. Musculoskeletal US is used to diagnose joint effusions, tendinopathy, and fractures. Procedural US is used for guided assistance of vascular access, paracentesis, thoracentesis, pericardiocentesis, arthrocentesis, lumbar puncture, foreign body removal, nerve blocks, and other procedures.

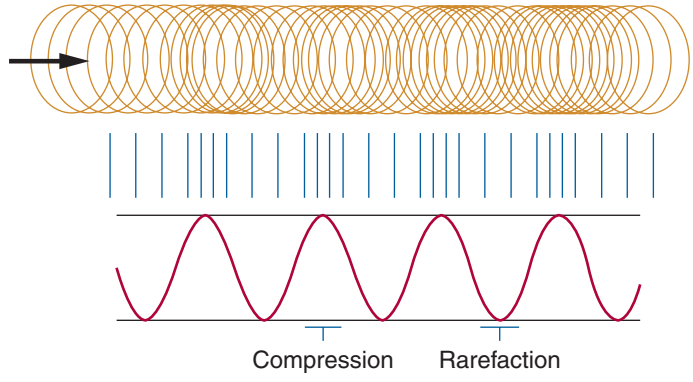


FIGURE 3-2. The longitudinal US wave. A force exerted in a parallel fashion along a coil will produce regions of compression and rarefaction. The particles of a sound wave vibrate in the direction the wave travels to create areas of high and low density and pressure. A sound wave is depicted as a classic waveform with peaks representing compression and valleys representing rarefaction.

US PHYSICS

HISTORY

Bats and toothed whales have used sound for echolocation for millions of years. Dolphins produce a series of clicks that pass through the lipid-rich melon on their heads, an acoustical lens of sorts that focuses the sound waves into a beam. Returning echoes are processed to determine the location of objects for navigational and hunting purposes.[5] Sonar (acronym for *so*und *na*vigation and *r*anging) is a maritime technique that uses sound waves for identifying oceanic objects. It was initially introduced in response to the sinking of the Titanic in 1912.[6] It was further developed and employed in World War I for submarine detection.[6] In the early 1950s, a radiologist named Douglas Howry and a team of other physicians introduced the first diagnostic US machine using a water-bath immersion tank. In the 1960s, direct contact (probe to patient) scanners were developed, and the contemporary saga of US as a viable diagnostic modality commenced.[7]

SOUND

Sound is a variation in pressure traveling through a medium and it is described as a wave. We commonly understand the sound of our vocal communication to travel through air, but sound may also travel through fluid and solid structures. Pressure variations produced by sound waves mechanically displace or oscillate the particles of the medium. This oscillation produces cycles of higher and lower densities, or compression and rarefaction, respectively. Sound waves differ from water waves in that they are longitudinal, meaning the cycles of compression and rarefaction travel in the same direction as the wave. Imagine an analogous spring coil with a force exerted into its length. A wave, or region of compression, will pass down through the coil in a longitudinal or parallel fashion (**Figure 3-2**). It is important to have an understanding of the terms that describe sound waves as described in the following sections.

FREQUENCY AND PERIOD

Frequency is the number of cycles of pressure variation per 1 second. A single cycle begins at a baseline of absent sound, increases to a maximum value (compression), decreases to a minimum value (rarefaction), and returns to baseline (**Figure 3-2**). Frequency is measured in hertz with a unit of cycles per second and corresponds to the pitch or tone of a sound. The upper acoustical frequency of human hearing is approximately 20,000 Hertz (Hz), beyond which is considered "US." Diagnostic US frequencies are generally in the range of 1 to 10 million Hz or MHz. US transducers operate on either the "low" or "high" end of this frequency spectrum, although for each transducer frequency can be adjusted within a limited range. Frequency is a principal determinant of the resolution and penetration of an image.

Period is the time required for one cycle to occur. Thus, it is the inverse of frequency (**Figure 3-3**). In ultrasonography, period is typically measured in microseconds (μs).

WAVELENGTH AND PROPAGATION SPEED

While period measures the duration in time of a single cycle, wavelength measures the distance in space of a single cycle (**Figure 3-3**). Wavelength is related to the propagation speed and the frequency of a wave. It is represented by the following equation: wavelength = propagation speed/frequency.

Propagation speed is the velocity at which sound travels through tissue. An average speed through soft tissues of 1540 m/s is generally assumed in basic US. Newer US machines incorporate the propagation speeds of different tissues to provide enhanced imaging.

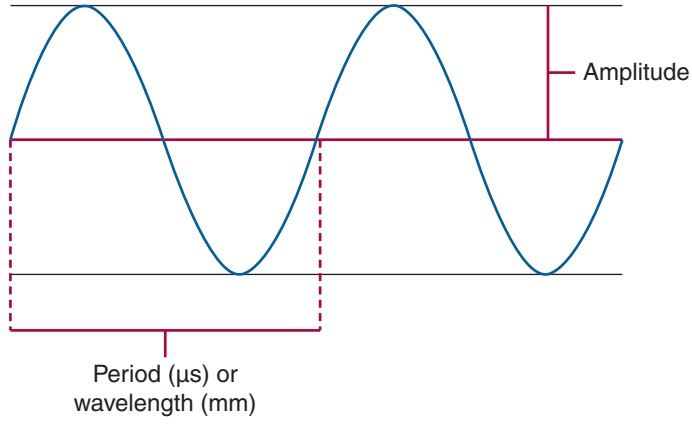


FIGURE 3-3. The characteristics of an US wave. Period is the duration in time of a single cycle of a wave, while wavelength is the distance in space. Amplitude measures the wave's variation (height) from baseline.

AMPLITUDE, OUTPUT, AND BIOEFFECTS

Amplitude is a measure of the height or maximum variation of a wave from baseline (**Figure 3-3**). While frequency corresponds to the pitch or tone of a sound, amplitude is the "loudness" or volume of a sound. In US, this correlates to the brightness of the image. Adjustments of the machine's output affect the amplitude, but changing the gain produces a similar effect on received echoes. It is preferable to alter brightness on the back end with gain, rather than subject the patient to increased output. While diagnostic US has proven to be exceedingly safe, concerns do exist over possible thermal and mechanical adverse bioeffects.[8] EPs should strive to perform studies in the shortest time frame and at the lowest output possible, in line with the safety acronym ALARA (*a*s *l*ow *a*s *r*easonably *a*chievable).

PULSED US

The earliest US machines produced a continuous stream of US waves. Today's machines release pulses or packets of waves, that is, a few cycles of US at a time. The repetitive pulses are separated by gaps of no sound. Machines can generate pulses of varying duration, frequency, and fraction of time with respect to the soundless gaps. Pulsed US has been essential in the development of advanced imaging.

AXIAL RESOLUTION

Axial resolution refers to the ability of the US machine to distinguish two separate structures that lie on top of one another and in a parallel plane to the US beam (**Figure 3-4**). As viewed on the screen, this is one structure on top of another. The structures must produce two separate echoes for each to be recognized as distinct. The smaller the wavelength of the transmitted US beam, the closer in position can be the two tiny distinguishable structures. The size of the wavelength can be decreased by increasing the frequency of the US beam. Increasing the frequency delivers greater axial resolution. But a sacrifice is seen in penetration because of increased attenuation at higher frequencies.

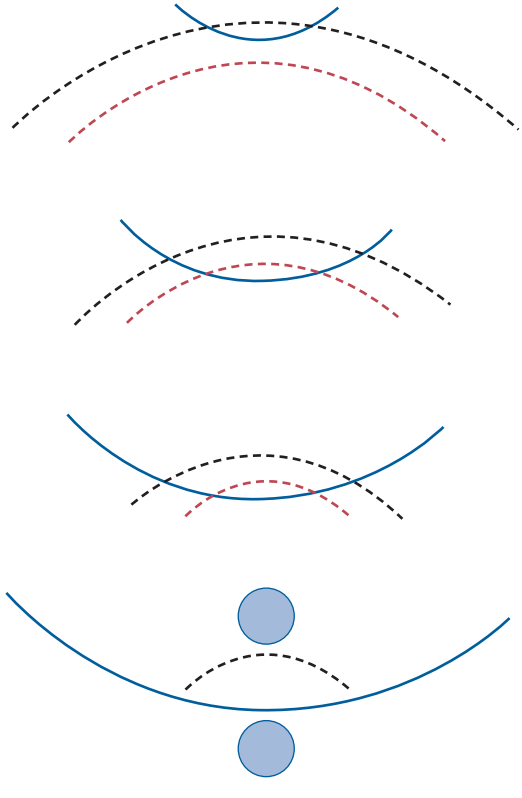


FIGURE 3-4. The axial resolution of structures. Blue curves represent the transmitted US beam. Red and black curves represent the returning echoes of the superficial and deep structures, respectively. Increasing the frequency, which shortens the wavelength, improves axial resolution.

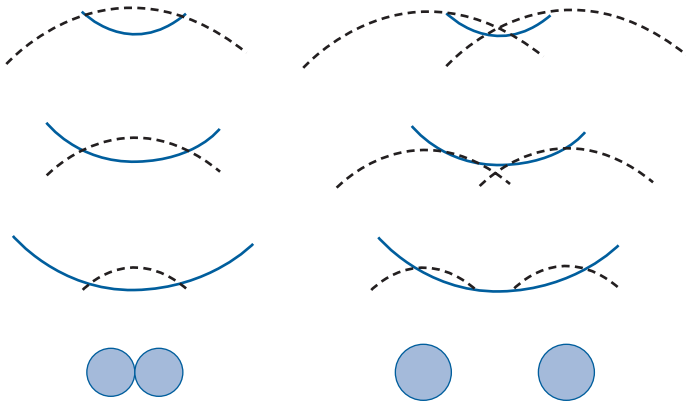


FIGURE 3-5. The lateral resolution of structures. Blue curves represent the transmitted US beam. Black curves represent the returning echoes. The structures must be able to produce separate echoes for the US machine to distinguish them. Focusing of the beam width improves lateral resolution.

LATERAL RESOLUTION AND FOCUS

Lateral resolution refers to the machine's ability to distinguish two separate structures that lie side-by-side in a plane perpendicular to the US beam (**Figure 3-5**). As seen on the screen, this is one structure to the side of another. Lateral resolution is a function of the beam width. The narrower the beam, the greater is the ability to produce separate echoes for two adjacent objects. Focusing narrows an US beam at specific depths. The focal zone is the narrowest part of the hourglass-shaped US beam. Focusing can be achieved automatically by the machine or manually by the operator. One or multiple focal zones can be set at specific depths to narrow the beam for optimal lateral resolution.

TEMPORAL RESOLUTION

Continuous US scanning is actually a collection of still frames displayed rapidly over time. US machines produce numerous frames per second as the scan beam is transmitted over and over again through the tissue. The number of frames per second is known as the frame rate. The greater the frame rate, the better the temporal resolution, and the smoother the moving image appears. High frame rates are particularly important for scanning moving structures such as the heart. Employing additional functions such as Doppler scanning may limit the machine's ability to produce high frame rates.

ECHOES

Diagnostic US is predicated on sound waves not only transmitting through tissues but also reflecting back to the transducer (**Figure 3-6**). At an interface of two different tissues, the proportion of transmission and reflection is determined by the acoustic impedance of the tissues. Acoustic impedance is a measure of a tissue's resistance to sound penetration (density × propagation speed). Acoustic impedance is high in "hard" tissues such as bone, lower in visceral organs, and negligible in fluid. Reflection of an echo is a function of the difference between the acoustic impedance of two

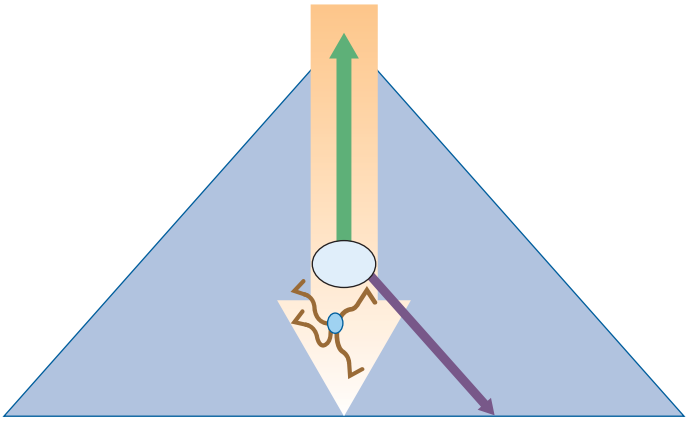


FIGURE 3-6. The echoes produced as the US beam penetrates tissue. The transmitted beam (orange) attenuates as it penetrates. A reflected echo (green) is produced at an interface. Refraction (purple) and scatter (brown) contribute to attenuation. Scatter produces the imaging within homogenous tissue.

adjacent tissues. For instance, when a sound wave travels from soft tissue to bone, a significant proportion of the wave will reflect back to the probe, and a minimal amount will transmit through for imaging of deeper structures.

When an US beam travels through parenchymal tissue without interfaces (of homogenous acoustic impedance), such as the liver, imaging is generated not by reflection but rather by scatter. Scattering occurs when a sound wave encounters particles smaller than its wavelength or objects with rough and irregular surfaces. An analogous effect is seen when light is shone through fog. There is some transmission and reflection of the light, but it is the scattering of light that reveals the mass of fog.

In order for an US machine to generate an image, it must determine not only the intensity of the returning echo but also the location of the reflecting structure (aka reflector). With a given propagation speed (velocity of sound through tissue), the machine uses the travel time of the sound wave to calculate the distance the reflector sits from the transducer. The longer the travel time, the deeper is the reflector or structure.

ATTENUATION

Sound weakens or attenuates as it propagates through a medium (**Figure 3-6**). Attenuation is a result of absorption, reflection, refraction, and scattering of the US wave. Absorption is the conversion of sound to heat as the wave passes through tissue and accounts for the vast majority of attenuation. Absorption has very limited clinical effect for diagnostic US but is the basis of therapeutic US. Reflection is the "echoing" of the wave back to the transducer. Refraction and scattering are the redirection of waves on encountering certain interfaces.

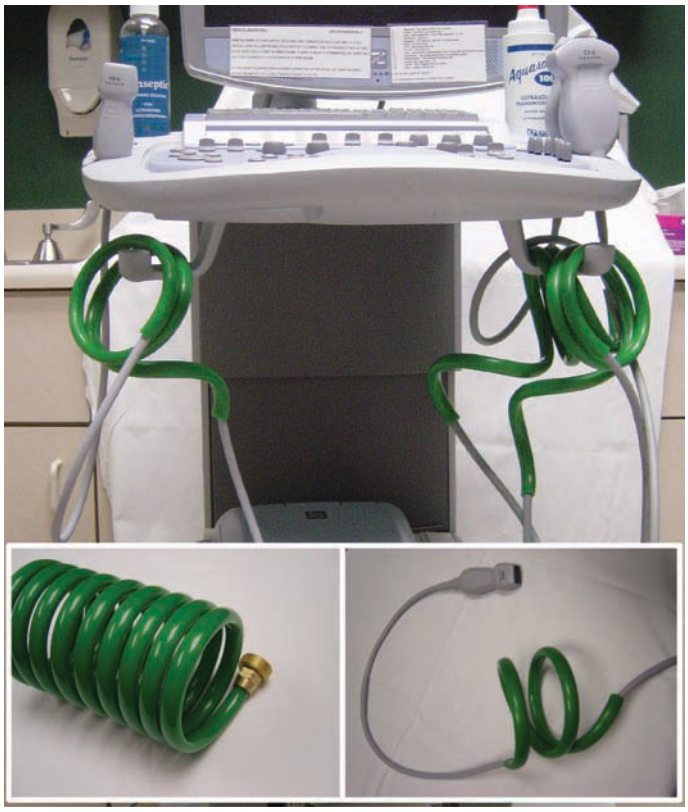


FIGURE 3-7. The Press-ervation technique for transducer cords. Segments of a coiled garden hose are sliced along their length and placed around the middle portion of a transducer cord. This prevents damage from wheels running over dangling cords.

US TRANSDUCERS (PROBES)

There are many types of transducers (also called probes) that vary in size, shape, construction, transmitted frequency, and function (**Table 3-2**). Transducers can be expensive and are at risk for damage in a busy ED. Probes are often dropped and cords frequently run over by the wheels of the US machine. Creative solutions to prevent damage to dangling cords have been developed (**Figure 3-7**), but the expense of replacing transducers should be factored into

TABLE 3-2 Common Types of US Probes Used in the ED

Transducer type	Vascular	Abdominal	Endovaginal	Cardiac
Transducer shape				
Type of scanning	Linear sequenced	Curved sequenced	Microcurved sequenced	Phased array
Transducer frequency Megahertz	High 7–10	Low 2–5	High 7–100	Low 2–5

Photographs courtesy of Zonare Medical Systems.

any warranty and maintenance considerations. Many US manufacturers offer multiport transducer connections that allow a number of probes to be connected at once, each activated by the push of a button. Limiting the connecting and disconnecting of transducers decreases the chance of damaging fragile connector pins.

Transducers are the link between the US machine and the patient. The essential component of the transducer for generating an image is the piezoelectric element. The piezoelectric principle states that when an electrical voltage is exerted on certain materials, a mechanical pressure or vibration will be produced. A transducer's piezoelectric elements, or crystals, when vibrated by an electrical voltage will generate a mechanical sound wave. The returning sound wave in turn vibrates the elements creating an electrical voltage that carries image data back to the US machine.

AUTOMATIC SCANNING

Transducers are constructed of numerous elements arranged along the width of the probe. Unlike a flashlight that emits a single continuous beam of light, the US beam is a composite of pulsed firings of the elements. Automatic scanning is the electronic activation of the elements or arrays of crystals to generate a beam for a cross-sectional image. Two types of automatic scanning currently employed by transducers are sequenced array and phased array scanning.

SEQUENCED ARRAY

Sequenced array scanning involves the sequential firing of groups of elements across the transducer assembly (**Figure 3-8**). One scan line after another is generated along the width of the probe. Linear transducers are flat-topped and produce a rectangular beam made up of parallel scan lines. Curved transducers transmit scan lines similarly, but following the curve of the probe and create a sector or pie-shaped image. The elements are fired rapidly and multiple frames of cross-sectional images are produced per second.

PHASED ARRAY

Phased array transducers generally have a narrow flat-topped footprint. The tightly packed elements are electrically activated as a single unit, but with a slight time lag between each element resulting in an angling of the pulse direction. The electronic activation and angling of each subsequent pulse is slightly changed, and the resultant composite beam is a sector or pie-shaped (**Figure 3-8**).

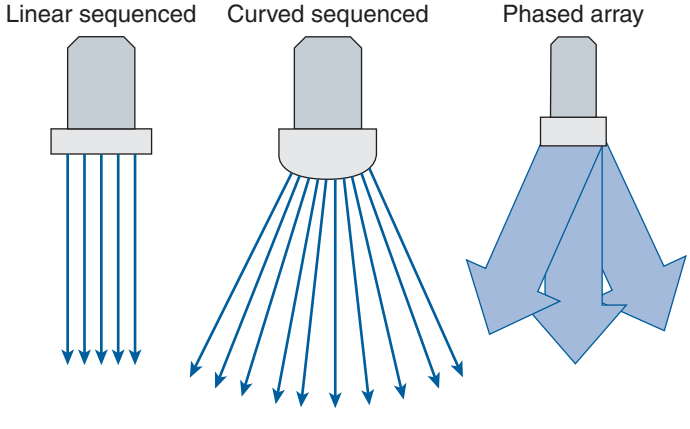


FIGURE 3-8. The basic types of transducers. Linear sequenced and curved sequenced array probes transmit beams in a sequential fashion following the shape of the transducer head to produce rectangular and pie-shaped images, respectively. The beams of phased array probes are steered by slight delays in the firing of the elements to produce a pie-shaped image.

TRANSDUCER TYPES

The typical arsenal of transducers for emergency US includes a low-frequency curvilinear or phased array probe, a high-frequency linear probe, and an endocavitary probe (**Table 3-2**). Numerous other types of transducers are manufactured. It is worthwhile evaluating the options available before purchasing a transducer.

CONVEX TRANSDUCERS

Convex or curved transducers are low-frequency probes that produce a sector-shaped image by sequenced array scanning. These are commonly used in EM, as they are useful for most US examinations of the torso. The resolution of these probes is inferior to that of linear transducers, but the greater penetration allows for imaging of relatively deep structures such as the aorta, gallbladder, liver, kidneys, and heart. Microconvex probes have a similar but smaller footprint with a tight curvature that allows for easier use between adjacent ribs.

PHASED ARRAY TRANSDUCERS

Phased array transducers are low-frequency probes made for echocardiography and general imaging of the torso. These probes have a small flat footprint ideal for maneuvering between ribs and imaging the heart.

LINEAR TRANSDUCERS

Linear transducers are high-frequency probes that are ideal for imaging superficial structures. They are generally wide and flat-topped, and produce a rectangular image by sequenced array scanning. These transducers are useful in the ED for imaging of blood vessels and guided line placement, skin abscesses, musculoskeletal pathology, pneumothoraces, ocular and testicular pathology, and a host of other superficial parts.

ENDOCAVITARY TRANSDUCERS

Endocavitary transducers are high-frequency probes that have elements arranged in a tight curve at the end of a long handle. They are designed primarily for vaginal insertion and high-resolution imaging of the female reproductive organs. These probes can be used for US-guided vascular access if no other high-frequency probe is available. The small footprint and room afforded by the handle may even prove superior to a linear probe in some instances. The probe can be used in a patient's mouth for the evaluation of oral and pharyngeal pathology, such as a peritonsillar abscess.

FREQUENCY AND TISSUE HARMONIC IMAGING

Transducers may differ in inherent frequency. The frequency of each probe can be adjusted within a narrow range of generally a few megahertz. If greater depth is required to view pertinent structures, lowering the frequency may be beneficial. Conversely, if finer resolution is desired more than deep penetration, increasing the frequency may improve visualization.

Tissue harmonic imaging is another means of enhancing US scanning. US echoes return from tissues in multiples of the transmitted frequency. The machine can filter out the transmitted frequency and focus on receiving the second harmonic frequency (twice the transmitted frequency). The returning harmonic beam is narrower than the beam of the fundamental frequency, and, hence, lateral resolution is improved. Artifacts and distortions are also reduced with harmonic imaging.

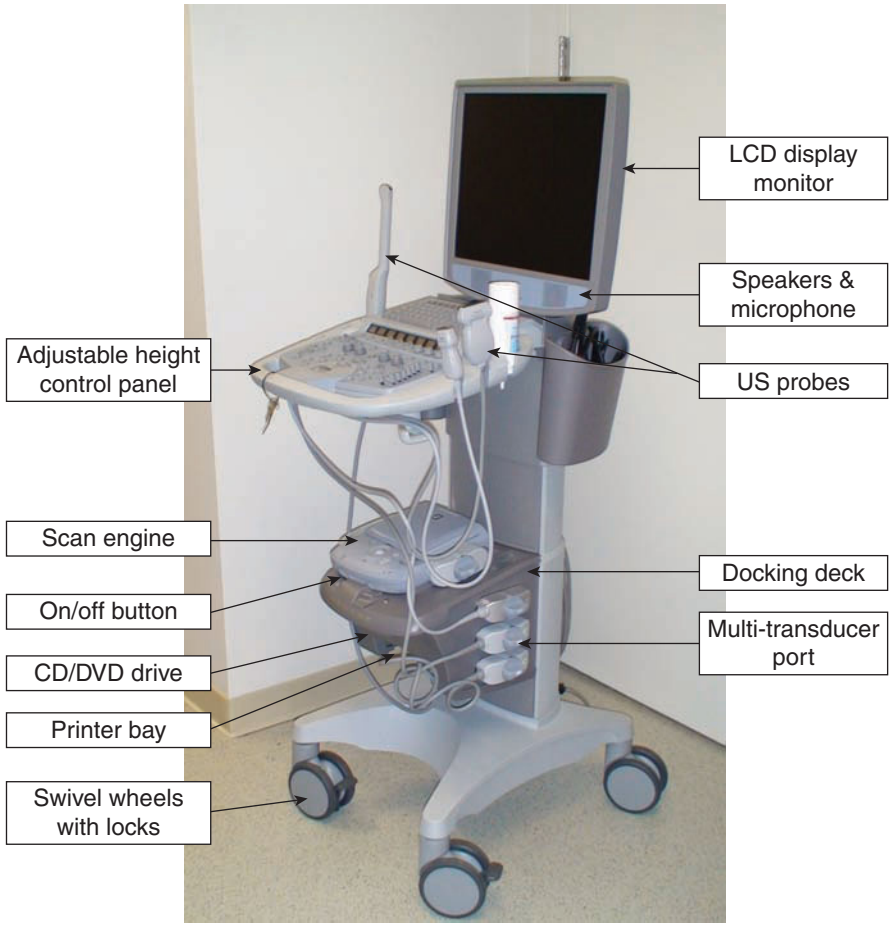


FIGURE 3-9. Components of a typical US machine.

COUPLING MEDIUM

Acoustic gel is the coupling medium used in diagnostic US. The gel obviates any air between the probe and the patient to improve US beam transmission. Apply the gel across the footprint of the probe or onto the patient's skin. A good rule of thumb is that too much gel is preferable to too little.

ULTRASOUND MACHINE INSTRUMENTATION

An US machine is made up of numerous components (**Figure 3-9**). The imaging system hardware consists of a beam former, signal processor, and image processor. The console allows the user to interface with and manage the imaging. The monitor screen provides for black and white as well as color viewing of the imaging. Transducers, single or multiple, have connecting ports onto the machine. Archiving tools, such as a printer or digital storage media, are available standard or as options. The following sections review the key functions that an EP should know when performing US examinations.

THE CONSOLE

The US console generally consists of a keyboard for data entry and numerous knobs, buttons, dials, and toggle switches for manipulating the images. Carefully read the user's manual or undergo a detailed operations briefing by the manufacturer's application specialist after purchasing a new machine. While there are many functions that are universal to US machines, each machine has its proprietary functions.

GAIN

Gain is the US analog to the volume control on a radio. It alters not the transmitted beam, but the returning echo to amplify intensity. Gain is measured in decibels and relates to the brightness of the image. Machines generally have a knob that can be dialed to adjust the gain, increasing or decreasing the overall brightness of the image (**Figure 3-10**).

Time gain compensation (TGC) allows for adjustments of gain at specific depths. Most TGC controls consist of a collection of sliding knobs arranged in a column (**Figure 3-11**). The knobs at the top of the column correspond to the near field and those at the bottom correspond to the far field. As an US beam penetrates to greater depths, the intensity of the beam is attenuated or dampened. TGC allows compensation for attenuation. For general abdominal imaging, arrange the sliding TGC knobs with a slope of increasing gain at greater depths. Use TGC to increase or decrease brightness at discreet depths of the image. To compensate for the artifactual brightness seen deep to a fluid-filled structure, decreasing the gain at that depth can improve visualization.

DEPTH

The depth of the field of view can be adjusted by the turn of a dial or toggle of a switch. Depth is conventionally measured in centimeters. Hash marks along the side of the image denote units of distance. Depth adjustments alter the penetration of the imaging beam and allow the user to appropriately "magnify" the organ or region of interest (**Figure 3-12**). If the depth is set too shallow

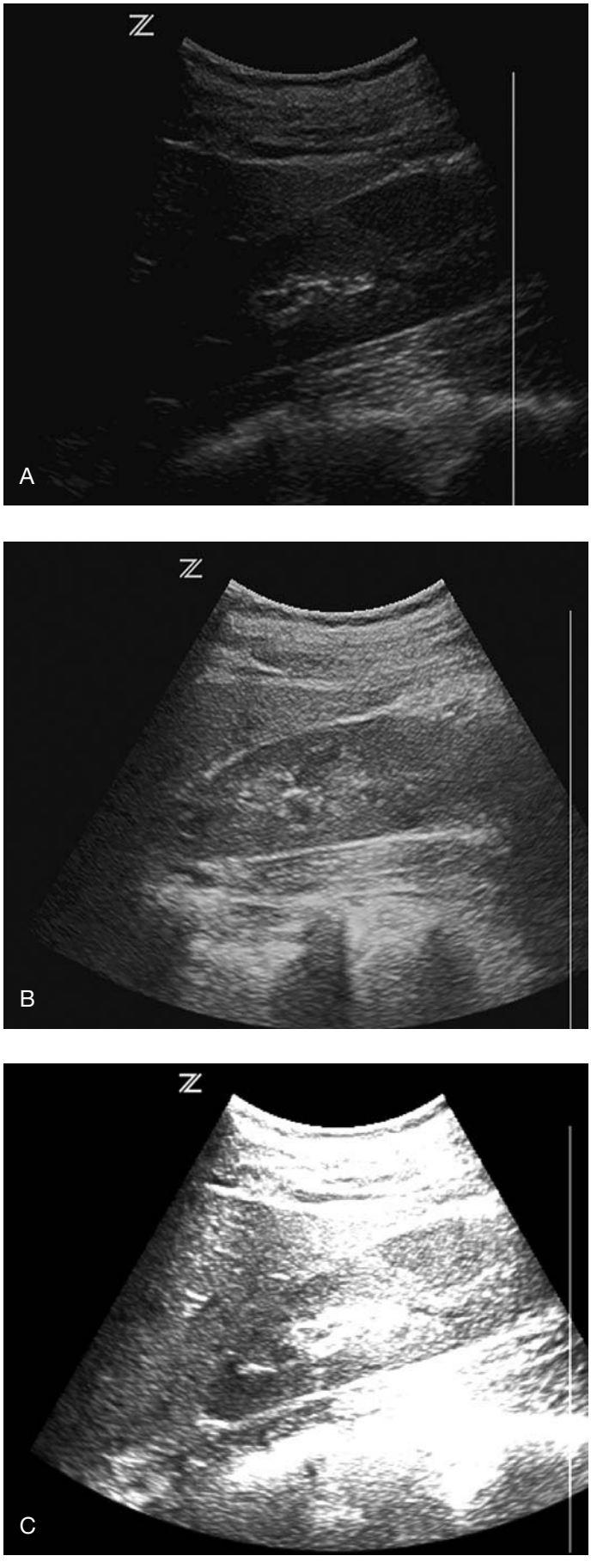


FIGURE 3-10. Gain adjustments brighten and darken the US image. These images of a kidney display a gain setting (**A**) too low, (**B**) appropriate, and (**C**) too high.

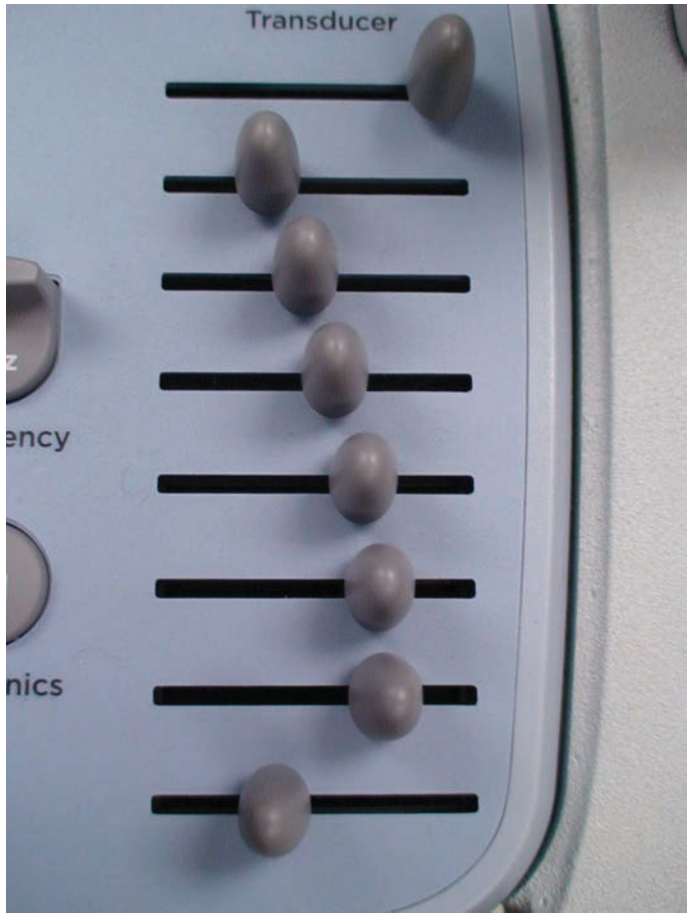


FIGURE 3-11. Time gain compensation (TGC) controls on an US machine consist of a column of knobs that slide back and forth to adjust the gain at specific depths.

("overmagnification"), the organ of interest will appear too large and its deepest portion may be cut off the screen. If the depth is set too deep ("undermagnification"), the organ of interest will appear too small in the near field with wasted space in the deeper regions.

PATIENT DATA ENTRY

All machines allow the entry of demographic information about the patient and the US examination. The patient data entry screen presents numerous fields that can be filled by typing on the keyboard. These fields commonly include patient name, medical record number, date of birth, and a comments section to name a few. Functions also often available on this screen are exam and transducer selection.

FREEZE AND CINE

Most machines allow both still images and video loops to be saved. Hitting the "freeze" button stops real-time continuous scanning. The most recent image is displayed on the screen with a few seconds worth of images (known as cine) available for review. Use the rollerball or trackpad to rewind through the cine memory of frames. This allows the viewing and subsequent saving of the most desired still image. A number of machines can allow the viewing of a loop of images as a video.

MISCELLANEOUS FUNCTIONS

There are numerous additional functions on the console. Magnify images with the "zoom" function. The "measure" button activates



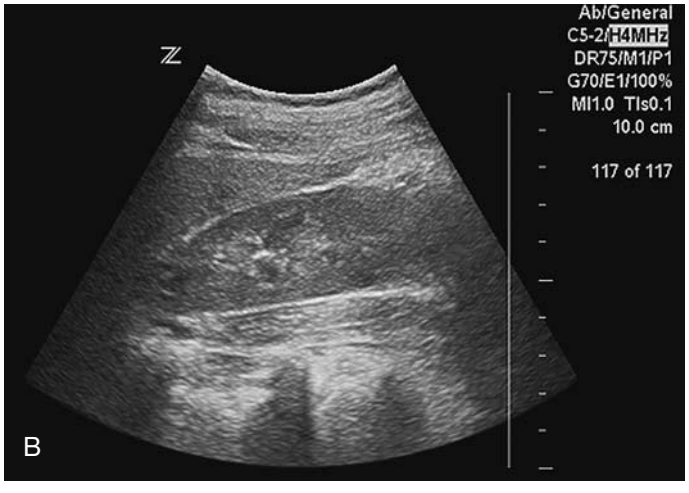




FIGURE 3-12. Depth adjustments increase and decrease the penetration of the US beam. These images of a kidney display a depth setting: (**A**) too deep at 22 cm, (**B**) appropriate at 10 cm, and (**C**) too shallow at 6 cm.

calipers that are moved with the trackpad or rollerball. This allows for precise measurements to the millimeter. Adjust the dynamic range to produce effects similar to modifying the contrast of a photograph. Other functions include gray-scale mapping, edge, and persistence for image alteration. A dual screen function displays two side-by-side imaging fields. Function keys can be set for easy access to commonly performed tasks.

PRINCIPLES OF GENERAL US IMAGING

DIMENSIONALITY

Imaging with US is akin to shining a flashlight in the dark. While a flashlight's beam is conical, the US beam is flat, and, hence, the image displayed on the screen is a two-dimensional slice. Sound transmits through most tissues to allow for visualization of deep structures in the cross-sectional slice. Scanning the beam back and forth stacks multiple two-dimensional slices in a movie format and provides a sense of spatial orientation. Rotating the probe 90° and scanning through the perpendicular plane helps to gain a three-dimensional comprehension of structures.

ORIENTATION

Orientation is entirely dependent on how the transducer is placed on the patient. Each transducer has a marker (usually a bump, ridge, or indentation) that correlates with an indicator on the screen to establish orientation. If the transducer is held with the marker aimed cephalad, the screen indicator is located on the left side of the screen (**Figure 3-13**). This results in the left side of



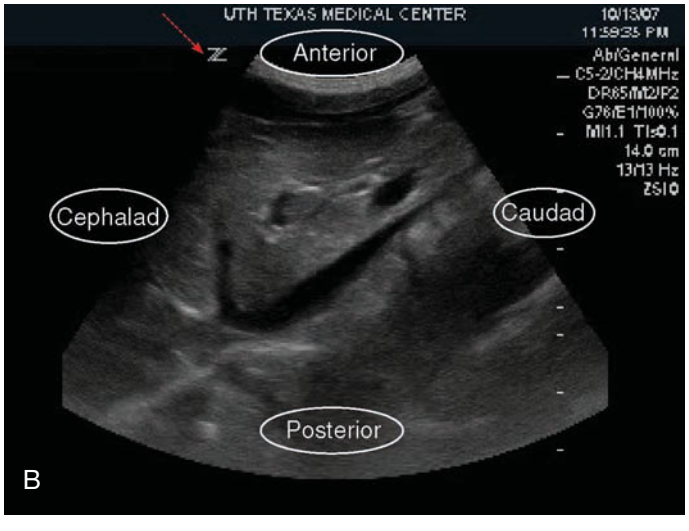


FIGURE 3-13. The orientation marker (white arrow) on the transducer corresponds with the indicator on the screen (red arrow).

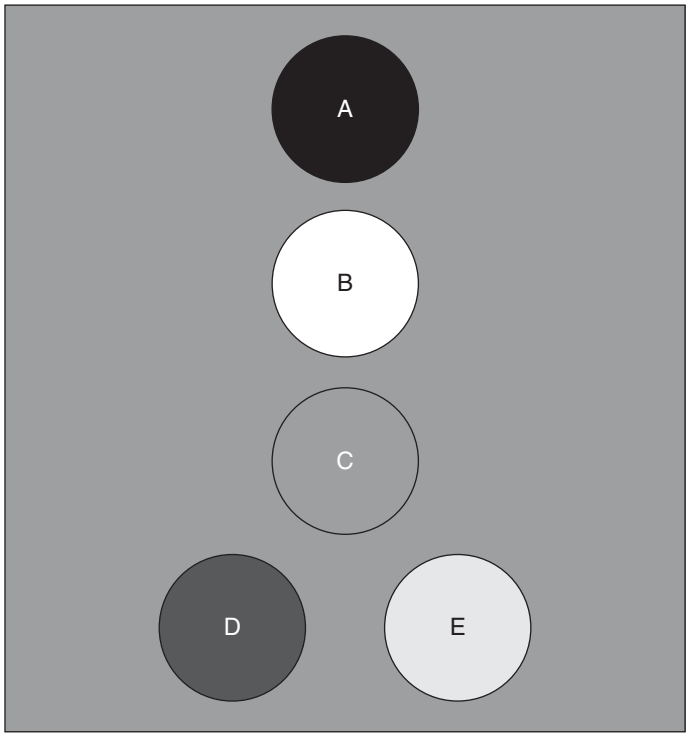


FIGURE 3-14. Echogenicity of structures is represented by their brightness on the screen. **A.** Anechoic fluid is black. **B.** Echogenic, or highly reflective, than adjacent tissues. **C.** Isoechoic, or same echo-texture, as adjacent tissue. **D.** Hypoechoic, or less echoic (darker), than adjacent tissues. **E.** Hyperechoic, or more echoic, than adjacent tissues.

the image representing the cephalad aspect and the right side the caudal aspect (**Figure 3-13**). For conventional radiology imaging, the screen indicator is located on the left side. Most emergency US examinations require views with the transducer marker aimed to the patient's head and the patient's right. The image is displayed with the near field (closest to the probe) at the top of the screen and the far field (farthest from the probe) at the bottom of the screen.

ECHOGENICITY

Fluid is anechoic, meaning US transmits through fluid without any reflected echoes. The echogenic silence is processed to generate black pixels on the screen. Highly reflective structures, such as the diaphragm and pericardium, are termed echogenic or hyperechoic. These structures will produce white imaging. Two structures of the same echo-texture are isoechoic. Less reflective tissue is hypoechoic and appears darker on the screen when comparing two tissues (**Figure 3-14**).

ARTIFACTS

Imaging artifacts are frequently encountered in ultrasonography. They are erroneous representations of the anatomy in the reflected echo. It is important to understand and expect certain artifacts to prevent misinterpretation of the images. Artifacts may also help to appreciate certain structures that would otherwise be less obvious.

SHADOWING

A highly reflective object allows very little of an US beam to transmit through it. Most of the beam is reflected back to the transducer and the structure is represented as hyperechoic or white on the screen. The US machine interprets the lack of returning

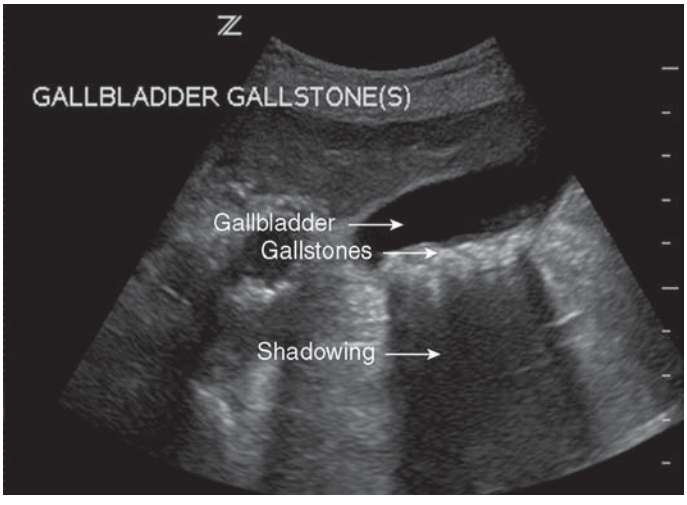


FIGURE 3-15. Echogenic gallstones are present in the gallbladder. Shadowing is seen deep to the gallstones.

echoes deep to a structure that is hyperechoic as the lack of reflection, similar to that seen with fluid. This is seen as a black shadow on the screen (**Figure 3-15**). While shadowing from ribs may obscure deep anatomy, the shadows of gallstones aid in their identification.

REVERBERATION

Highly reflective interfaces may result in multiple reflections. Bouncing of the sound beam between the reflector and the transducer can create false echoes known as reverberation (**Figure 3-16**). It can be seen when the sound beam encounters two closely spaced interfaces, such as the two walls of a needle or the visceral and parietal pleura. The echo reflects back and forth between the interfaces, but with some transmission of the beam back to the probe each time. These returning echoes generate artifactual reflections on the screen termed reverberation or comet tails (**Figure 3-17**).



FIGURE 3-16. The two walls (white arrows) of a cylindrical bullet are seen superficially. Reverberation artifact produces an additional false echo (red arrow). Shadowing is seen deep to the bullet.

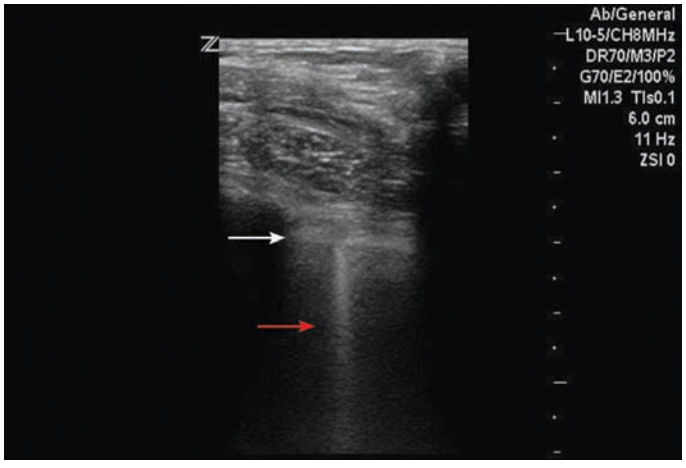


FIGURE 3-17. Each back and forth reflection between the visceral and parietal pleura (white arrow) results in an echo transmitted back to the probe. Multiple echoes returning one after another produce echogenic artifacts, each deeper than the next. The artifact resembles a comet tail (red arrow).

MIRROR IMAGE

Highly reflective tissues can cause mirror-image artifacts. Structures seen on the near side of a bright reflector are displayed on the other side of the reflector as well. This is common with the diaphragm. Triangulation of the beam path delays the return time of the echo to mirror a second reflector (**Figure 3-18**). Mirror-image artifact can help to exclude a hemothorax by visualizing the liver or spleen cephalad to the diaphragm (**Figure 3-19**).

ENHANCEMENT

Attenuation does not occur when a sound beam passes through a fluid-filled structure. The beam's high intensity is maintained through the fluid. A strong echo is generated off the posterior wall of the fluid-filled structure. The artifact seen on the screen is a very hyperechoic region deep to the fluid-filled structure that may obscure the actual anatomy (**Figure 3-20**).

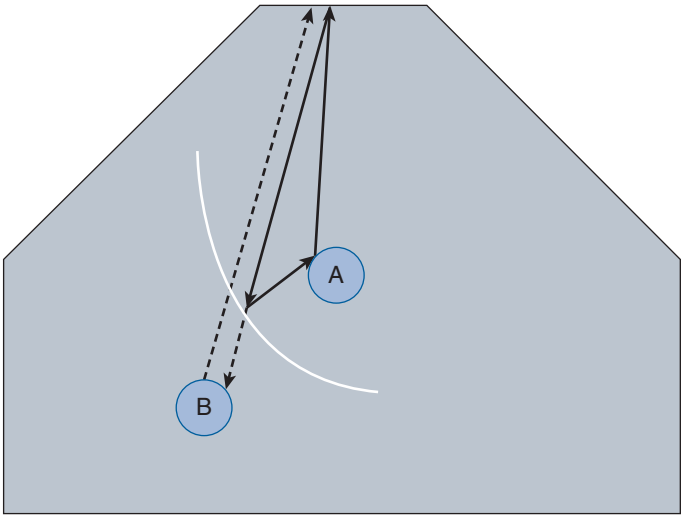


FIGURE 3-18. Bright reflectors like the diaphragm (white) can generate mirror-image artifacts. The initial beam (solid arrow) reflects off the diaphragm and then an anatomical structure (**A**) before returning to the transducer. The machine processes the delay as a signal from a deeper structure along the initial scan line (dashed arrow) and generates an artifact (**B**) on the screen.

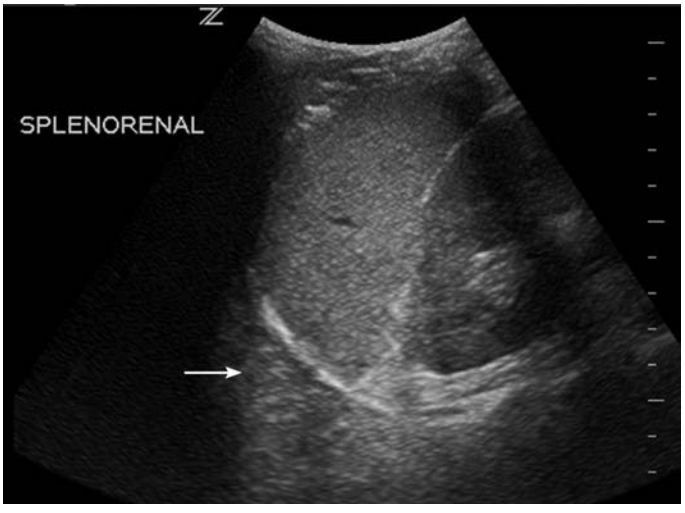


FIGURE 3-19. A mirror-image artifact (white arrow) of the spleen is seen cephalad to the diaphragm. This is distinct from fluid that appears black.

MISCELLANEOUS ARTIFACTS

A number of additional artifacts can interfere with imaging. Side lobes are weak beams emitted lateral to the central axis of the scanning beam that may produce false echoes. Section thickness artifact is a result of interfering information from the outside of the flat slice of the scanning beam. Refraction of the beam tangentially off an interface may produce a double image of a structure lateral to the original. Shadowing in the narrow angle of refraction may be seen deep to the interface.

US MODES

BRIGHTNESS MODE

Brightness mode is commonly referred to as B-Mode. This is the basic scanning mode for US. It displays the standard two-dimensional gray-scale image.



FIGURE 3-20. High-intensity echo returns from the posterior wall of the bladder result in a hyperechoic region of enhancement artifact (white arrow).

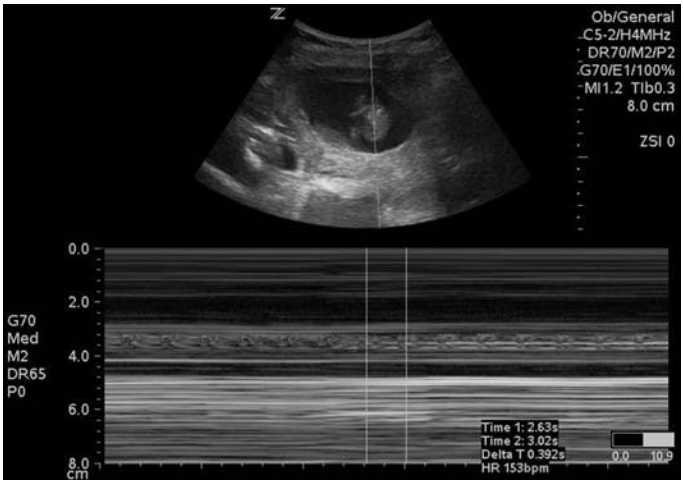


FIGURE 3-21. The M-Mode. The B-Mode image is displayed at the top of the screen. A green vertical line is seen over the B-Mode image. The area under the green line is displayed over time at the bottom of the screen. The fetal heartbeat is seen at a depth of 3.6 cm and measured at 153 beats/min.

MOTION MODE

Motion mode or M-Mode is used to assess moving structures. Activating M-Mode produces a vertical line on the image (**Figure 3-21**). The line can be moved left or right with the rollerball or trackpad. The US beam penetrating the tissue along that single line is displayed in a continuous graphical manner on the bottom of the screen (**Figure 3-21**). The *x*-axis of the display is depth and the *y*-axis is time. If the line is set on immobile tissue, there will be no variation in the M-Mode display. Movement along the line, such as a beating heart, allows measurements and rate determinations (**Figure 3-21**).

DOPPLER MODE

Doppler scanning allows the assessment of the presence, direction, speed, and character of blood flow and tissue movement. Doppler takes full advantage of the real-time dynamic nature of US. If an object is moving toward or away from the transducer, the frequency of the reflecting echo will be higher or lower, respectively, than the transmitted frequency. The Doppler shift is the difference between the transmitted and reflected frequencies. The US machine can calculate velocity using the Doppler shift. Turbulence, or the variance in velocity of multiple objects in flow, can be assessed. The complexities of Doppler physics and operations are beyond the scope of this chapter.

Emergency Physicians can utilize Doppler in the assessment of deep venous thromboses, testicular or ovarian torsion, compromised vascular flow in the extremities, inflamed or hypervascular tissues, to differentiate vessels from nonvascular structures for diagnostic and procedural purposes, and for advanced echocardiography.

COLOR DOPPLER MODE

A "C" button on the machine's console usually signifies color Doppler mode. Activating color Doppler produces a box, or region of interest (ROI), overlying the image. The ROI can be maneuvered over the desired area. The size of the box can be manipulated to be larger or smaller depending on the study being performed. Within the ROI, flow will be displayed in a color schematic (**Figure 3-22**). Flow toward the probe is typically red. Flow directed away from the probe is typically blue. Gradients of red and blue signify the speed of the flow.

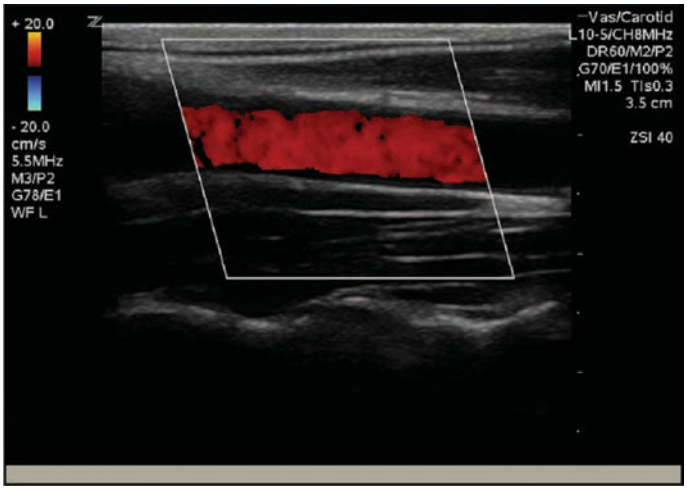


FIGURE 3-22. The color Doppler box, or region of interest (ROI), placed over the carotid artery reveals flow in the direction of the probe (red).

PULSED WAVE DOPPLER MODE

Pulsed wave Doppler provides a quantitative assessment of flow velocities. Activating pulsed wave Doppler splits the screen, typically placing the image at the top of the screen and a dynamic graph of flow velocities at the bottom (**Figure 3-23**). A small "gate" can be positioned over a specific vascular area to measure flow. The size of the gate can be adjusted, allowing very narrow regions to be accurately assessed. The dynamic Doppler graph displays time on the *x*-axis and velocity on the *y*-axis. Movement toward the probe is depicted as a positive velocity deflection. Movement away from the probe is depicted as a negative deflection.

POWER DOPPLER MODE

Power Doppler is another method of displaying blood flow or tissue motion (**Figure 3-24**). It utilizes the same ROI box as color Doppler, but with only one shade of color. Power Doppler is very sensitive in identifying the presence of flow but does not reveal direction. It is advantageous in identifying low flow states, subtle tissue motion, and imaging small or deep vessels.



FIGURE 3-23. The pulsed wave Doppler mode. A Doppler gate is placed over the center of the carotid artery. Flow is displayed in active graphical format at the bottom of the screen. Positive deflections indicate systolic flow in the direction of the probe.

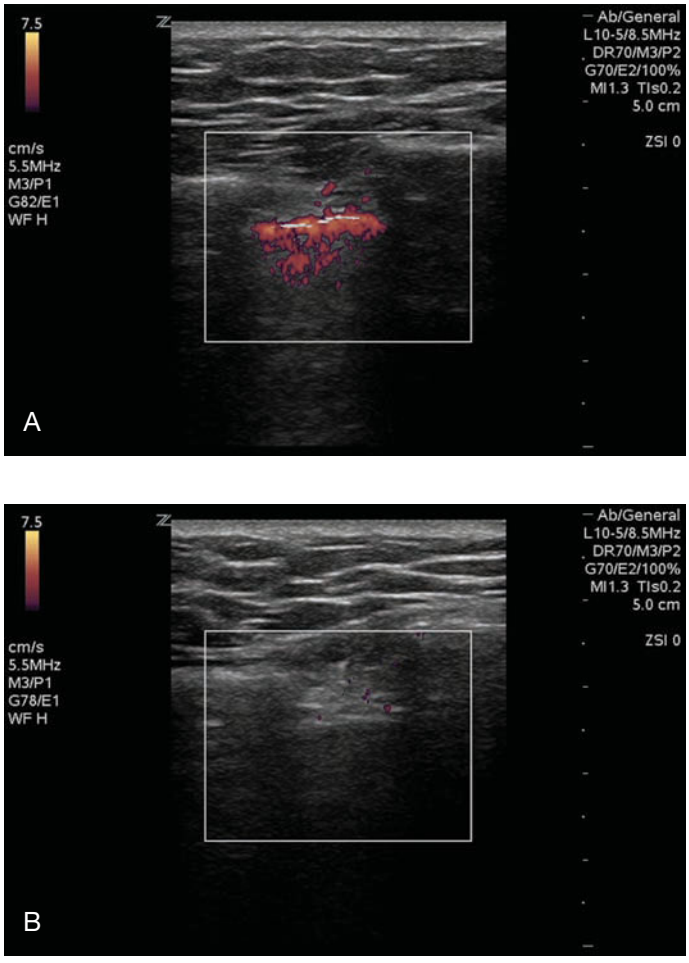


FIGURE 3-24. The power Doppler mode. **A.** Normal lung slide at the pleural line. The tissue movement generates a power Doppler signal. **B.** No lung slide or tissue motion is seen in the setting of pneumothorax.

US IMAGE ARCHIVING

There are numerous ways to archive US images. Still images can be sent to printers for hard copy archiving. Thermal printers are relatively small and can be attached to the US cart. The gray-scale printouts are fine reproductions of the image, but are at risk for degradation over time.

Digital archiving allows users to save both still images and videos with a far reduced need for physical storage space. Examinations can be saved to hard drives built into the US machine or to peripheral devices. Machines today offer many options for peripheral storage including compact discs, digital video discs, external drives with universal serial bus connections, and magneto-optical disks.

Specific formats for digital archiving of medical imaging have been developed, in particular the digital information and communication in medicine (DICOM) format. Most US machines today have the ability to save images in the DICOM file format. Picture archiving and communication system (PACS) has been developed for viewing medical imaging in DICOM and other formats. These systems are employed by radiology departments for viewing US images, as well as computed tomography, magnetic resonance imaging, plain radiographs, and other imaging modalities. Advantages to saving DICOM images on PACS include improved organization, reliability, and the ability to transmit remotely.

SUMMARY

Ultrasound is fast becoming a commonly used modality in EDs. All EPs should become familiar with US as it will soon become the standard of care for patient evaluation, patient management, and procedural guidance. Take the time to investigate the various options available for machines, probes, and accessories. A thorough understanding of the functioning and features of an US machine is essential before making clinical decisions. Training is readily available through US fellowships, CME courses, and ultrasound manufacturers.

4 Ultrasound-Assisted Procedures

Jehangir Meer, Sam Hsu, and Brian Euerle

INTRODUCTION

Emergency Physicians commonly perform invasive procedures. These procedures have traditionally been taught using surface landmarks, with the assumption that anatomy is reliably similar from patient to patient. The increasing use of ultrasound (US) to assist in procedural guidance has demonstrated that this is not the case. **Utilizing US to assist with procedures has numerous benefits.[1–9] It is safer for patients as it has been shown to reduce complications. US improves patient comfort and satisfaction. This is due primarily to decreased attempts at the procedure. The use of US usually decreases the duration of the procedure.**

This chapter reviews the basic information regarding the use of US to assist or guide procedures in the Emergency Department (ED). US can assist in many commonly performed ED procedures (**Table 4-1**). The specific US technique for a procedure is described in the chapter for the particular procedure.

The sonographer must make several decisions prior to beginning a procedure using US. Will the procedure be performed under real-time US guidance or will US only be used to map the anatomy? Will one person (the sonographer) or two people (the

TABLE 4-1 Common ED Procedures that Use US Assistance or Guidance

Body region	Procedures
Abdomen and pelvis	Paracentesis
	Suprapubic bladder aspiration
	Suprapubic bladder catheterization
Airway	Endotracheal intubation
Bones and joints	Arthrocentesis
	Closed fracture reduction
	Fracture identification
Chest	Pericardiocentesis
	Thoracentesis
	Cardiac pacing (transvenous and transthoracic)
ENT	Peritonsillar abscess incision and drainage
Nervous system	Peripheral nerve blocks
	Lumbar puncture
Soft tissue and musculoskeletal	Abscess identification
	Abscess incision and drainage
	Foreign body identification and removal
Vascular	Arterial line placement
	Central venous access
	Peripheral venous access

sonographer and an assistant) be necessary? Which US probe is the most appropriate for the procedure? Should the instrument or needle be imaged in the long-axis view or the short-axis view? Are needle guides necessary? What is the ideal location of the US machine in relation to the sonographer and patient? These general questions must be kept in mind when using US for invasive procedures and are discussed below.

US GUIDANCE VERSUS MAPPING

US can be used in one of the two ways for procedural assistance: the dynamic technique or the static technique. The dynamic technique is also known as US guidance. The sonographer uses US guidance in real time during the procedure to survey the anatomy, to confirm a diagnosis, and to visualize the needle or instrument as it enters tissue and reaches the target. The static technique is also known as US mapping. The sonographer uses US mapping prior to starting the procedure to map the local anatomy, to confirm a diagnosis, and to mark the site of needle entry. The US probe is then put away and the procedure performed in the traditional fashion without real-time US.

The decision between US guidance versus US mapping is influenced primarily by the degree of inherent danger of the procedure. Perform procedures that carry a higher risk or have greater technical difficulty (e.g., central venous access, pericardiocentesis, or foreign body removal) under US guidance. Perform lower risk procedures (e.g., thoracentesis, paracentesis, or abscess I&D) with US mapping. Another factor is sonographer experience. The experienced sonographer is more technically adept and comfortable doing procedures under real-time US guidance. Novice sonographers who do not have as much psychomotor training and experience may find it easier to use US mapping.

ONE-PERSON VERSUS TWO-PERSON TECHNIQUE

The decision to perform a procedure with one or two people is based on the sonographers experience and the availability of an assistant. Sonographers with more experience often prefer to guide the US probe and manipulate the instrument themselves. Their experience and expertise allows them to work with a higher efficiency without an assistant. Assistance during the procedure may not be an option during a busy ED shift, in an ED with single physician coverage or in an ED with limited personnel. For one-person US guidance, the sonographer holds the US probe with the nondominant hand and guides the needle or instrument with the dominant hand. This requires a degree of hand-and-eye coordination to maintain continuous alignment of the needle with the US probe.

Novice sonographers may find it less daunting to use the two-person technique and work with an assistant. The assistant holds the US probe while the sonographer guides the needle or instrument. The assistant's responsibility is to maintain alignment of the US probe with the needle during the procedure. The sonographer must maintain good communication with the assistant throughout the procedure in order to maintain sight of both the needle tip and the target organ on the US screen.

TYPES OF US PROBES

The following general principle will be helpful in determining which US probe is the most appropriate for a given procedure. **The higher the frequency of the US probe, the better the resolution of the structures visualized, but the shallower the maximum depth of view.** In other words, use a high-frequency US probe for superficial structures and a low-frequency US probe for deep structures. Low-frequency US probes include the curvilinear probe and the phased-array probe (**Table 4-2**). High-frequency US probes include the linear probe and the endocavitary probe (**Table 4-2**). More than one probe may be required for some procedures. Another factor in selecting the US probe is its footprint or surface area. A larger footprint is recommended to get a larger scan image unless specific anatomic barriers (e.g., ribs) dictate a smaller footprint. The types of US probes recommended for specific procedures are listed in **Table 4-2**.

TABLE 4-2 Recommendations for the US Probe Type to Use for Specific Procedures

Probe type	Procedure
Curvilinear	Endotracheal intubation
	Lumbar puncture
	Paracentesis
	Pericardiocentesis
	Suprapubic bladder aspiration
	Suprapubic bladder catheterization
	Transcutaneous cardiac pacing
	Transvenous cardiac pacing
Endocavitary	Peritonsillar abscess incision and drainage
Linear array	Abscess incision and drainage
	Endotracheal intubation
	Fracture identification
	Fracture reduction
	Lumbar puncture
	Peripheral nerve blocks
Phased array	Pericardiocentesis
	Thoracentesis
	Transvenous pacing

ORIENTATION OF THE NEEDLE AND THE US PROBE

Two orientations or approaches are used for US guidance during procedures. The longitudinal or long-axis approach refers to placing the long axis of the needle in-line with the long axis of the US probe



FIGURE 4-1. The longitudinal or long-axis approach of the US probe to the needle.

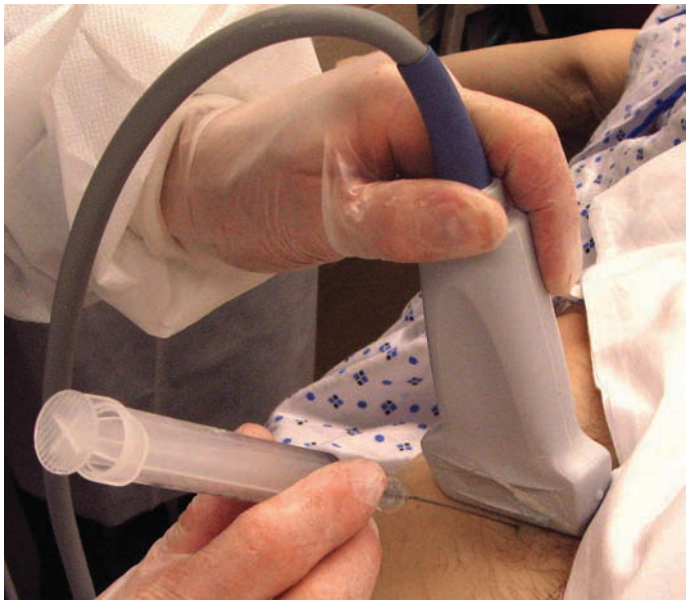


FIGURE 4-2. The transverse or short-axis approach of the US probe to the needle.

(**Figure 4-1**). The transverse or short-axis approach refers to placing the long axis of the needle 90° to the long axis of the US probe (**Figure 4-2**). **It is paramount for the sonographer to keep sight of the needle regardless of which approach is used during the procedure.** It is helpful to have the US probe indicator facing the same side as the marker on the top of the US screen to maintain left-to-right alignment.

The long-axis approach allows the entire length of the needle to be visualized as it approaches the target (**Figure 4-3**). Depth perception is better with this approach. This is a more intuitive approach for some ultrasonographers. The main disadvantage of the long-axis approach is the poor lateral resolution. A needle located to the side of a structure may appear in the same plane as the structure when actually it is not. This approach requires precise alignment of the US probe with the needle, otherwise the sonographer can lose sight of the needle. The one procedure best performed with the long-axis approach is a peripheral nerve block.

The short-axis approach requires the sonographer to center the target of interest on the US screen. The long axis of the needle is positioned 90° to the long axis of the US probe, at the center of the long axis of the US probe (**Figure 4-2**). The short-axis view of the needle is visible on the US monitor, resulting in better lateral resolution (**Figure 4-4**). One disadvantage of this approach is the challenge to maintain sight of the needle tip. The sonographer must move the US probe forward along with the needle tip as it is advanced. The depth of the needle tip can be misjudged if one is not careful. This can sometimes result in the inadvertent puncture of the anterior and/or posterior wall of the target structure or vessel, or of another adjacent structure.

MECHANICAL NEEDLE GUIDES

Needle guides are attachments to the US probe that keep the needle in a predictable path during the procedure. They are often utilized by radiologists for aspiration or biopsy of deep structures. The benefit of using a needle guide is that less hand-to-eye coordination is required to keep the needle aligned with the US probe during the procedure. The disadvantage of a needle guide is that the path angle is fixed and cannot be changed in the midst of the procedure. A needle guide is not necessary for the vast majority of Emergency Medicine procedures. It may actually be disadvantageous since it does not allow "on-the-fly" corrections of the needle path.



FIGURE 4-3. Long-axis US view of the needle (arrows).

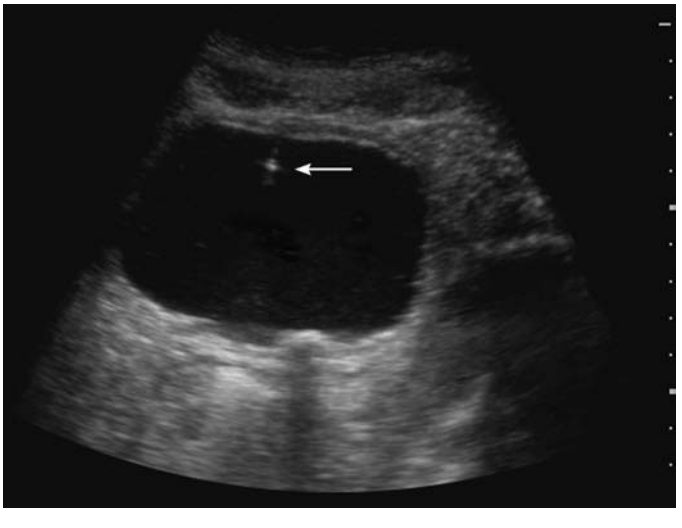


FIGURE 4-4. Short-axis US view of the needle (arrow).



FIGURE 4-5. An example of a good setup with the US machine in relation to the sonographer and the patient.

GENERAL TIPS WHEN USING US GUIDANCE

Always ensure that there is a direct line of sight from the procedural field to the US machine (**Figure 4-5**). The sonographer should not need to turn their head to the side during the procedure to view the US screen. This will greatly improve the sonographer's comfort during the procedure and increase the likelihood of success. Having to turn your head back-and-forth can result in the needle or the US probe moving, an unsuccessful procedure, puncture of incorrect structures, and potential morbidity. Hold the US probe comfortably in the nondominant hand using a pencil-like grip and maintaining light contact with the patient. It is best to use short controlled movements to maintain visualization when manipulating a needle or other instrument under US guidance.

Misalignment of the US probe and the needle is the most common reason for the needle tip not being visualized during the procedure. Stop advancing the needle if it is not visible on the US screen. Reposition the US probe by dragging or fanning it back and forth over the area of the needle until the needle can be seen. Gently rocking or bouncing the needle within the soft tissue can sometimes assist in determining the location of the needle tip.

Indirect clues can help determine the location of the needle tip if it cannot be seen directly. These include the ring-down artifact (**Figure 4-6**) and the needle shadow artifact (**Figure 4-7**). The ring-down artifact is a bright hyperechoic streak due to reverberation of the US beam from the highly reflective interface of the needle. The shadow artifact is a hypoechoic line below the needle due to the needle blocking the US beam. Follow either artifact until the needle can be visualized on the US screen. Continue to follow the needle until the tip is found.

Other factors can affect the ability to visualize the needle. Consider these when preparing to perform a procedure. Use the appropriate probe and depth of field for the procedure. Smaller gauge needles produce smaller artifacts and are more difficult to visualize, especially in cross section. It is easier to visualize needles perpendicular, or in the short axis, to the US beam. Consider using needles specific for ultrasonography that are extra reflective. The costs of these needles are hard to justify, but may be acceptable for teaching. Normal needles are appropriately reflective and it is difficult to justify these specific needles clinically. The beveled tip of the needle is easier to visualize than the shaft. The irregular surface of the bevel will reflect the US beam better than the shaft. Insert and advance the needle with a slight "to-and-fro" motion to easily follow the needle path.

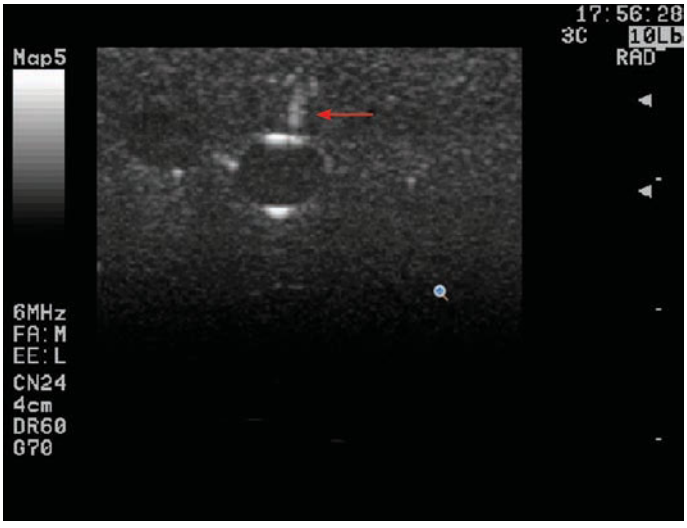


FIGURE 4-6. Ring-down artifact (arrow) showing the hyperechoic vertical line originating from the needle tip.

SUMMARY

The use of US assistance for procedures is an important skill set in the armamentarium of the Emergency Physician. It allows potentially dangerous procedures (e.g., incision and drainage of a peritonsillar abscess) to be performed in a safer manner due to visualization of the surrounding anatomy. It allows for the rapid confirmation of a diagnosis at the bedside, resulting in faster therapeutic interventions (e.g., pericardiocentesis). It usually results in greater patient satisfaction because of fewer attempts being required to successfully complete the procedure. ED ultrasonography can truly be a lifesaving modality when used by trained Emergency Physicians.

ACKNOWLEDGMENTS

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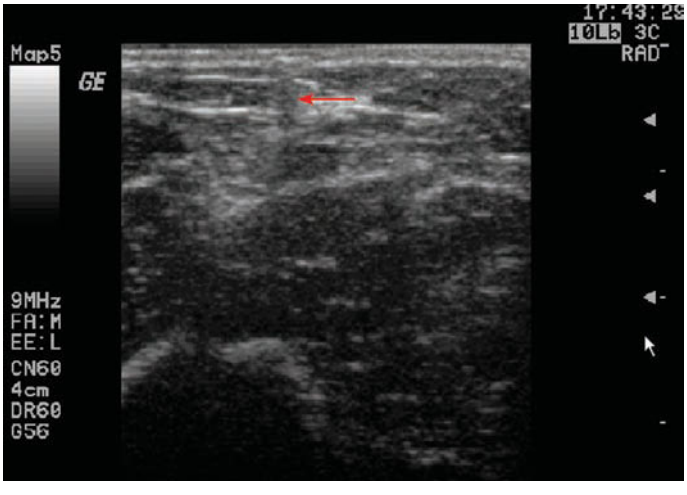


FIGURE 4-7. Needle shadow artifact (arrow) showing the hypoechoic vertical line originating from the needle tip.

5 Trauma Ultrasound: The FAST Exam

Wes Zeger

INTRODUCTION

Evaluation of blunt trauma patients with ultrasound (US) has been described for over 30 years.[1,2] Its use in the United States in the early assessment of blunt abdominal trauma patients rapidly increased in the 1990s.[1] It is currently taught as an adjunct to the secondary survey in the Advanced Trauma Life Support (ATLS) course.[1,3] US evaluation of the trauma patients decreases the time to operative care, resource utilization, and the costs of blunt trauma patients.[4,5] The focused assessment with sonography in trauma exam, also known as the FAST exam, can be completed within 5 minutes.[1] It has essentially replaced the need for a diagnostic peritoneal lavage in the initial assessment of all but a few trauma patients.[6,7] This chapter reviews the technique and interpretation of the FAST exam.

ANATOMY AND PATHOPHYSIOLOGY

The FAST exam evaluates four anatomical areas or potential spaces for the presence or absence of intraperitoneal fluid. These include the hepatorenal recess (Morrison's pouch), the splenorenal recess, the rectovesical or rectouterine space, and the pericardial space. The assumption is that fluid represents blood in the setting of trauma. The presence of ascites, urine, and bowel fluid can appear similar. These spaces represent the most dependent areas in the supine patient (**Figure 5-1**). The volume of fluid accumulation required for visualization by US ranges from 250 to 620 mL.[8,9] More experienced sonographers are able to visualize volumes closer to 250 mL.[8]

INDICATIONS

The FAST exam is performed after the primary survey. It can be performed in conjunction with ongoing resuscitative efforts. It is indicated when evaluating for the presence of intraperitoneal or pericardial blood in the setting of acute thoracoabdominal trauma. It is useful in determining resource allocation in the setting of multipatient trauma scenarios.[1]

BLUNT THORACOABDOMINAL TRAUMA

The most studied use of the FAST exam has been in adult patients with blunt abdominal trauma. The early diagnosis of hemoperitoneum and/or hemopericardium in the setting of blunt trauma is critical in the management of these patients. The sensitivity and specificity for the presence of hemoperitoneum varies depending on the comparison "gold standard," and is generally reported between 78% to 90% and 98% to 100%, respectively.[7,10–14] It has been reported to approach 100% sensitivity and 100% specificity in hypotensive patients.[6,10] One study by Miller et al. reported a sensitivity of 42% and a specificity of 98%.[15] The difference between these studies was how CT was utilized as the gold standard. Pediatric blunt trauma patients have been less well studied, but the FAST exam has shown a similar sensitivity and specificity.[16–19] When used to predict the need for operative intervention in pediatric trauma patients, its sensitivity approached 90%, but its specificity dropped.[20] Current guidelines recommend evaluation of the pericardial space in patients with blunt thoracoabdominal trauma.[21]

PENETRATING THORACOABDOMINAL TRAUMA

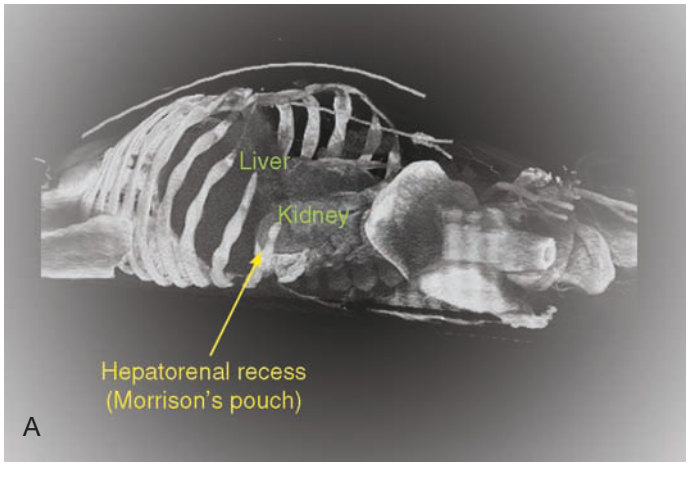
Decreased mortality using US in the assessment of trauma was first described in relation to penetrating chest trauma.[22] Its application in patients with penetrating abdominal trauma is less clear. The sensitivity ranges from 48% to 100%, but its specificity remains high at 98% to 100%.[13,14,23,24] Assessment of the pericardial space can be helpful in guiding operative intervention in the unstable patient.

CONTRAINDICATIONS

US is a noninvasive diagnostic modality. In the setting of trauma, it is contraindicated only if it would delay and negatively impact a clinically obvious need for emergent operative intervention. The FAST exam should not be performed unsupervised by providers who have not been adequately trained.[21]

EQUIPMENT

- US machine
- US gel
- Abdominal US probe
- US probe cover or glove



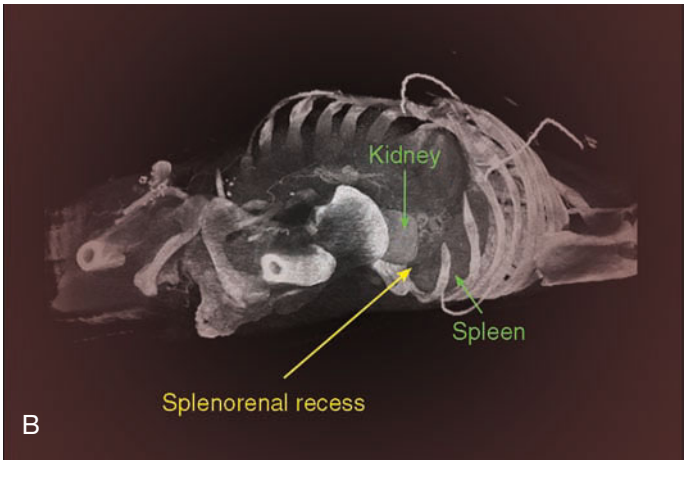


FIGURE 5-1. The posterior reflection of the peritoneum is where blood initially layers in the supine patient. The hepatorenal (**A**) and splenorenal (**B**) recesses represent the posterior peritoneal reflections between the inferior pole of the kidney and the liver or spleen, respectively.

A complete discussion of US equipment is beyond the scope of this chapter. Decisions regarding machines and probes depend on the user, cost, and intended applications. The FAST exam can be performed with a good-quality general abdominal probe. Probes with smaller footprints allow for easier viewing between the ribs.

The US probe is generally used directly against the patient's skin, with gel between them. Place the probe in a probe cover or glove to prevent contamination of the probe if the patient's skin is covered with blood, urine, feces, or other substances. Place US gel in the probe cover or glove before inserting the probe. Squeeze out any air in the space between the tip of the probe and the probe cover or glove.

PATIENT PREPARATION

Little to no preparation is required to perform the FAST exam. Wipe any debris and liquids from the patient's skin in the areas to be scanned. Place the US probe in a probe cover or glove, as described above, if the patient's skin is contaminated with blood, vomit, other body fluids, or other substances that may contaminate or damage the probe.

TECHNIQUE

Performance of any US exam assumes the probe marker orientation is generally cephalad or toward the right relative to the patient. The FAST exam traditionally demonstrates two-dimensional grayscale images of four views reflective of their anatomic potential spaces. These are the hepatorenal recess (Morrison's pouch), the splenorenal recess, the rectovesical or rectouterine space, and the pericardial space. View the rectovesicle space, the area between the rectum and the bladder, in the male patient. View the rectouterine space, the area between the rectum and the uterus, in the female patient.

The overall exam time should be less than 5 minutes, and frequently can be completed in 1 or 2 minutes. If complete views of either the liver or spleen are not visualized with a single image, more than one image of the area is required. The order of image acquisition depends on the mechanism of injury. In blunt trauma, Morrison's pouch is generally imaged first (the area where fluid will most likely first accumulate), followed by the splenorenal view, the rectovesical or rectouterine view, and then the pericardial space. In penetrating trauma, the pericardial space is often imaged first followed by Morrison's pouch, then the remaining two views.

HEPATORENAL RECESS (MORRISON'S POUCH)

The hepatorenal recess is located between the inferior margin of the liver and inferior pole of the right kidney (**Figure 5-1A**). Place the probe on the midaxillary line at the level of the 8th to 11th ribs (**Figure 5-2A**). The liver and kidney should be visualized from the diaphragm to the inferior tip of the liver (**Figure 5-2B**). **It is important to visualize the space between, and including, the inferior liver tip and the inferior pole of the right kidney as fluid tends to accumulate near the tip of the liver first.** A black, echolucent, stripe between the liver and the kidney represents blood and a positive FAST exam (**Figure 5-3**). Rib shadows obscuring portions of the image may be prevented by a slight counter-clockwise rotation of the probe so it lies between the ribs.

SPLENORENAL RECESS

The splenorenal recess is located between the inferior margin of the spleen and the inferior pole of the left kidney (**Figure 5-1B**). Place the probe on the posterior axillary line at the level of the sixth to ninth ribs (**Figure 5-4**). **The spleen and kidney should be visualized from the diaphragm to the inferior tip of the spleen.** A black, echolucent, stripe between the spleen and the kidney represents blood and a positive FAST exam (**Figure 5-5**). Rib shadows obscuring portions of the image may be prevented by a slight clockwise rotation of the probe so it lies between the ribs.

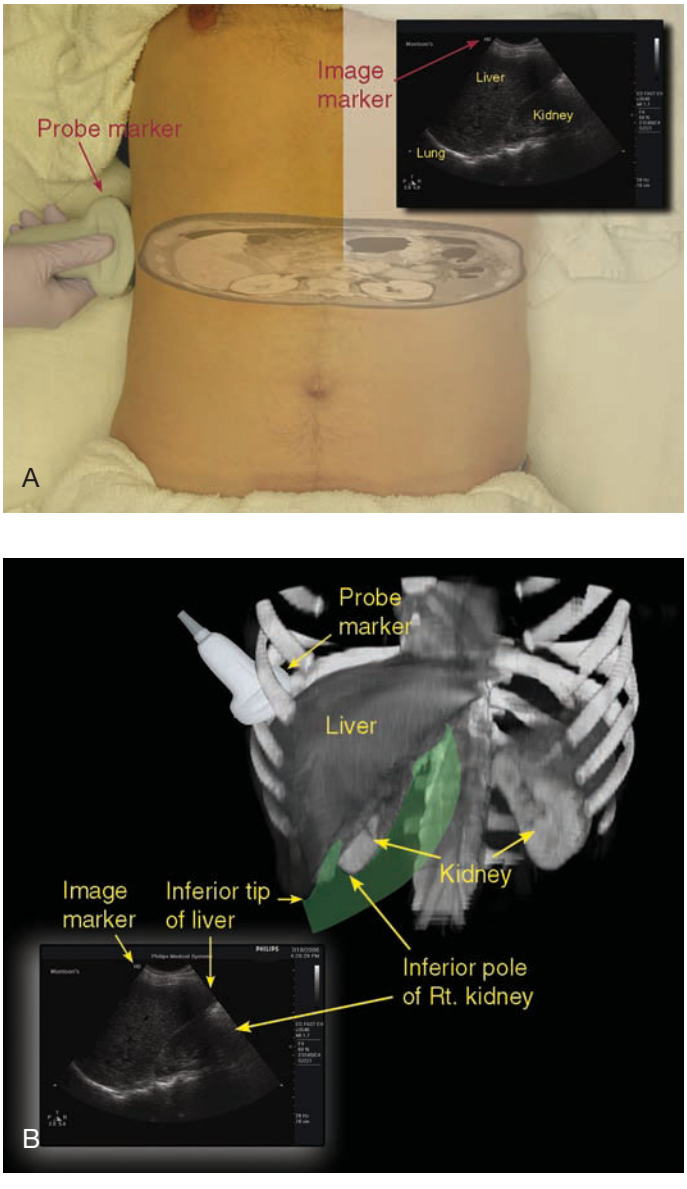


FIGURE 5-2. Imaging of the hepatorenal recess. **A.** US probe placement with the corresponding US screen image. **B.** A view of the US beam (green) as it passes through the liver and kidney with the corresponding US image.

RECTOVESICAL OR RECTOUTERINE SPACE

The rectovesical or rectouterine space represents the most inferior–posterior reflection of the peritoneum. Place the probe just superior to the pubic ramus (**Figure 5-6**). The probe can be oriented in either the sagittal or transverse plane. View the rectovesicle space (**Figures 5-6A & B**) or the rectouterine space (**Figures 5-6C & D**) in both the sagittal and transverse planes. A black, echolucent, stripe in either space represents blood and a positive FAST exam (**Figures 5-7 & 5-8**).

PERICARDIAL SPACE

In the supine trauma patient, fluid accumulates initially in the inferior–posterior portion of the pericardial space. The probe and

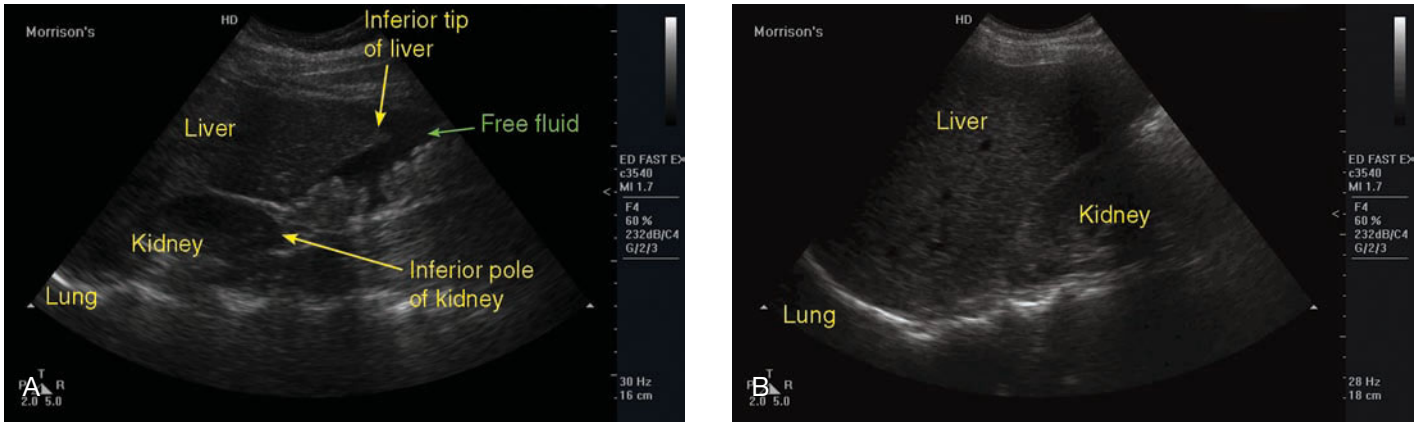


FIGURE 5-3. A positive FAST exam of the hepatorenal recess. **A.** An echolucent fluid stripe in Morrison's pouch. **B.** A normal exam for comparison.

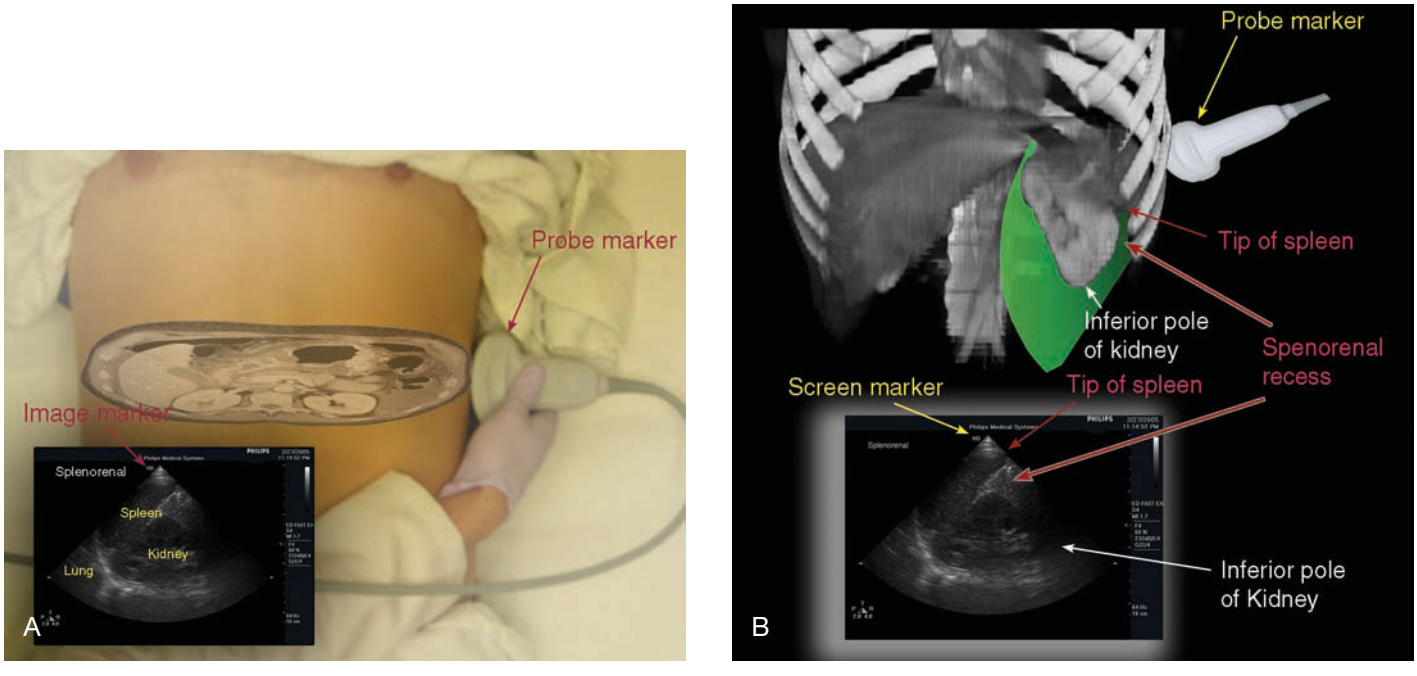


FIGURE 5-4. Imaging of the splenorenal recess. **A.** US probe placement with the corresponding US screen image. **B.** View of the US beam (green) as it passes through the spleen and kidney.

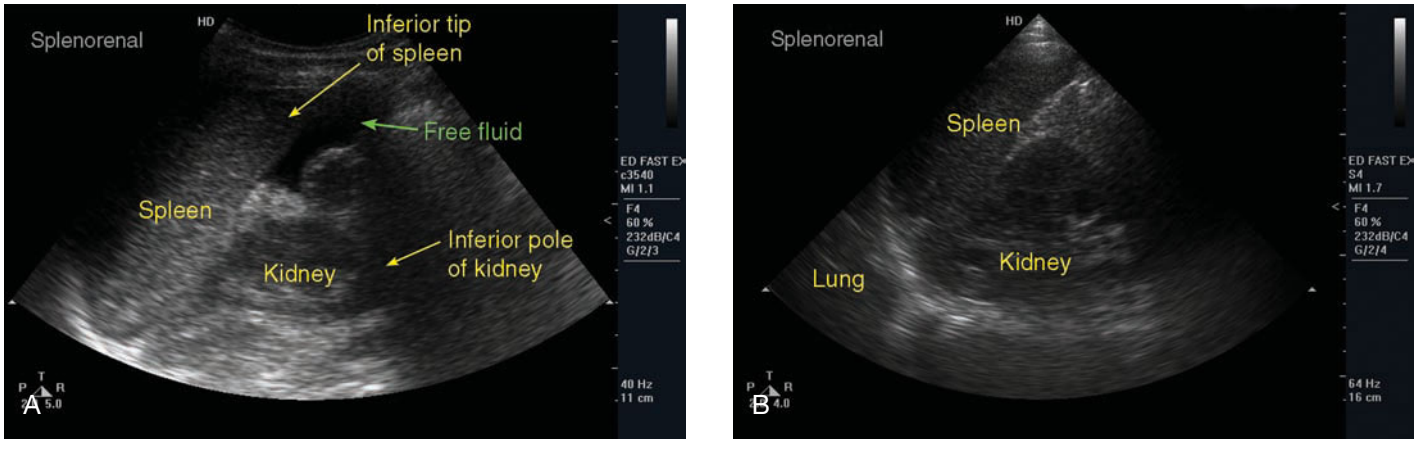
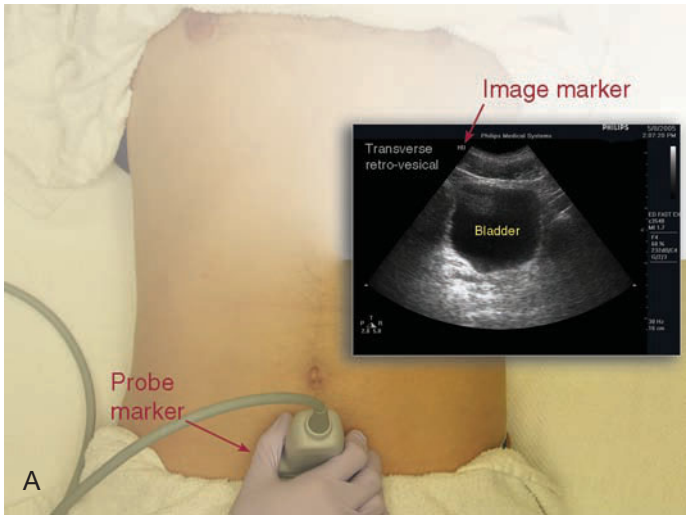
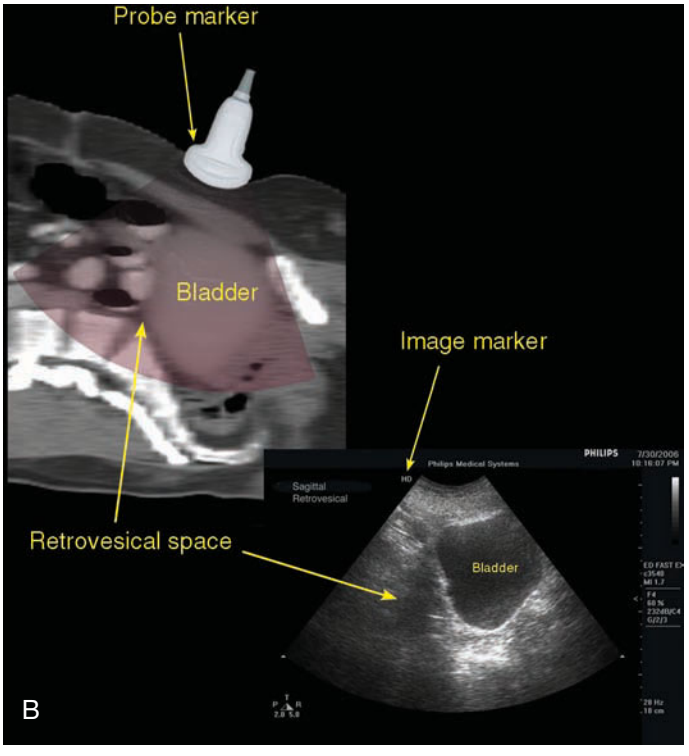
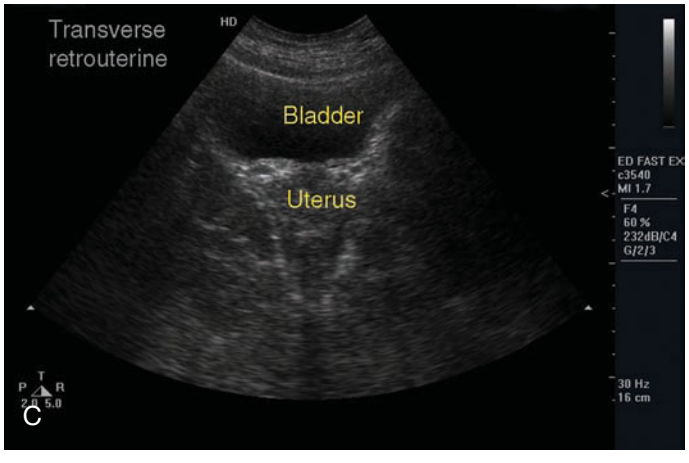


FIGURE 5-5. A positive FAST exam of the splenorenal recess. **A.** An echolucent fluid stripe. **B.** A normal exam for comparison.







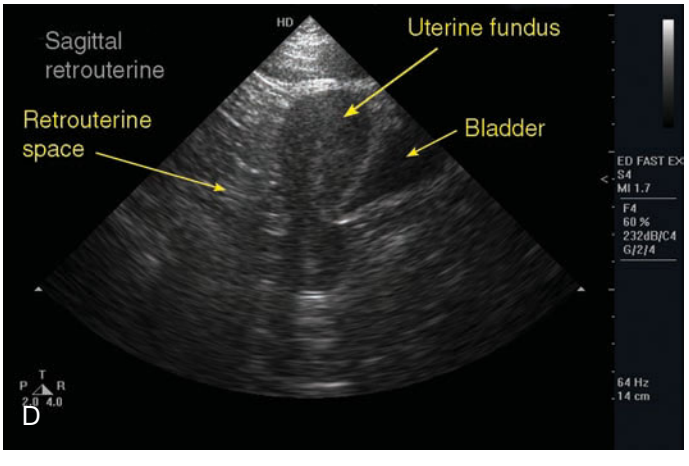
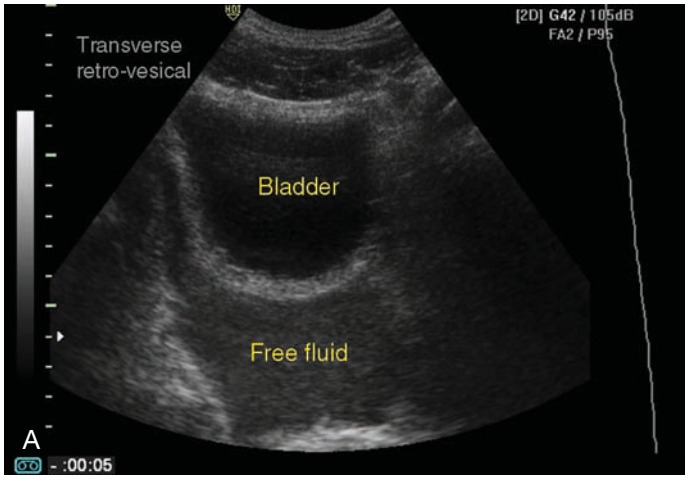


FIGURE 5-6. Imaging of the rectovesical and the rectouterine spaces. **A.** Transverse US probe placement for the rectovesical view with the corresponding US image. **B.** Sagittal view, and probe orientation, of the rectovesical space displaying the US beam path (pink) and the corresponding US image. **C.** Transverse view of the rectouterine space. **D.** Sagittal view of the rectouterine space.



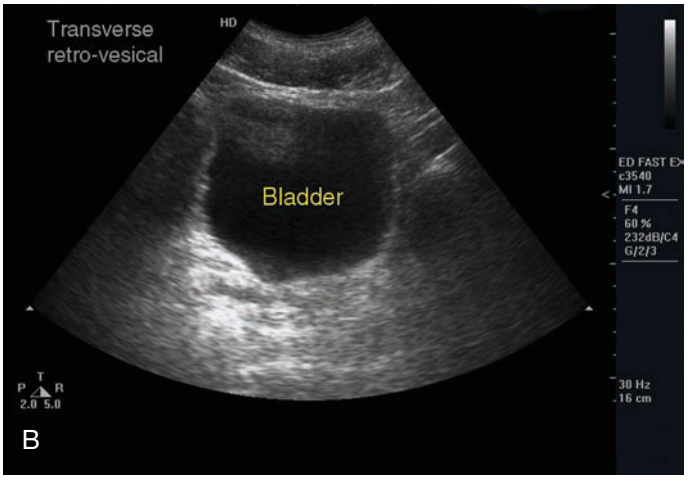


FIGURE 5-7. A positive FAST exam of the rectovesical space. **A.** Transverse view of an echolucent fluid area. **B.** A normal exam for comparison.

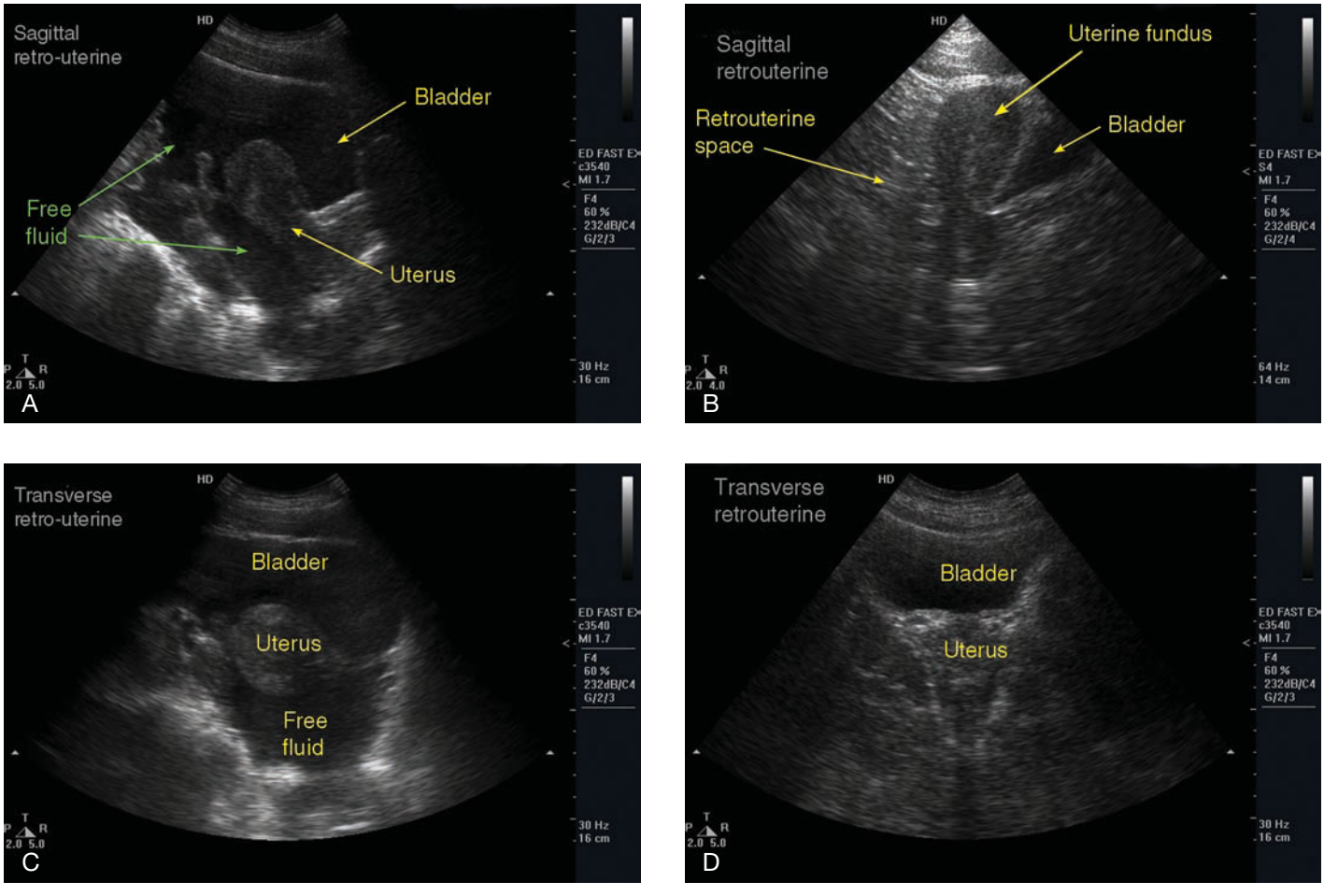


FIGURE 5-8. A positive FAST exam of the rectouterine space. **A.** Sagittal view of an echolucent fluid area. **B.** A normal sagittal exam for comparison. **C.** A transverse view of an echolucent fluid area. **D.** A normal transverse exam for comparison.

screen image orientation are different than traditional echocardiographic views. Place the probe with the marker oriented toward the patient's right and the tip of the probe aimed toward the patient's left shoulder (**Figure 5-9**). Use the liver as an acoustic window and increase the depth of the US beam to increase image quality. Fluid will initially accumulate near the top of the US image, representing the inferior portion of the pericardial space (**Figure 5-9 inset**). Visualize both the inferior and superior areas of the pericardial space. A black, echolucent, stripe in either the inferior or superior areas of the pericardial space represents blood and a positive FAST exam (**Figure 5-10**).

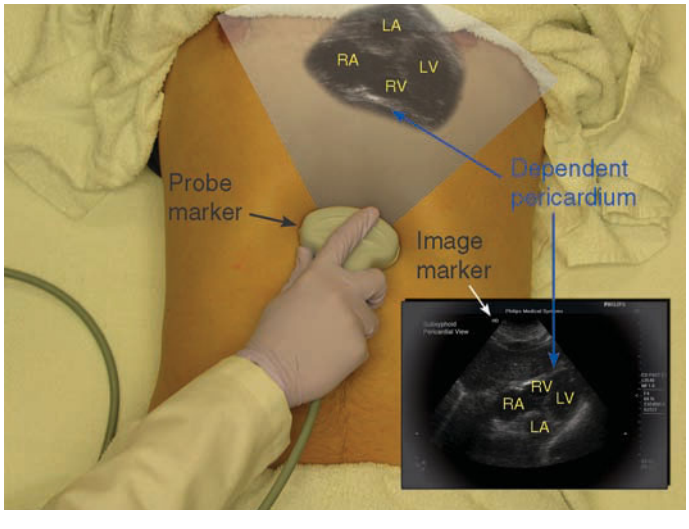


FIGURE 5-9. Imaging of the pericardial space. US probe placement for the subxyphoid view with the corresponding US image. (RV, right ventricle; RA, right atrium; LV, left ventricle; LA, left atrium).

ALTERNATIVE TECHNIQUES

The incorporation of thoracic imaging coupled with the traditional FAST exam has been referred to as an extended FAST or EFAST exam. This additional imaging assesses for the presence of a hemothorax or a pneumothorax. A hemothorax is best assessed by visualizing the inferior–posterior aspect of the plural cavity in the supine patient (**Figure 5-11**). This area is often visualized in routine views of Morrison's pouch, but moving the US probe superior one rib interspace may be required. The lung edges are not normally visualized on US. However, the lung can be seen "floating" in fluid in the presence of a hemothorax (**Figure 5-11B**). Another sign suggestive of a hemothorax is the "spine" sign (**Figure 5-11B**). In the presence of a hemothorax, the portion of the thoracic spine above the diaphragm can be visualized with US. The thoracic spine is not normally well visualized on US superior to the diaphragm (**Figure 5-11C**).

A pneumothorax is best assessed in the supine patient with either a linear or a curvilinear probe. Place the probe on the anterior chest wall in the area bounded by the clavicle, sternum, nipple, and anterior

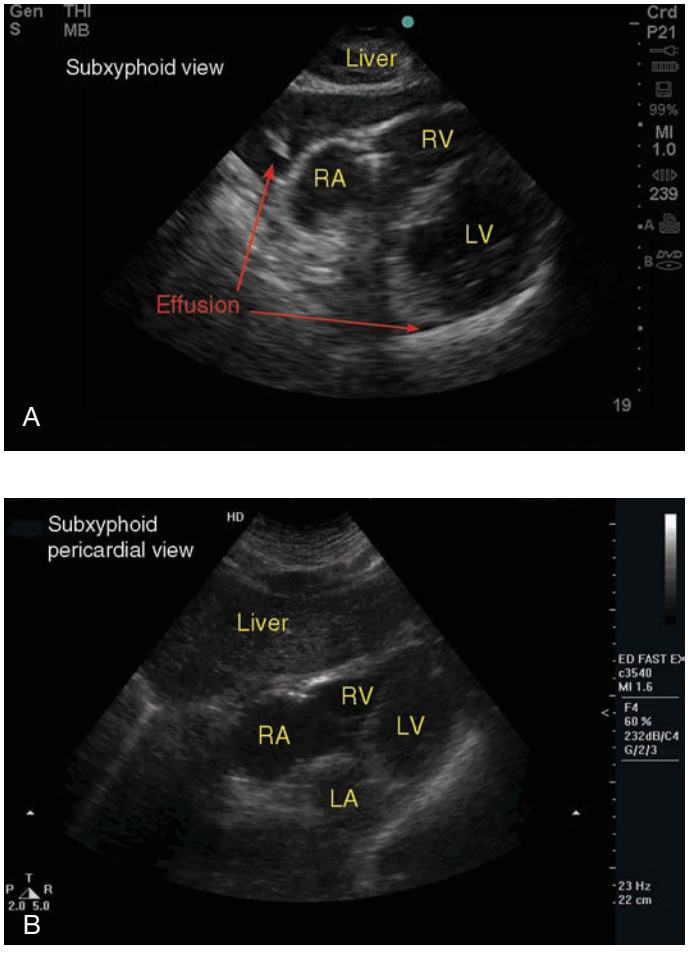


FIGURE 5-10. A positive FAST exam of the pericardial space. **A.** A large echolucent area of fluid in the inferior–posterior aspect of the pericardial space and a small amount of fluid in the more superior area of the pericardial space. **B.** A normal exam for comparison.

axillary line. Start with the probe on the midclavicular line between the nipple and the clavicle. It may be moved within the area to obtain the best image possible. Position the probe perpendicular to two adjacent ribs to visualize the intercostal space (**Figure 5-12**). The normal sliding of the visceral pleura against the parietal pleura during respiration can be visualized (**Figure 5-12A**). This interface between the two pleura is known as the "sliding-lung" sign and is absent in a pneumothorax.

Use M-Mode to visualize the "sea-shore" sign (**Figure 5-12B**). This is visualized as slightly wavy parallel lines from the thoracic wall over an echogenic line (the pleural line), under which is a sandy pattern produced by the lung parenchyma. The parallel lines at the top of the screen represent the waves of the "sea." The sandy pattern at the bottom of the screen represents the "shore." Together they form the "sea-shore" sign. The echogenic line between the "sea" and the "shore" represents the pleural lines. The "sea-shore" sign indicates a normal chest wall–lung interface. Air interposed between the chest wall and lung forms parallel, horizontal echogenic lines and the loss of the "sea-shore" sign (**Figure 5-12C**).

ASSESSMENT

The interpretation of each of the four views, and of the overall FAST exam, is classified into one of the three categories: positive, negative, or indeterminate. Positive exams demonstrate echolucent

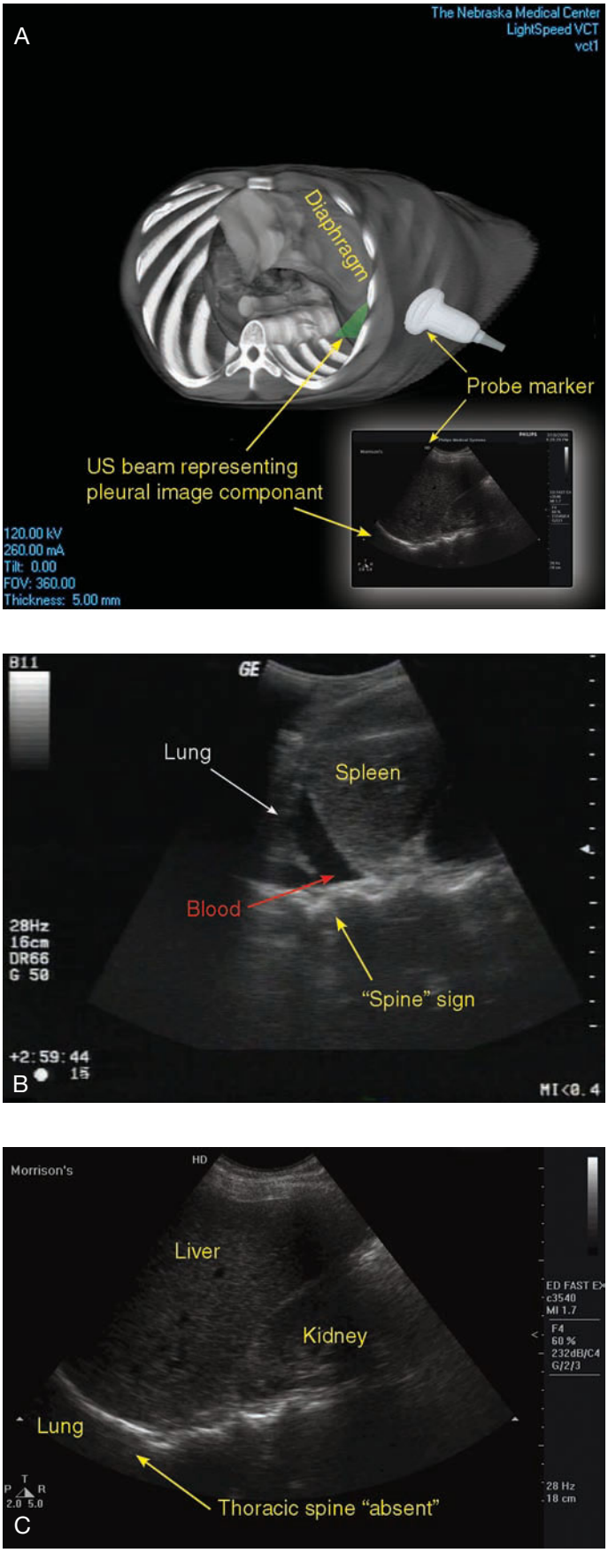
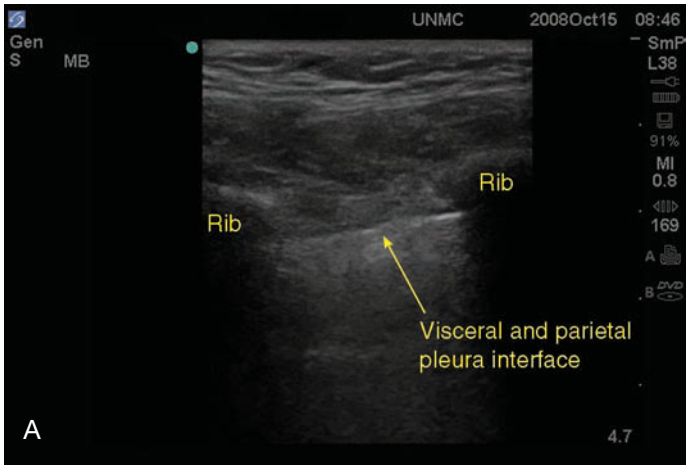
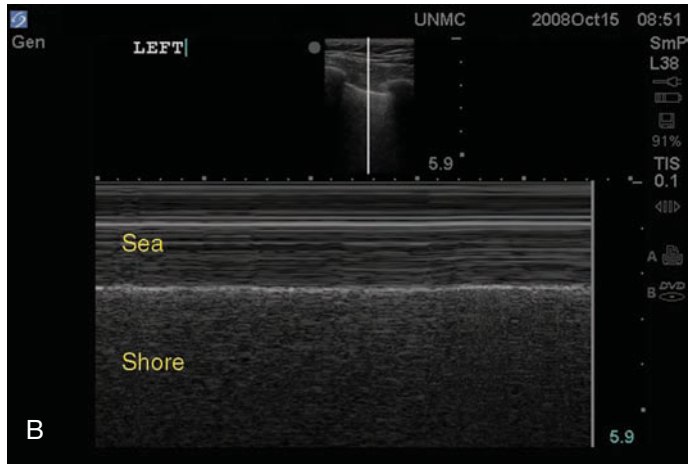


FIGURE 5-11. Imaging a hemothorax. **A.** The patient and US probe position. The US beam path (green) generates the pleural component (inset). **B.** Blood in the pleural space provides an acoustic window to visualize the thoracic spine ("spine sign"). **C.** A normal exam for comparison.





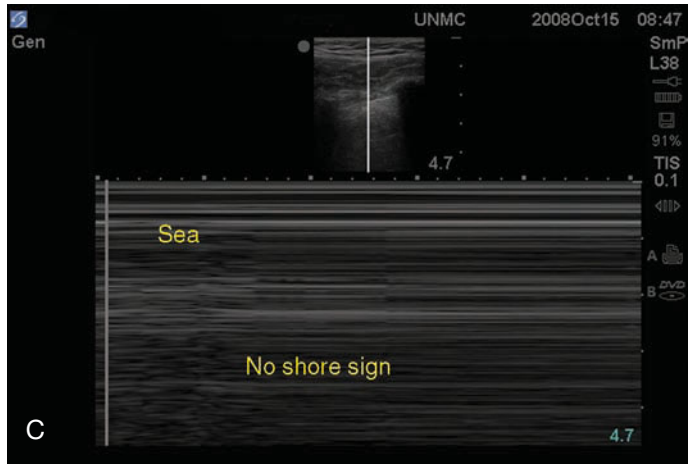


FIGURE 5-12. Imaging a pneumothorax. **A.** Rib shadowing is seen on both sides of the intercostal space. The echoic interface of the parietal and visceral pleura demonstrates the "sliding-lung" sign. **B.** The "sea-shore" sign. It is visible when the lung and chest wall are in contact with each other. Note the bright echogenic stripe of the pleural interface between the chest wall ("sea") and the lung ("shore"). **C.** The "sea-shore" sign and the pleural interface are absent when a pneumothorax is present.

(seen as black on the image) fluid accumulations in any one of the four views. Negative exams and scans demonstrate no fluid with complete visualization of all structures of each view. Indeterminate exams are uncommon but may occur when fat or bowel cannot be distinguished from peritoneal fluid, or if there is incomplete visualization of any of the four views. Women and children may normally have a small amount of physiologic fluid in their pelvis. This finding may lead to an indeterminate exam in the setting of trauma.

AFTERCARE

Multiple algorithms exist for the management of trauma patients.[1,3] In general, these are differentiated into blunt trauma versus penetrating trauma and hemodynamically stable versus unstable. In the hemodynamically stable blunt trauma patient, a positive FAST exam is typically followed with an abdominal cat exam. In the hemodynamically unstable adult blunt trauma patient, a positive FAST exam indicates the need for emergent operative intervention without further imaging. In adult patients with penetrating trauma, a positive FAST exam has good correlation with need for a therapeutic laparotomy.[23] Management of these patients may vary between institutions. An unstable pediatric patient with a positive FAST exam may not necessarily proceed to laparotomy as the indications for operative management differ between adults and children.[3]

A negative FAST exam needs to be evaluated within the patient's clinical context (history, exam findings, vitals, etc.). In the hemodynamically stable or unstable penetrating trauma patient, a negative FAST exam is a reliable screen for the presence of intrapericardial blood. It is not a reliable screening test for the presence of abdominal injury. In the unstable patient, its use is not well defined. In the hemodynamically stable blunt trauma patient, a negative FAST exam should be followed by serial clinical exams and a repeat FAST exam.[25] A negative FAST exam in the presence of hemodynamic instability has a high sensitivity, and an extraperitoneal source of bleeding or the instability should be considered. Indeterminate FAST exams require a follow-up alternative diagnostic modality, usually a CAT exam.

COMPLICATIONS

Performance of the actual FAST exam has no associated complications. However, inaccurate interpretation or inappropriate application of US findings in clinical decision making may complicate its use.

SUMMARY

The FAST exam is a useful adjunct in the management of blunt and penetrating trauma patients. It can be performed rapidly, it is very specific, and it can positively impact patient outcomes. Proper training is required to ensure good-quality images and appropriate interpretation.

SECTION 2

Respiratory Procedures

6 Essential Anatomy of the Airway

Ned F. Nasr, Serge G. Tyler, Gennadiy Voronov, and Isam F. Nasr

INTRODUCTION

A thorough understanding of anatomy is essential for the performance of any medical procedure.[1–10] Untoward events due to a procedure are usually the result of inexperience and/or an inadequate understanding of the regional anatomy. The anatomy of the airway and airway procedures are no exception. From the evaluation of external anatomic landmarks to the performance of nerve blocks for fiberoptic intubation, an understanding of the anatomy of the airway will result in fewer attempts at intubation and improved success with fewer iatrogenic misadventures.

GENERAL ANATOMY

The upper airway comprises the nasal and oral cavities, the pharynx, and the larynx. The lower airway consists of the subglottic larynx, the trachea, and the bronchi.[8] Airway management typically involves the upper airway, the focus of this chapter. The anatomy of the pharynx, larynx, and trachea are depicted in **Figure 6-1**.

The nares serves as the functional beginning of the airway, namely warming and humidification of air.[4] The mucosa of the nasal passage is extremely vascular and fragile and therefore susceptible to trauma. The nasal blood supply originates from branches of the internal and external carotid arteries. It is wise to consider the use of a vasoconstricting agent, when appropriate, to help avoid epistaxis which may obscure further attempts at securing the airway. Although patients tolerate nasal intubation better than oral intubation for a longer period of time, it is more important in an emergency to definitively secure the airway using a straightforward oral intubation if possible.

The sensory innervation of the upper airway is provided by branches of several cranial nerves. The mucous membrane of the nose is innervated anteriorly by the anterior ethmoid nerve (ophthalmic division of the trigeminal nerve) and posteriorly by the sphenopalatine nerve (maxillary division of the trigeminal nerve). The tongue is innervated by the lingual nerve on its anterior two-thirds (a branch of the facial nerve) and by the glossopharyngeal nerve posteriorly. The glossopharyngeal nerve also innervates the adjacent areas, including the palatine tonsils, the undersurface of the soft palate, and the roof of the pharynx.[1] The anatomy of the oropharynx is discussed further under the "Airway Evaluation" section and the anatomy of the larynx is covered in the next section.

The trachea measures 10 to 16.5 cm in an average adult.[4] The trachea is a tubular structure that begins at the level of the fifth or sixth cervical vertebrae and bifurcates at the level of the fifth thoracic vertebra into two primary bronchi. The posterior aspect of the trachea is flat and membranous, while its anterior and lateral aspect is lined by 16 to 20 horseshoe-shaped cartilaginous rings. The primary bronchi subsequently branch into three secondary bronchi on the right and two secondary bronchi on the left. The angle between the primary bronchus and the trachea on the left is more acute than on the right. This is due to the heart being located on the left side. This is clinically significant during aspiration and endobronchial intubations. **Because of the more direct path on the right side due to the obtuse angle of the primary bronchi, objects (food, fluid, and foreign bodies) are more likely to enter the right lung.** The tracheal mucosa removes waste products by producing and moving mucus toward the pharynx via ciliary action. The trachea has a rich innervation from the vagus nerve, which permits a vigorous cough reflex (accompanied by hypertension and tachycardia) if a foreign body is aspirated.

The inner diameter of the trachea varies between normal adult males and females. It ranges from about 15 to 20 mm.[4] Since the external diameter of a 7.5 mm internal diameter (ID) endotracheal tube is 11.0 mm, the size must be taken into consideration in selecting an endotracheal tube. These considerations usually preclude using tubes much larger than 7.5 mm ID for normal adult females or larger than 8.0 or 8.5 mm ID for normal adult males.

ANATOMY OF THE LARYNX

The innervation of the larynx is relatively simple. The internal branch of the superior laryngeal nerve provides sensation above the vocal cords (vocal folds). The recurrent laryngeal nerve supplies sensation below the vocal cords. The recurrent laryngeal nerve provides the motor input to all of the intrinsic muscles of the larynx except to the cricothyroid muscle, which is supplied by the external branch of the superior laryngeal nerve. Bilateral injury to the recurrent laryngeal nerve will result in total airway closure due to unopposed stimulation of the vocal cord adductor, the cricothyroid muscle.[1]

There are three paired and three unpaired cartilages of the larynx.[2] The paired cartilages are the smaller arytenoid, corniculate, and cuneiform cartilages (**Figure 6-2**). The unpaired cartilages are the larger thyroid, cricoid, and epiglottic cartilages. Although not part of the larynx, the hyoid bone has many ligamentous and muscular attachments to the larynx. The cricoid cartilage is signet ring-shaped, as opposed to the C-shaped cartilages of the trachea (**Figure 6-2**). Because it forms a complete circle, depression of the cricoid cartilage will put pressure on structures located posteriorly (i.e., the esophagus). **The application of posteriorly directed pressure on the cricoid cartilage during intubation is known as the Sellick maneuver (Figure 6-3). The Sellick maneuver will not prevent regurgitation from active vomiting. It has been shown to be effective in the prevention of passive regurgitation and subsequent aspiration.**[3] However, the Sellick maneuver can impair insertion of the laryngoscope or an airway introducer, and can cause airway obstruction.

The cricoid cartilage is also an important landmark for locating the cricothyroid membrane, which lies inferior to the thyroid cartilage and superior to the cricoid cartilage (**Figure 6-2**). The

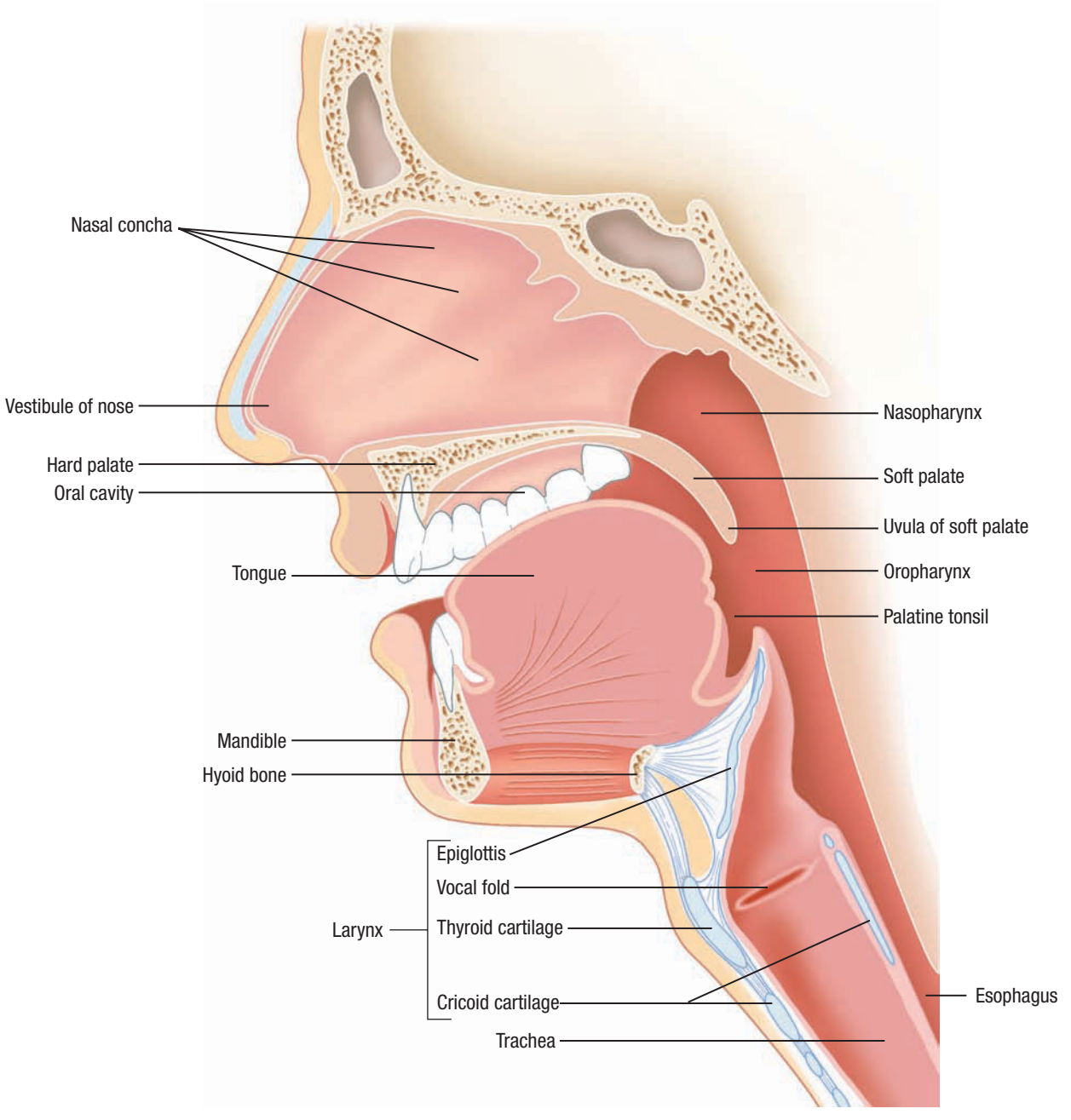


FIGURE 6-1. Anatomy of the airway as visualized in a midsagittal section through the head and neck.

cricothyroid membrane is usually located at the level of the sixth cervical vertebra. It is the anatomic location where emergency cricothyroidotomies and recurrent laryngeal nerve blocks are performed.

The three paired cartilages are located on the posterior aspect of the larynx (**Figure 6-2**). This position renders them vulnerable to injury during intubation.[2] By maintaining an anterior insertion of the laryngoscope blade and by not inserting it too deeply during intubation attempts, it is less likely that these cartilages will become dislocated or otherwise injured. This is particularly true if a straight laryngoscope blade is used.

The hyoid bone is an important supporting structure of the upper airway. One of the attachments of the hyoid bone to the larynx is the hyoepiglottic ligament located at the base of the vallecula (**Figure 6-4**). This ligament is important because it is where the tip of the curved Macintosh laryngoscope blade is placed to move the epiglottis anteriorly and out of the path of vision during intubation. Another attachment of the hyoid bone to the larynx is the thyrohyoid membrane (**Figure 6-2**). As its name implies, it runs from the inferior border of the hyoid bone to the superior aspect of the thyroid cartilage. Just inferior to the lateral border of the hyoid bone, the internal branch of the superior laryngeal nerve passes through the thyrohyoid membrane (**Figure 6-2**). At this point, the internal branch of the superior laryngeal nerve is superficial and very easily anesthetized with an injection of local anesthetic solution.

AIRWAY EVALUATION

The evaluation of the airway should always start with a thorough history. **An airway history should be conducted, when feasible, prior to the initiation of airway management in all patients.** It

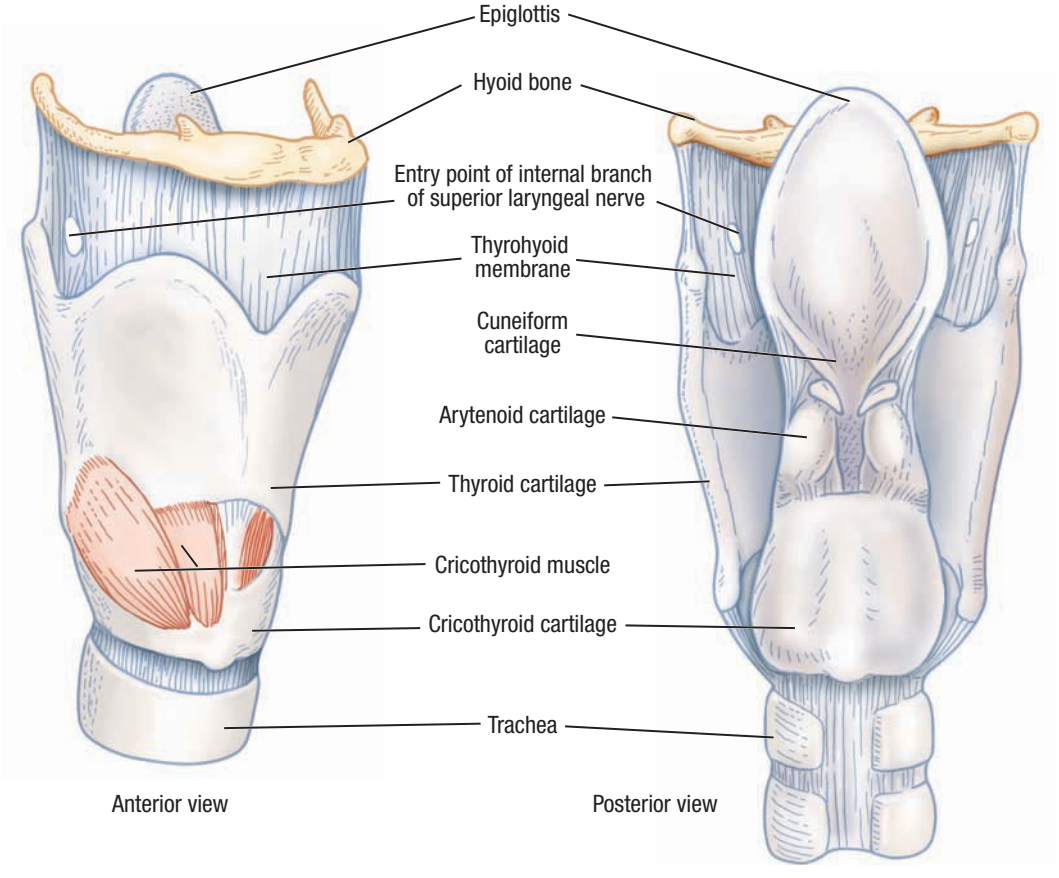


FIGURE 6-2. Right anterolateral and posterior views of the skeleton of the larynx. The thyroid cartilage shields the smaller cartilages of the larynx.

should include whether the patient has ever required intubation and if there was any difficulty. Additional history should focus on the patient's dentition and any surgery on or near the airway. There are many congenital syndromes (**Table 6-1**) and acquired conditions (**Table 6-2**) that can complicate airway management. These should be kept in mind when performing the airway history and physical examination.

External evaluation of the airway is a critical step to a successful intubation. These brief evaluations are helpful in predicting a difficult intubation. External inspection should identify some obvious problems that may interfere with airway management. These include as facial hair which prevents a good mask seal, cervical collars which restrict neck movement, face and/or neck trauma, severe micrognathia, or obesity.

The next steps in evaluating the airway may help to identify patients with potentially difficult airways. In adults, the distance between the thyroid cartilage ("Adam's apple") and the inside of the

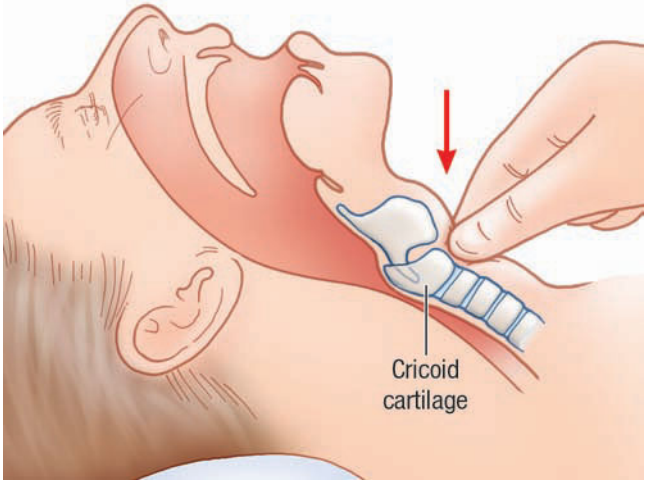


FIGURE 6-3. The Sellick maneuver. Posteriorly directed pressure is applied to the cricoid cartilage to occlude the esophagus and prevent regurgitation and subsequent aspiration of gastric contents.

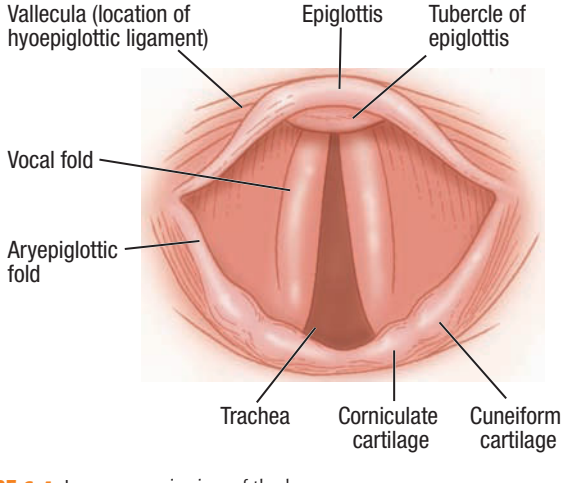


FIGURE 6-4. Laryngoscopic view of the larynx.

TABLE 6-1 Selected Congenital Syndromes Associated with Difficult Endotracheal Intubation

Syndrome	Description
Down's	Cervical spine spondylolisthesis; large tongue, small mouth make laryngoscopy difficult; small subglottic diameter possible; frequent laryngospasm
Goldenhar (oculoauriculovertebral anomalies)	Mandibular hypoplasia and cervical spine abnormality make laryngoscopy difficult
Klippel–Feil	Neck rigidity because of cervical vertebral fusion
Pierre Robin	Small mouth, large tongue, mandibular anomaly; awake intubation essential in neonate
Treacher Collins (mandibulofacial dysostosis)	Laryngoscopy difficult
Turner	High likelihood of difficult intubation

Source: Data from Barash et al.[1]

TABLE 6-2 Acquired Conditions Affecting the Airway and Associated with Difficult Endotracheal Intubation

Condition	Principal pathologic clinical features of the airway
Acromegaly	Macroglossia; prognathism
Acute burns	Edema of airway (worsens with time, secure airway early!)
Angioedema	Obstructive swelling renders ventilation and intubation difficult
Arthritis	
Rheumatoid arthritis	Temporomandibular joint ankylosis, cricoarytenoid arthritis, deviation of larynx, restricted mobility of cervical spine
Ankylosing spondylitis	Ankylosis of cervical spine; less commonly ankylosis of temporomandibular joints; lack of mobility of cervical spine
Benign tumors	Stenosis or distortion of airway
Cystic, hygroma, lipoma, adenoma	
Diabetes mellitus	May have reduced mobility of atlantooccipital joint
Foreign body	Airway obstruction
Hypothyroidism	Large tongue, abnormal soft tissue (myxedema) make ventilation and intubation difficult
Infectious	
Supraglottitis	Laryngeal edema
Croup	Laryngeal edema
Abscess (intraoral, retropharyngeal)	Distortion and stenosis of airway and trismus
Ludwig's angina	Distortion and stenosis of airway and trismus
Malignant tumors	Stenosis or distortion of airway; fixation of larynx or adjacent tissues secondary to infiltration or fibrosis from irradiation
Carcinoma of tongue, larynx, or thyroid	
Morbid obesity	Short, thick neck, and large tongue are likely to be present
Pregnancy	Edema of airway
Sarcoidosis	Airway obstruction (lymphoid tissue)
Scleroderma	Tight skin and temporomandibular joint involvement make mouth opening difficult
Temporomandibular joint syndrome	Severe impairment of mouth opening
Thyromegaly	Goiter may produce extrinsic airway compression or deviation
Trauma	Cerebrospinal rhinorrhea, edema of airway; hemorrhage; unstable fracture(s) of maxillae and mandible; intralaryngeal damage; dislocation of cervical vertebrae
Head, face, or cervical spine injury	

Source: Modified from Miller.[4]

anterior aspect of the mandible is known as the thyromental distance. It should be at least 5 cm or about three large finger breadths.[1] A lesser distance suggests that the patient's vocal cords are positioned more anteriorly than normal. **Distances less than 5 cm may indicate that visualization of the larynx during intubation may be difficult or impossible due to a lack of space in which to displace the tongue.** The next evaluation requires the patient to open his or her mouth maximally. Ideally, the patient will be in a seated or semisitting position. The distance between the maxillary and mandibular incisors in an average adult is 3 to 5 cm or about two large finger breadths.[5] Limited mouth opening may impair visualization of the airway as well as expose the teeth to damage during intubation. Adults should be able to flex their cervical spine 35° and extend the cervical spine (atlantooccipital joint) 80° from a neutral position.[6] This range of neck movement allows for the alignment of the oral, pharyngeal, and laryngeal axes during orotracheal intubation (**Figure 6-5**). This alignment of the axes provides the greatest chance for a successful intubation. Recent evidence suggests that slight head extension in infants and young children by placing a rolled towel behind their shoulders better aligns the vision of the glottic and laryngeal axes.[10] Observe the patient's neck for length and thickness. A short, excessively long, or thick neck may indicate difficulty in placing the patient in the "sniffing position" and align the airway axes.

The internal examination should evaluate the patient's dentition, palate, and tongue. Note any protuberant incisors, loose teeth, broken teeth, dental work, and dental devices. Prominent upper incisors may complicate the insertion of the laryngoscope blade, make laryngoscopy difficult, and predispose the patient to dental trauma. Assess the relation of the maxillary and mandibular incisors during normal jaw closure. Lack of an overbite forces the laryngoscope blade to enter the mouth in a more cephalad direction than normal. This can result in difficulty visualizing the airway. Observe the maxillary and mandibular incisors during voluntary protrusion of the mandible to determine the degree of temporomandibular joint mobility. Determine if the palate is normal, high and arched, or cleft. Determine if the tongue is elevated, larger, or wider than normal in comparison to the oral cavity. Any abnormality can make the procedure of orotracheal intubation more difficult.

A common classification used by Anesthesiologists to grade the difficulty of laryngoscopy and intubation involves the identification of the size of the tongue in relation to the tonsillar pillars, the fauces, the soft palate, and the uvula.[7] It is important to perform this evaluation by first instructing patients to open their mouths and protrude their tongues maximally in the sitting position. The patient should not say "ahhh," as this distorts the anatomy and may falsely improve the airway classification. The Mallampati classification, named after its author, has four grades or classes.[7] The anterior and posterior tonsillar pillars, the fauces, the soft palate, and the uvula can be fully visualized in class I (**Figure 6-6A**). The fauces, the soft palate, and the uvula can be visualized in class II (**Figure 6-6B**). The anterior and posterior tonsillar pillars are covered by the base of the tongue and not visible. Only the soft palate and the base of the uvula are visible in class III (**Figure 6-6C**). None of the structures are visible in class IV (**Figure 6-6D**). The predictive value of this classification is that during direct laryngoscopy, the entire glottis can be exposed in 100% of class I airways, 65% of class II airways, 30% of class III airways, and 0.1% of class IV airways.[7]

The airway evaluation is imperfect in predicting potential problems and an airway strategy (combination of plans) should be drawn up for each patient. Additional evaluation may be indicated in some

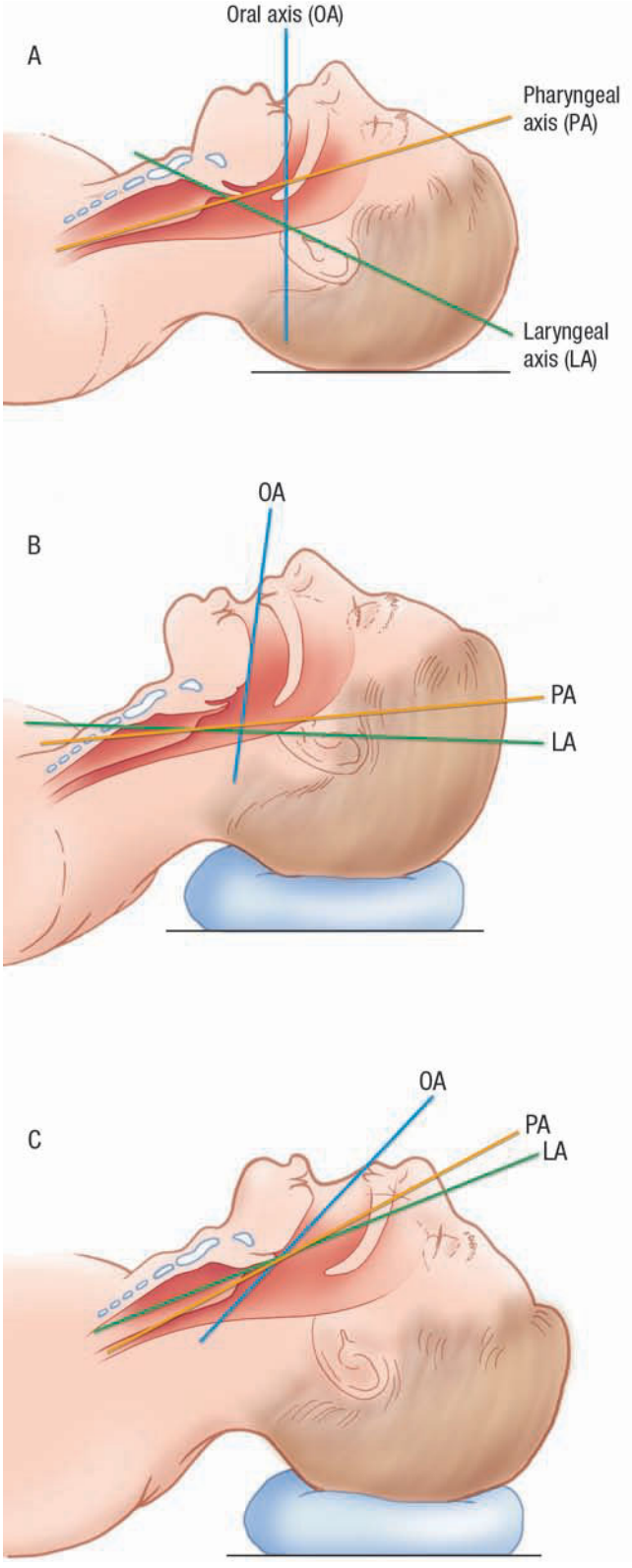


FIGURE 6-5. Schematic diagram demonstrating head positioning for endotracheal intubation. **A.** The normal alignment of the oral, pharyngeal, and laryngeal axes. **B.** Elevation of the head about 10 cm with pads below the occiput, while the shoulders remain on the table, aligns the laryngeal and pharyngeal axes. **C.** Subsequent head extension, at the atlantooccipital joint, serves to create the shortest distance and most nearly a straight line from the incisor teeth to glottic opening.

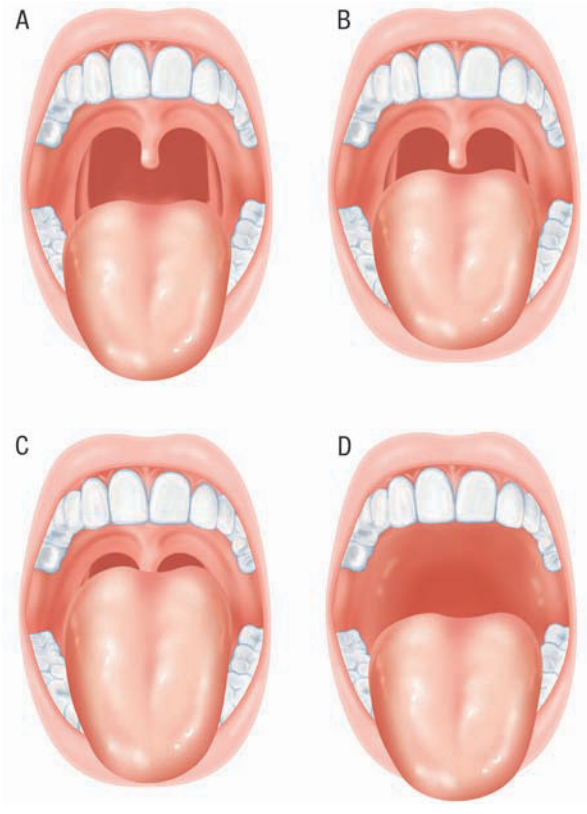


FIGURE 6-6. The Mallampati classification. **A.** Class I. **B.** Class II. **C.** Class III. **D.** Class IV.

patients to characterize the likelihood or nature of the anticipated airway difficulty. The findings of the airway history and physical examination may be useful in guiding the selection of specific diagnostic tests and consultation.

ANATOMIC DIFFERENCES BETWEEN THE ADULT AND THE YOUNG CHILD

There are numerous differences between the airway of an adult and that of a child. The head-to-body ratio is larger in the child. This causes the neck to be flexed when the child is supine. Placing a rolled towel under the child's shoulders will correct the flexion. A child has a small mouth with a relatively large tongue as compared to an adult. This can make orotracheal intubation difficult. The presence of adenoidal tissue in the child makes nasotracheal intubation difficult and orotracheal intubation the preferred method.

The anatomic differences between the larynx of an adult and that of a young child are summarized in **Table 6-3** and **Figure 6-7**.[1] The vocal cords are more obliquely inclined in the child. The cricothyroid membrane is very small and narrow. **The most important difference is that the narrowest portion of the infant or young child's airway is below the level of the vocal cords at the level of the cricoid cartilage. In an adult, the narrowest point of the airway is at the level of the vocal cords.** The cricoid cartilage is the only complete cartilaginous ring and the narrowest part of the trachea. An endotracheal tube may therefore pass through the vocal cords of a young child but might not advance past the cricoid cartilage due to normal anatomy. Forcing an endotracheal tube past the vocal cords in a young child may result in trauma to the airway and subsequent tracheal stenosis. Because the child's larynx is located more cephalad at the level of the third or fourth cervical vertebrae and

TABLE 6-3 Anatomic Differences Between the Child's and the Adult's Larynx

	Child's larynx	Adult's larynx
Size	Smaller	Larger
Shape	Lumen is funnel shaped with the narrowest part below the vocal cords and within the cricoid ring	Narrowest part of lumen is at the vocal cords
Location	Higher, closer to the tongue base; vertical extent is opposite C3, C4, C5 vertebrae; more anterior	Vertical extent is lower, opposite C4, C5, C6 vertebrae
Epiglottis	Longer, narrower, and "U" shaped; the angle between glottis and epiglottis is more acute; increased chance of airway obstruction (see Figure 6-7)	Shorter and wider
Vocal cords	Angled in relation to the axis of trachea; shorter; more cartilaginous; more distensible; more likely to be injured	Perpendicular to the axis of trachea
Rigidity	The laryngeal cartilages are softer and more pliable	More rigid
Response to trauma	Mucous membrane is more loosely attached and swells more readily when traumatized or infected	Less vulnerable to trauma and infection

angulated anterior to the glottis, blind nasal intubation in the case of airway emergencies is not possible. The child's laryngeal inlet is narrow and more susceptible to obstruction. The U-shaped epiglottis and a more acute angle between the epiglottis and glottis cause the aryepiglottic folds to be more in the midline (**Figure 6-7B**).

Differences also exist in the trachea. Children have a relatively shorter trachea. This makes both right main bronchial intubation and accidental extubation much easier. The narrower diameter of the trachea with smaller spaces between the cartilaginous rings makes a tracheostomy more difficult to perform. To avoid injury and subsequent subglottic stenosis, uncuffed endotracheal tubes should be used in children less than 28 days of age.[11] A correctly sized endotracheal tube should have a leak at 15 to 25 cm water. Using the uncuffed endotracheal tube with high leak pressure more than 25 cm of H_2O or the cuffed endotracheal tube can not only cause croup after extubation, but also create an erosion of the mucosa and subglottic stenosis. A cuffed endotracheal tube is recommended for anyone above the age of 28 days.[10–13]

The differences also continue into the chest. The infant thoracic cage is more compliant than the older child and adult. This can lead to more effective ventilation. The child's diaphragm is shorter and flatter than the adult, and thus has a decreased excursion during respiration. The child's relatively narrower airways result in an increased resistance to inspiratory and expiratory airflow. They are also more susceptible to airway edema and mucous plugs obstructing their narrow airway. Children have smaller and fewer alveoli. This results in less surface area for gas exchange compared to adults.

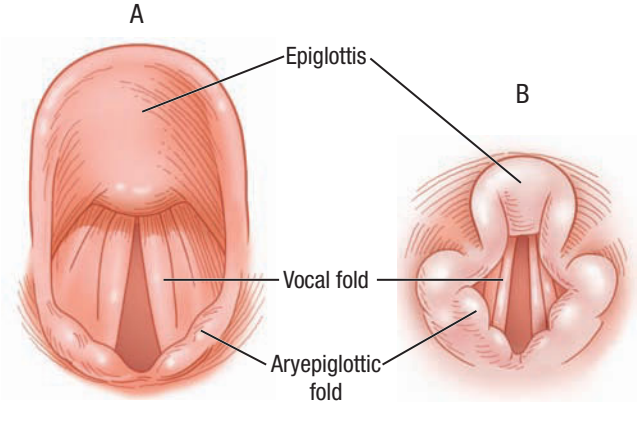


FIGURE 6-7. Differences between the adult's larynx (**A**) and the child's larynx (**B**).

SUMMARY

It is essential for Emergency Physicians to know the anatomy of the airway, especially the differences found in the young child. The airway assessment is an essential element in the preparation to intubate a patient. Unfortunately, there may be limited information and time available to perform the full assessment in an emergent setting. Performing the airway assessment in every patient before orotracheal intubation will allow one to perform it quickly in an emergency.

7 Basic Airway Management

Christopher J. Russo and Zach Kassutto

INTRODUCTION

Airway management is one of the most basic and important aspects of Emergency Medicine. The concepts and techniques described in this chapter can be applied in a variety of environments. Understanding the following concepts and having an opportunity to practice them will allow one to provide the most fundamental of all medical care, support of a patient's airway.

Airway management remains crucial. Without oxygen, the brain begins to die within minutes.[1] The primary purpose of airway management is to facilitate the transport of oxygen to the lungs. The secondary purpose is to protect the airway from contamination with blood, fluids, or food. Airway management can be as simple as lifting a snoring patient's chin or as involved as awake, fiberoptic-guided endotracheal intubation.

The fundamental importance of airway management is reflected by the fact that two-thirds of basic life support taught by the American Heart Association is concerned with this vital function.[2] **The mission of airway management is to ensure a patent airway, provide supplemental oxygen, and institute positive-pressure ventilation when spontaneous breathing is inadequate or absent.[3] These three key aspects of airway management warrant repeating. Ensure a patent airway. Provide supplemental oxygen. Provide positive-pressure ventilation.**

Time is always critical when a patient needs airway support. The body's limited oxygen stores are rapidly exhausted once breathing stops. A healthy individual having maximally breathed 100% oxygen will begin to desaturate and have brain injury after 5 minutes of apnea. However, a sick patient breathing room air will desaturate almost immediately upon becoming apneic.[1]

Oxygenation and ventilation remain the essential goals of airway management. Inadequate ventilation may occur for a variety of reasons. Spontaneously breathing patients may develop an airway obstruction due to food, blood, secretions, or tissue obstruction from the loss of normal pharyngeal tone. The conscious patient with airway obstruction will be in obvious distress and is more likely to have obstruction due to a foreign body, tissue swelling from an infection, laryngeal edema, tumor, or laryngospasm. The unconscious patient,

despite spontaneous respiration, is at risk for aspiration of gastric contents. Unconscious patients should have their airway secured as well as receive mechanical ventilation.

ANATOMY AND PATHOPHYSIOLOGY

The "upper airway" includes the nasal, oral, pharyngeal, and laryngeal anatomy and physiology. This highly complex system is responsible for conveying warmed and filtered air to the trachea and lungs while simultaneously allowing for passage of liquids and solids to the esophagus. Phonation is a secondary physiologic function of the larynx.[4] This highly sophisticated system allows us to drink liquid, eat food, breathe, and talk simultaneously. However, if a small drop of liquid or a particle of food enters the airway, a profound system of reflexes is activated to protect its integrity.[5]

The nasal cavity and the nasopharynx is the area from the tip of the nose to the palate. The nasal cavity is bounded laterally by the bony framework of turbinates and medially by the nasal septum. This area is highly innervated by the ophthalmic and maxillary branches of the trigeminal nerve. The mucosa of the nasal cavity and the nasopharynx is highly vascular. It is this high degree of vascularity that allows cool air from the environment to be warmed and humidified prior to entering the lungs. It also dictates that care be taken when nasal airways are placed. It takes very little trauma to the nasal mucosa to cause significant epistaxis. Polyps or mucus can obstruct the nasopharynx, as can congestion due to an upper respiratory infection. The nasopharynx is oriented in an anteroposterior plane. In the supine patient, nasal airways or nasogastric tubes should always be passed perpendicular to the horizontal axis and not in a cephalad direction.

The oropharynx extends from the palatoglossal fold down to the epiglottis. The primary structure contained within the oropharynx is the base of the tongue. The anterior two-thirds of the tongue is innervated by the lingual nerve, a branch of the facial nerve. The posterior one-third of the tongue, the tonsils, and the palate are innervated by the glossopharyngeal nerve.[6] Salivary glands located in the oropharynx can produce a significant volume of saliva, creating potential problems for mask ventilation or intubation. Loose teeth can be inadvertently dislodged into the oropharynx, becoming potentially hazardous foreign bodies in the airway.

Edentulous patients present a unique set of problems for mask ventilation.[7] The lack of a maxillary alveolar ridge allows the face mask to collapse into the airway. Redundant tissue, due to lack of teeth, tends to collapse into the airway as well, making mask ventilation without an oral or a nasal airway extremely difficult. An appropriately sized and placed oral airway is the best way to overcome the problem of upper airway obstruction in the unconscious and edentulous adult patient.

The laryngopharynx extends from the epiglottis to the inferior border of the cricoid cartilage. The piriform recesses lie in the pharynx, on either side of the larynx, and the esophagus resides posteriorly. The larynx is positioned at the entrance to the trachea, acts as the sphincter of the pulmonary system, and is made up of nine cartilages to support this function.[6] There are three paired and three unpaired cartilages. The unpaired cartilages are the epiglottis, the thyroid cartilage, and the cricoid cartilage. The paired cartilages are the arytenoids, the corniculates, and the cuneiforms. **The cricoid cartilage is the only complete ring in the entire airway.** This presents a unique opportunity for the practitioner to help prevent gastric aspiration. **The cricoid cartilage can be firmly pressed posteriorly to pinch the esophagus against the cervical spine and prevent the passive regurgitation of gastric contents. This is known as the Sellick maneuver.**[8] The cricoid cartilage is the narrowest point of the airway in the pediatric patient while the glottic narrowing is the most narrow point in adults. The cricoid and thyroid cartilages are the landmarks for identifying the cricothyroid membrane, which is essential in obtaining an emergent surgical airway.

TABLE 7-1 Indicators that Warrant Respiratory Assistance

SaO_2 < 90%
PaO_2 < 60 mmHg on 40% O_2
Respiratory rate > 35
$PaCO_2$ > 55 mmHg
Vital capacity < 15 mL/kg
A-a gradient > 350 mmHg on 100% O_2

Source: Data from Shapiro et al.[10]

The sensory and motor innervation of the larynx is derived from the vagus nerve.[6] The superior laryngeal nerve is a branch of the vagus nerve and gives rise to the internal branch, which provides the sensory innervation of the upper larynx. The superior laryngeal nerve also gives rise to the external branch, which provides the motor innervation to the cricothyroid muscle (a vocal cord adductor). The recurrent laryngeal nerve provides the sensory innervation to the larynx below the vocal cords and motor innervation to all other laryngeal muscles.[6]

The trachea is approximately 15 cm long in an adult. It is composed of 17 or 18 C-shaped cartilaginous rings.[6] The rings are essential to prevent the trachea from collapsing during the negative intrathoracic pressures generated on inspiration.

INDICATIONS

The decision to institute airway support must often be made very quickly and frequently without the aid of laboratory results, radiographic studies, or pulmonary function tests. **The decision to institute emergent airway support is usually based on clinical judgment and the signs and symptoms of inadequate oxygenation and ventilation.** The signs of impending respiratory failure are tachypnea, dyspnea, cyanosis, agitation, and the use of accessory muscles.[9] In the case of a partial airway obstruction, the patient will demonstrate extreme anxiety, audible wheezing or stridor, as well as aggressive attempts to clear the obstruction. If the obstruction is complete, there may be no audible breath sounds at all.

If time permits, a more formal evaluation of the indicators that warrant respiratory assistance should be performed (**Table 7-1**). The ultimate signs indicating the necessity for airway assistance are hypoxia and hypercarbia. The most common etiologies resulting in the need for airway support are cardiopulmonary arrest, drug overdoses, toxic reactions, and airway obstruction (food, vomit, or foreign body). Impending ventilatory failure due to congestive heart failure, severe asthma, or pneumonia are also common indications for endotracheal intubation.

CONTRAINDICATIONS

There are no absolute contraindications for basic airway management. The contraindications for the various methods of endotracheal intubation are discussed in subsequent chapters.

EQUIPMENT

- Bag-valve-mask device
- Oxygen source
- Clear face masks, various sizes and shapes
- Oropharyngeal airways, various sizes
- Nasopharyngeal airways, various sizes
- Head strap

- Yankauer suction catheter
- Suction source
- Pulse oximeter
- Tongue blades or tongue depressors
- Water-soluble lubricant or anesthetic jelly

TECHNIQUES

PATIENT POSITIONING

The first goal of airway management, regardless of a patient's ability to breathe spontaneously, is the establishment of a patent airway. This may be all that is required in a patient who has an upper airway foreign body or a patient who has suffered a loss of consciousness with loss of pharyngeal tone. **The importance of proper positioning cannot be overemphasized.** The success of airway management is predicated on this very basic but often overlooked issue. Placing the patient in the "sniffing" position, or lateral decubitus position, may correct many upper airway obstructions due to soft tissue impingement.[11] **The "sniffing" position is achieved by flexing the cervical spine approximately 15° and extending the atlantooccipital joint maximally (Figure 7-1)**. This is the position one subconsciously adopts in order to sniff and smell. Head extension in this manner must be omitted in the patient for whom cervical spine precautions are in effect. **This position can also be achieved with the chin-lift and/or jaw-thrust maneuvers.**

If the patient is obese or has large breasts, they often cannot be effectively managed in a supine position. The normal sniffing position in an obese person is often not sufficient to relieve an airway obstruction (**Figure 7-2A**). Place a ramp or shoulder roll under the patient's upper back to achieve the sniffing position (**Figure 7-2B**).

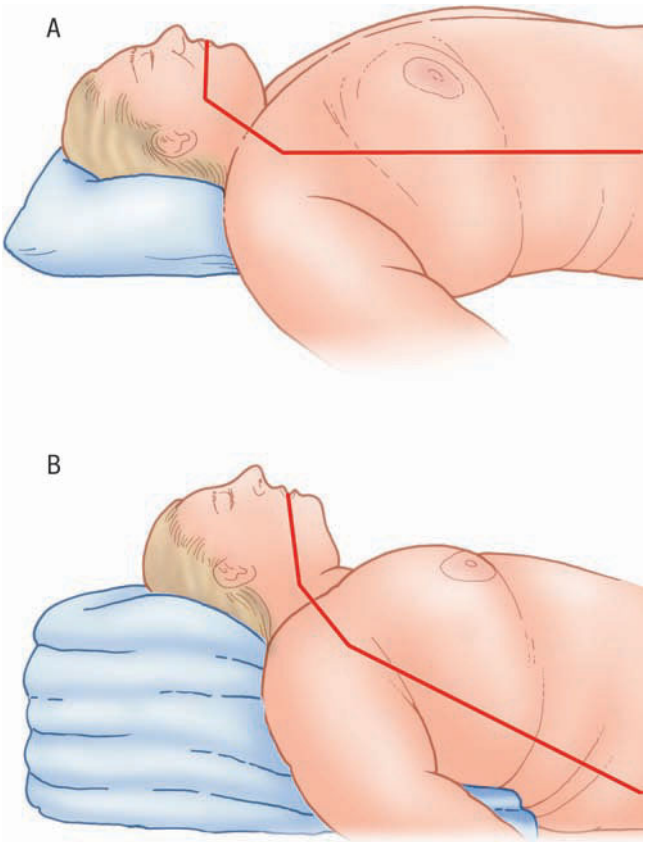


FIGURE 7-2. Airway management in the obese patient. **A.** The normal "sniffing" position is inadequate to open the airway. The dotted line represents the axis of the airway. **B.** A ramp placed under the head and shoulders will achieve the "sniffing" position.

JAW-THRUST MANEUVER

The jaw thrust is one of the most basic maneuvers and an initial method of establishing a patent airway.[12] The tongue is attached to the mandible and falls into the pharynx in the supine patient. **The goal of the jaw-thrust maneuver is to move the tongue away from the palate and posterior pharyngeal wall.** The jaw-thrust maneuver is a two-handed technique that can also be used with the face mask and a second person to provide positive-pressure ventilation. The operator is positioned at the head of the patient and places their fingers on the angles of the patient's mandible bilaterally, then displaces the mandible anteriorly (**Figure 7-3**). This maneuver elevates the tongue from the pharynx and allows air to flow unobstructed and posterior to the tongue.

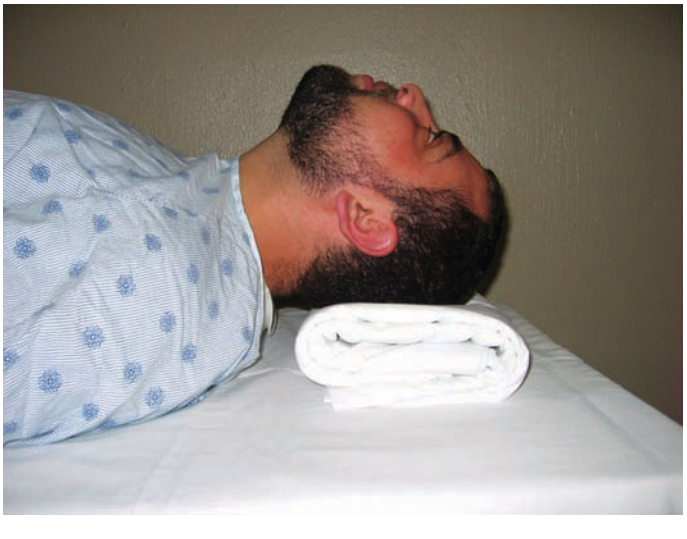


FIGURE 7-1. The "sniffing" position for successful airway management.

CHIN-LIFT MANEUVER

The chin lift is also one of the most basic maneuvers and an initial method of establishing a patent airway.[12] The chin lift is performed by the operator placing their fingers on the inferior surface of the patient's mandible (**Figure 7-4**). **Do not place any of the fingers on**



FIGURE 7-3. The jaw-thrust maneuver.



FIGURE 7-4. The chin-lift maneuver.

the soft tissues of the submandibular space, as this will elevate the tongue and cause further obstruction. Lift the chin in an anterior and cephalic direction. The head may also be tilted slightly posterior to aid in opening the airway.

NASOPHARYNGEAL AIRWAYS

The majority of airway obstructions occurs in the region of the pharynx.[13] In addition to proper positioning, one can use various aids to overcome this site of obstruction and facilitate effective ventilation. The most commonly used devices are oropharyngeal (oral) and nasopharyngeal (nasal) airways. Regardless which device is chosen, it is important to place a large enough airway to bridge the area of soft tissue impingement on the pharynx.

Nasal airways are soft rubber or plastic tubes that are inserted through the nostril and into the oropharynx, just above the epiglottis. Nasal airways are available in numerous sizes (**Figure 7-5**). The proximal end has an enlarged flange that rests against the patient's nares and prevents the nasal airway from slipping backward into the nose and becoming a foreign body in the patient's airway. The larger the inner diameter, the longer the tube. Once positioned, the



FIGURE 7-5. Nasopharyngeal airways.



FIGURE 7-6. Insertion of the nasopharyngeal airway.

nasal airway is more comfortable for the patient than an oral airway, but nasal airways carry the significant risk that their placement may result in epistaxis.[3,10] A size 30 or 32 French nasal airway is appropriate for most adults. It can be safely placed in the conscious, semiconscious, or unconscious patient, and can also be used when an oral airway cannot be placed (e.g., oral trauma, braces, seizures, trismus, etc.). **It is imperative to also perform the jaw thrust and/or chin lift to prevent the tongue from obstructing the patient's airway when using a nasal airway.**

Insertion of a nasal airway is a rapid procedure. Choose the proper size nasal airway by placing the flared end of the airway near the tip of the patient's nose. The distal end of the nasal airway should be at the external auditory canal. Liberally apply a water-soluble lubricant or an anesthetic jelly to the nasal airway. If not contraindicated, apply a vasoconstrictor to the patient's nasal mucosa. Gently insert and advance the nasal airway with the beveled tip against the nasal septum (**Figure 7-6**). This will prevent any epistaxis from the tip of the nasal airway getting caught on the inferior or middle turbinate. Also insert it along the floor of the nasal cavity adjacent to the septum. Continue to advance the nasal airway completely until the flared end is against the patient's nostril. Rotate the nasal airway 90° so it is concave upward. If resistance is encountered during insertion, slight rotation will often facilitate the passage of the nasal airway. If resistance is still encountered, insert the nasal airway into the other nostril or use a smaller nasal airway. Supplementary oxygen or positive-pressure ventilation with a bag-valve-mask device can be started after insertion of the nasal airway.

Insertion of a nasal airway may be associated with complications. If the device is too long, it may cause laryngospasm and vomiting. It may also be placed with its tip in the esophagus, resulting in gastric distention and subsequent aspiration. Nasal mucosal injury upon insertion can result in epistaxis and aspiration of blood.

OROPHARYNGEAL AIRWAYS

The oropharyngeal (oral) airway is a semicircular plastic device that holds the tongue up and away from the posterior pharyngeal wall (**Figure 7-7**). Oral airways cause less trauma and are more easily placed than nasal airways. **Oral airways must be used only in unconscious patients. They may result in laryngospasm and vomiting if placed in a conscious or semiconscious patient.**[14] An 8.0, 9.0, or 10.0 cm oral airway is appropriate for most adults.

Oral airways have many uses. The primary indication is to maintain a patent airway. It will prevent the patient from biting,



FIGURE 7-7. Oropharyngeal airways.

occluding, and lacerating an endotracheal tube. It facilitates oropharyngeal suctioning by removing the tongue from the airway, and will also protect the tongue from bites during seizure activity.

Insertion of the oral airway is a quick and simple procedure. Choose the proper size oral airway. The correct size is estimated by placing the proximal flange of the oral airway next to the patient's mouth. The distal tip should lie just above the angle of the mandible. Clear the mouth and oropharynx of any blood, secretions, or vomit with a Yankauer suction catheter. Open the patient's jaw with the nondominant hand. Separate the patient's jaws with a "scissors-like" action of the thumb on the lower teeth and the index or middle finger on the upper teeth. Insert the oral airway curved side down (**Figure 7-8A**). The tip will slide along the hard palate. Insert it until the plastic flange on the proximal end is at the patient's lips. Rotate it 180° so that the curve of the oral airway follows the curvature of the tongue.

An alternative method is to use a tongue blade to depress the tongue and then insert the oral airway as described above. If the tongue blade is used, the oral airway may also be inserted with the curve side upward (**Figure 7-8B**). Supplementary oxygen or positive-pressure ventilation with a bag-valve-mask device can be started after the insertion of the oral airway.

Insertion of an oral airway is not a benign procedure. If the oral airway is not inserted properly, it can push the tongue posteriorly and further obstruct the oropharynx. Significant lacerations can occur if the lips or tongue are caught between the teeth and the oral airway. If the oral airway is too long, it can force the epiglottis closed against the vocal cords and produce a complete airway obstruction. Too small of an oral airway will force the tongue against the pharynx and produce an obstruction.

MASK VENTILATION

The likelihood of success in airway management is often predictable, given enough time to fully assess a patient's history and anatomy (please refer to Chapter 6).[15] The ease of mask ventilation and intubation is directly related to anatomy. Anesthesiologists rely on a series of evaluations and classification criteria to help predict the success of airway management. The most widely used classification is the Mallampati classification (**Figure 6-6**).[16] This evaluation—coupled with an examination of the patient's body habitus, thickness of the patient's neck, temporomandibular joint function, ability to fully open the mouth, dental structures, cervical range of motion, and thyromental distance—can help predict the ease or difficulty of airway management.[15–21]



FIGURE 7-8. Insertion of the oropharyngeal airway. **A.** It is inserted with the curve toward the tongue. After insertion, it is rotated 180°. **B.** It is inserted with the curve toward the palate. A tongue blade is used to depress the tongue and facilitate insertion.

A distinction must be made between ease of mask ventilation and ease of oral endotracheal intubation. The two are often correlated but can, at times, be completely unrelated. For example, a patient with a normal body habitus who is in a cervical halo may be very easy to ventilate by mask but impossible to intubate orally via direct laryngoscopy. Conversely, the patient who is obese, suffers from sleep apnea, but has a Mallampati class 1 airway may be very easy to intubate but virtually impossible to ventilate by mask.

After achieving the proper positioning, the presence of spontaneous respirations must be evaluated. If the patient is not breathing and there is no evidence of a foreign body, positive-pressure ventilation must be initiated. In the awake patient with complete airway obstruction due to a foreign body, the Heimlich maneuver is the method of choice.[2] If the patient has become unconscious and the foreign body is clearly visible, remove it. **However, caution must be used to prevent forcing the object further into the airway.** Instrument removal of airway foreign bodies with a McGill forceps is possible if the foreign body is visible and within reach of the forceps.

Once the airway is patent, the options for positive-pressure ventilation include mouth-to-mouth, mouth-to-mask, and bag-valve devices (mask ventilation). The remainder of this section will review the latter, as the other two options are not used in Emergency Departments or hospitals. **The key to effective mask ventilation is ensuring a continually patent airway. This is initially achieved by placing the patient in the sniffing position, coupled with**



FIGURE 7-9. The one-handed, one-person mask ventilation technique.



FIGURE 7-10. The two-handed, two-person mask ventilation technique.

a combination of chin lift and jaw thrust. Neglect of this key maneuver leads to an excessive use of positive-pressure ventilation in an attempt to compensate for an obstructed upper airway. Improper patient positioning associated with positive-pressure ventilation will force gas into the stomach, increasing intraabdominal pressure and resulting in the need for ever-increasing positive pressure on the airway. Rising intraabdominal pressure will eventually make ventilation difficult or impossible, and significantly increase the risk of gastric aspiration. When called upon to mask ventilate a patient, **always keep in mind the importance of proper positioning and the use of an appropriately sized oral or nasal airway as an adjunct.**

Face masks should be made of clear plastic and/or silicone, have a soft seal, and have an anatomic shape that conforms to the contours of the patient's face. Typical adult sizes are 3, 4, and 5. **The mask must be large enough to completely cover the nose, mouth, and chin but not so large as to allow a leak.** It should not cover any part of the patient's eyes. There are two ways to properly hold a face mask. The one-handed technique is performed with the nondominant hand (**Figure 7-9**). The operator should be positioned at the top of the bed looking down at the patient's head. Place the little, ring, and middle fingers under the patient's mandible. Place the index finger and thumb on the bottom and top portions of the mask. **This technique allows the operator to simultaneously lift the mandible and extend the atlantooccipital joint while applying enough downward pressure on the face mask to create an airtight seal.** An elastic head strap is a very helpful device to aid in sealing the mask tightly. The dominant hand is used to ventilate the patient through the bag-valve device.

A two-handed technique may be necessary in patients with facial hair and those who are obese, elderly, or edentulous. Two people are required to perform this technique, in which both of the operator's hands are applied to the face mask to aid in the creation of a tight seal and align the airway properly (**Figure 7-10**). Place the face mask on the patient's face. Place the index, middle, ring, and small fingers of the left hand on the body of the left side of the patient's mandible. Position the right hand similarly on the right side of the patient's mandible. Apply both thumbs to the mask and apply pressure to create a seal. Anteriorly elevate the mandible to perform the jaw-thrust maneuver. This is the two-person technique and makes it necessary to have an assistant apply positive pressure through the bag-valve device attached to the face mask. It is preferable, whenever possible, to use the two-person technique which allows for improved bag-valve-mask ventilation.[25]

THE NuMask™

A relatively new device can be used to assist in ventilation instead of a traditional face mask. The NuMask™ (NuMask Inc., Woodland Hills, CA) solves the problem of having to create an airtight face mask seal in patients. This device is an intraoral mask for teenagers and adults that connects to a bag-valve device and eliminates the need for a face mask (**Figure 7-11A**). It is especially useful in patients whom it is difficult to get a good face mask seal (e.g., obese, facial hair, and facial trauma) or for the one-person bagging technique. The company makes a retention shield that wraps around the patient's head to secure the device and seal the patient's nostrils. This allows for easy one-person bagging.

The NuMask™ is simple to insert into the patient's mouth. Place the device into the patient's mouth. It should sit between the patient's teeth/gums and the cheeks/lips (**Figure 7-11B**). Use the thumb and index finger of the nondominant hand to pinch the patient's nostrils closed (**Figures 7-11C & D**). Use the hand and remaining fingers to wrap around the external tube portion and to seal the patient's lips over the intraoral portion of the device (**Figures 7-11C & D**). The moisture in the patient's oral cavity maintains the airtight seal. Attach the bag-valve device and begin ventilations. If ventilation is difficult, remove the NuMask™, insert an oral airway, replace the NuMask™, and begin ventilations.

There are numerous advantages of using the NuMask™ over the traditional face mask. It is ideal for operators with small hands who have difficulty grasping and maintaining a seal with a face mask. While initially cumbersome to use, it is easier to maintain a seal than a face mask. Ventilation is easier when only one person is available to bag and ventilate the patient. It can be used in patients in whom a good face mask seal is difficult. The device can be used in both conscious and unconscious patients as it should not cause a gag reflex. Finally, the one size available will fit most teenagers and adults. A pediatric version is not available.

THE BAG-VALVE DEVICE

A bag-valve device is used to provide positive-pressure ventilation. It consists of a self-inflating bag connected to oxygen on one end and a one-way (nonrebreathing) valve on the other. They are available in several sizes depending on the age of the patient (**Figure 7-12**). The valve end is connected to the face mask, or other airway device, to allow one-way flow of oxygen. The other end has tubing to attach the bag to an oxygen source. This device can also force air into the esophagus and stomach and place the patient at risk for aspiration if not used properly.

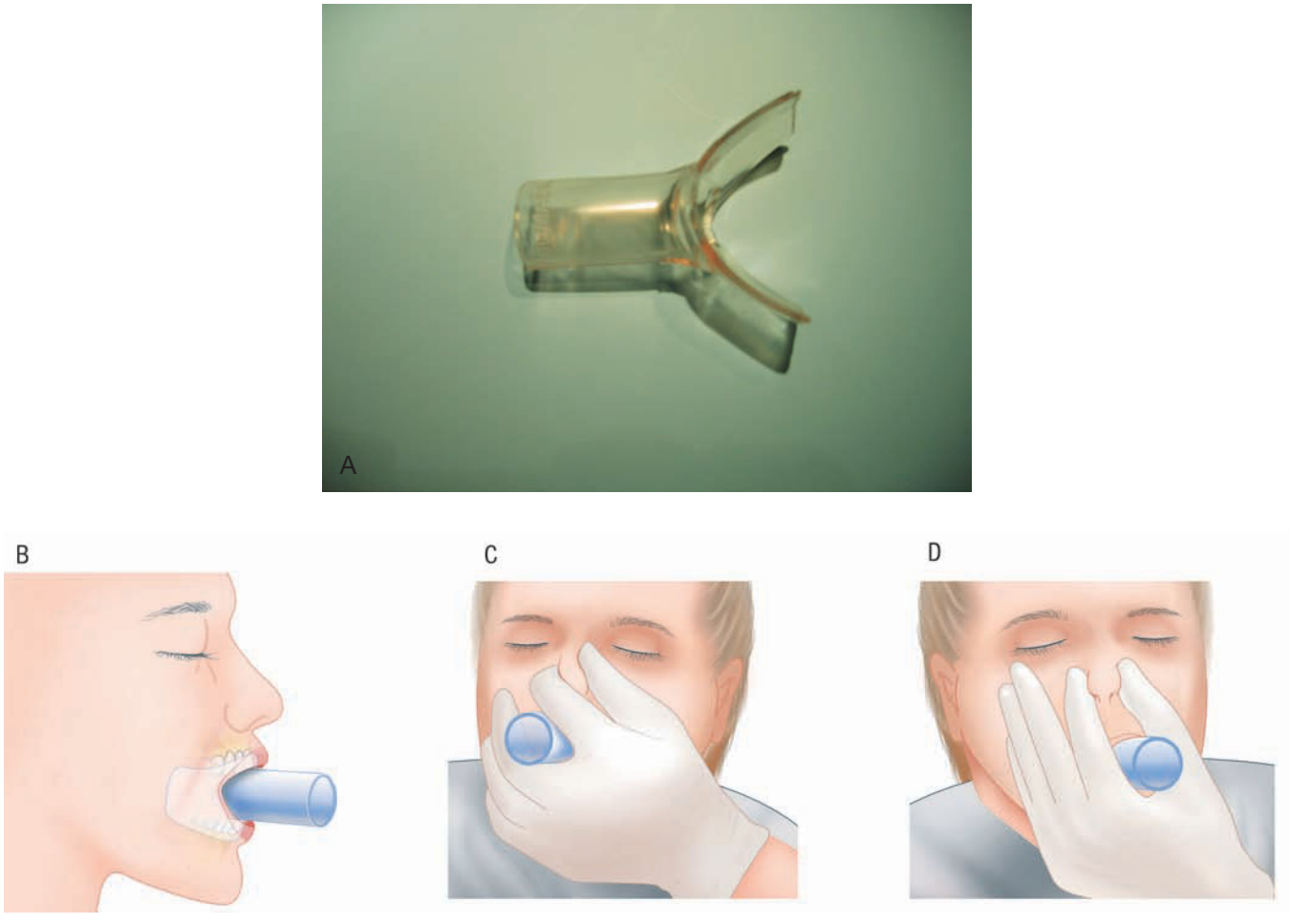


FIGURE 7-11. The NuMask™ intraoral mask. **A.** The device. **B.** The device is inserted between the patient's teeth/gums and their lips/cheeks. **C.** Proper hand positioning to seal the patient's nostrils and lips. **D.** An alternative hand positioning.

It may be difficult to provide adequate ventilatory volumes through the bag-valve device attached to a face mask. This is often due to an inadequate seal of the face mask on the patient while maintaining an open airway. It can also result from inadequate squeezing of the bag to generate an appropriate volume of air flow. Consider using the two-person technique to resolve these issues. If ventilation is difficult in a child, change the face mask from the standard teardrop shaped mask to a circular-shaped face mask.



FIGURE 7-12. The bag-valve-mask device. From left to right: adult size, child size, and infant size.

Stand above the patient's head. Place the patient in the sniffing position. Apply a face mask. Attach the bag-valve device to the face mask and begin positive-pressure ventilation. Begin ventilations at a rate of 10 to 12 per minute, or squeeze the bag every 5 to 6 seconds. If ventilation is difficult, apply the jaw-thrust and/or chin-lift maneuvers. If ventilation is still difficult, insert an oral or nasal airway. If ventilation is still difficult, the patient requires an invasive airway device immediately.

The American Society of Anesthesiologists has published an algorithm to facilitate decision making in the face of airway management problems. A detailed discussion of the various intubation options is presented in following chapters.

PEDIATRIC CONSIDERATIONS

Significant differences exist between the adult and pediatric airway as described in Chapter 6. The ratio of head-to-body size is greater in infants and young children. Care must be taken to achieve proper positioning for optimal airway angulation. A towel may be placed under an infant's shoulders, while younger children may be optimally positioned while lying flat on the stretcher. Older children may require a towel under the head to achieve ideal positioning.[23] Despite proper head positioning, loss of tone in the muscles

supporting and protecting the upper airway may still result in an airway obstruction. This may be corrected by the use of a jaw thrust, chin lift, nasal airway, or oral airway.

Infants and children have a higher minute ventilation and cardiac output than adults, as well as higher basal oxygen consumption. They also have a lower functional residual capacity which leads to oxygen desaturation more rapidly than in adults when apnea occurs. When oxygenation and ventilation are provided in an effective and efficient fashion, hypoxic bradycardia can be prevented or reversed.[23]

Properly sized equipment remains crucial to the success of airway management, and can be addressed by the use of the Broselow tape. It should be noted that there is insufficient evidence for or against the routine use of laryngeal mask airways during pediatric cardiac arrest. While an acceptable adjunct in the hands of experienced providers, it is associated with a higher incidence of complications in young children.[24]

COMPLICATIONS

The most serious complication of basic airway management is aspiration of gastric contents. The aspiration of acidic gastric contents can result in an acute chemical pneumonitis. This phenomenon is known as the Mendelson syndrome and has an associated 50% mortality.[22] It is a significant risk when airway management is needed emergently or routinely in the pregnant, trauma, diabetic, or obese patient.

Less serious complications include soft tissue trauma to the lips, tongue, oral cavity, and eyelids. Tooth fractures or avulsions are uncommon but possible. A dermatitis or allergic reaction to the plastic material is rarely seen. Facial nerve dysfunction due to pressure effects of the mask are transient. Corneal abrasions, conjunctival chemosis, and increased intraocular pressure are common with masks that are too large.

SUMMARY

Basic airway management is a fundamental skill that must be mastered by all caregivers. With an oxygen source, a means to deliver positive-pressure ventilation, attention to detail in positioning, and the use of airway adjuncts, it is usually possible to prevent hypoxia and hypercarbia in the apneic patient. The ultimate measure of the efficacy of ventilation and oxygenation is a normal $PaCO_2$ and PaO_2. The various methods of securing the airway are discussed elsewhere in this text.

8 Pharmacologic Adjuncts to Intubation

Ned F. Nasr, David W. Boldt, and Isam F. Nasr

INTRODUCTION

Oral endotracheal intubation without pharmacologic assistance should be reserved for the unresponsive and apneic patient. Unconscious patients capable of resisting laryngoscopy or those with spontaneous respiratory effort should be intubated with the assistance of pharmacologic adjuncts. A rapid sequence induction optimizes intubation conditions while minimizing the risk of aspiration for the patient. It can be performed with a high rate of success and minimal complications.[1] Rapid sequence intubation requires the use of several pharmacologic adjuncts (**Tables 8-1 & 8-2**). This includes a potent anesthetic agent to induce unconsciousness and a neuromuscular blocking agent to produce paralysis.

TABLE 8-1 Recommended Anesthetic Doses of Pharmacologic Agents Used for Rapid Sequence Induction

Medication	Adult dose (mg/kg)	Pediatric dose (mg/kg)	Onset (sec)	Duration (min)
Thiopental	2–5	2–6	<30	5–10
Methohexital	1–3	1–2	<30	5–10
Etomidate	0.2–0.3	0.2–0.3	15–45	3–12
Ketamine	1–2	1–3	45–60	10–20
Propofol	1.5–2.5	2.5–3.5	15–45	5–10
Midazolam	0.2–0.4	0.5–1.0	30–90	10–30
Fentanyl	0.005–0.015	0.005–0.015	15–45	30–60

INDUCTION AGENTS

The ideal induction agent has an extremely rapid onset of action, produces predictable deep anesthesia, has a short duration of action, and has no adverse effects.[2] Unfortunately, such an agent does not yet exist. However, there are at least six drugs that can safely be used for induction of anesthesia and intubation. These include thiopental, methohexital, etomidate, ketamine, and propofol. Midazolam and fentanyl may also be used alone or in conjunction with the above agents.[2] **The decision as to which induction agent is the most suitable is largely dependent on the Emergency Physician's experience and his or her understanding of each drug's properties.** In this section, each of these drugs is briefly detailed as to its pharmacokinetics, mechanism of action, pharmacodynamics, administration, and adverse effects.

BARBITURATES

For more than 50 years, barbiturates have been a mainstay in the induction of anesthesia. They rapidly produce sedation and hypnosis in a dose-dependent fashion. They are also less expensive than many of the newer induction agents.[3] Because of their high potency, rapid onset, and short duration of action, the most commonly used barbiturates are thiopental (Pentothal™) and methohexital (Brevital™).

PHARMACOKINETICS

When injected intravenously, these ultra-short-acting barbiturates can produce effects in one arm-brain circulation time, or less than 30 seconds.[4] The onset of central nervous system (CNS) depression is primarily due to the rapid distribution of thiopental and methohexital to the well-perfused, low-volume central compartment,

TABLE 8-2 Recommended Neuromuscular Blocking Agents for Intubation and Rapid Sequence Induction

Medication	Adult dose (mg/kg)	Pediatric dose (mg/kg)	Onset (min)	Duration (min)
Succinylcholine	0.6–1.0	1–2	1	2–3
Succinylcholine for RSI	1.5	2	1	3–5
Pancuronium	0.1	0.07–0.10	2–5	40–60
Atracurium	0.5	0.5	3	20–35
Vecuronium	0.1	0.05–0.10	3	30–40
Vecuronium for RSI	0.3–0.5	0.3–0.5	1	45–60
Rocuronium	0.6	1.0	4–6	15–85
Rocuronium for RSI	0.9–1.2	1.0–1.2	1.0–1.5	30–110

consisting mainly of the brain and liver. Approximately 15% of these lipid-soluble drugs remain unbound and free to diffuse across the blood–brain barrier at high initial concentrations. Brain levels peak in about 1 minute. The duration of a single dose of thiopental is approximately 5 to 10 minutes, while an equipotent dose of methohexital lasts approximately 4 to 6 minutes.[5] The short duration of action is due to the redistribution of the drugs from the small-volume central compartment to the large-volume peripheral compartment, which is predominantly made up of lean muscle.

Both thiopental and methohexital are metabolized in the liver and excreted by the kidneys. Methohexital has a substantially higher hepatic extraction ratio, which may account for its shorter duration of action. Clearance of the drugs has little to do with the cessation of CNS effects in single or multiple small doses. If barbiturates are given in multiple high doses or in an infusion, the concentration in the peripheral tissue approaches the plasma concentration and the rate of redistribution is greatly diminished.[6] This prolongs their anesthetic effects.[6]

MECHANISM OF ACTION

Barbiturates, along with other common intravenous (IV) anesthetic agents, are postulated to act on the γ-aminobutyric acid (GABA) receptor complex. Specifically, these drugs work on the $GABA_A$ receptor.[7] GABA is the principal inhibitory neurotransmitter in the CNS. The GABA receptor complex forms a transmembrane chloride channel when activated. The influx of chloride ions causes hyperpolarization and functional inhibition of the postsynaptic neurons. Barbiturates can act on the GABA receptor in two ways. At lower doses, they may potentiate the action of endogenously produced GABA by decreasing the rate of its dissociation from the receptor complex. At higher doses, barbiturates may directly activate the chloride ion channels and inhibit neuronal activity.[3] **It is important to note that barbiturates do not inhibit sensory impulses and therefore have no analgesic effect.** In fact, they may produce hyperalgesia (increased response to painful stimuli) when given in subhypnotic doses.[3]

PHARMACODYNAMICS

Barbiturates produce dose-dependent depression of cerebral oxygen metabolism ($CMRO_2$), cerebral blood flow (CBF), and electroencephalogram (EEG) activity. A flat EEG tracing correlates to a maximal barbiturate suppression of $CMRO_2$ to 55% of normal.[3] The diminished $CMRO_2$ and CBF lead to a decrease in intracranial pressure (ICP). Since barbiturates lower mean arterial pressure less than they lower ICP, cerebral perfusion pressure (CPP) is usually enhanced. Barbiturates are commonly used in neuroanesthesia and in treatment of acute brain injury.

The cardiovascular effects of barbiturates include decreased cardiac output, decreased systemic arterial pressure, and a direct negative inotropic effect on the myocardium. Barbiturates decrease cardiac output primarily by depressing the vasomotor center, causing peripheral vasodilatation, and decreasing venous return to the heart. Both thiopental and methohexital have a positive chronotropic effect on the heart. Methohexital produces a greater increase in heart rate, which may explain why an equipotent dose of methohexital produces significantly less hypotension than does thiopental.[3] Although the increase in heart rate mitigates the drop in blood pressure, myocardial oxygen demand is increased while coronary vascular resistance is decreased. If the aortic pressure remains stable, coronary blood flow will increase to meet the increased demand. **Therefore, barbiturates must be used cautiously in any patient whose condition is sensitive to tachycardia or a decrease in preload (e.g., hypovolemia, congestive heart failure, ischemic heart disease, or pericardial tamponade).** Methohexital has less cardiovascular depressant effects and a shorter duration of action, likely making it more useful than thiopental in the Emergency Department setting.

Barbiturates cause dose-dependent central respiratory depression characterized by diminished tidal volume and minute ventilation. The rate and depth of respiration may be suppressed to the point of apnea. The physiologic response to hypercarbia and hypoxemia may also be blunted, even after the hypnotic effects have dissipated. All these effects may be greatly exaggerated with the concomitant use of opioids and in patients with chronic obstructive pulmonary disease.[8]

ADMINISTRATION

Thiopental and methohexital are available as sodium salts and should be dissolved in 0.9% saline. The recommended dose of thiopental is 3 to 5 mg/kg in adults, 5 to 6 mg/kg in children, and 6 to 8 mg/kg in infants IV given over 1 minute. The recommended dose of methohexital is 1 to 3 mg/kg IV over 30 seconds. The induction dose should be reduced in patients premedicated with fentanyl or midazolam. Doses may have to be adjusted in patients with known hepatic or renal disease because decreased plasma albumin levels leave a greater fraction of barbiturate available to cross the blood–brain barrier. A 30% to 40% reduction should be made in the geriatric population since their diminished muscle mass slows the rate of redistribution and lengthens the duration of CNS effects.[3]

ADVERSE EFFECTS

The most significant complications of barbiturate therapy stem from their cardiopulmonary depressant effects. As stated above, these agents should be used with caution in patients who are hypovolemic, have significant cardiovascular disease, or have reactive airway disease. Thiopental can raise plasma histamine levels, which may be associated with a transient skin rash and bronchospasm. Its use should be avoided in patients with a history of hypersensitivity to barbiturates. Severe anaphylactic reactions are extremely uncommon.[3] Laryngeal reflexes appear to be more active with thiopental than with propofol. Thiopental should be avoided in people with asthma.[3] Laryngospasm following induction with thiopental is more likely the result of airway manipulation in a "lightly anesthetized" patient.[3] Methohexital has known epileptogenic effects and is frequently associated with myoclonic tremors and other CNS excitatory side effects, such as hiccups.[3] Barbiturates stimulate the production of porphyrins and thus are contraindicated in patients with acute intermittent porphyria, variegate porphyria, and hereditary coproporphyria.[3] Pain at the site of intravenous injection is more common with the administration of methohexital than thiopental. Due to their high alkalinity (pH 10), extravascular or intraarterial injection of these drugs may cause severe pain, tissue necrosis, and thrombosis, leading to potential nerve damage and gangrene.

Intraarterial injection should be treated promptly by initially diluting the barbiturate with saline injected through the catheter in the artery. Next, intraarterial injections of heparin, papaverine, lidocaine, or phenoxybenzamine may be administered to cause vasodilation and prevent vessel thrombosis.[3] Lastly, sympathectomy of the involved upper extremity by a stellate ganglion or brachial plexus block can be performed by an Anesthesiologist to relieve the vasoconstriction.

An additional concern relating to the high alkalinity of these solutions is that if they are injected rapidly through the same intravenous line along with highly acidic drugs, such as neuromuscular blockers, precipitation will occur. This may lead to permanent blockage of the line at a time when intravenous access is crucial. It

is recommended that the line be flushed thoroughly both before and following the administration of barbiturates, and before the administration of the next agent.

ETOMIDATE

Etomidate (Amidate™) is an ultra-short-acting hypnotic unrelated to any other intravenous anesthetic agent. Like barbiturates, it is highly potent and produces a rapid onset of anesthesia. It lacks the barbiturates' cardiodepressant side effects. Given its favorable profile, etomidate has become a popular induction agent and, in many Emergency Departments, is now the induction agent of choice for rapid sequence intubation.[9]

PHARMACOKINETICS

Etomidate is a carboxylated imidazole agent that undergoes a molecular rearrangement at physiologic pH, which grants it greater lipid solubility. Approximately 75% of the drug is plasma protein bound. The free fraction accumulates readily in the CNS. Unconsciousness is produced within one arm-brain circulation time. Peak brain concentration is achieved within 1 minute. Redistribution of the drug is quite rapid. A single bolus dose produces hypnosis in 10 seconds and lasts approximately 3 to 5 minutes. Since it has a high extraction ratio and undergoes rapid hydrolysis by the liver, clearance of etomidate is dependent on hepatic blood flow, with inactive metabolites excreted in the urine.[10]

MECHANISM OF ACTION

By modulating GABA receptors to produce hyperpolarization and functional inhibition of the postsynaptic neurons, etomidate (like barbiturates, propofol, and benzodiazepines) produces dose-dependent CNS depression. GABA antagonists, such as flumazenil, may attenuate its effects. **Etomidate has no analgesic properties.**[11]

PHARMACODYNAMICS

Etomidate produces dose-dependent depression of $CMRO_2$, CBF, and EEG activity analogous to that of the barbiturates. Since it does not affect mean arterial pressure, **etomidate decreases ICP with minimal effect on CPP.** It is useful in patients with elevated ICP, especially those who are hemodynamically unstable.[12] **Etomidate causes minimal cardiovascular depression, even in the presence of significant cardiac disease.** Heart rate, blood pressure, and cardiac output are all adequately maintained. The respiratory depressant effects of etomidate appear to be substantially less than those of thiopental or propofol, making it a safer choice than barbiturates in patients with diminished pulmonary function. **Etomidate is therefore considered to be the induction agent of choice in patients with severe cardiopulmonary disease and high-risk patients in whom maintenance of blood pressure is crucial.**[13] Because it does not blunt the sympathetic response to laryngoscopy and intubation, etomidate should be combined with an opioid analgesic in patients who would be at risk from a transient elevation of blood pressure or heart rate.[14] **Etomidate is the only available intravenous anesthetic that does not induce the release of histamine and thus is safe for patients with reactive airways.**[15]

ADMINISTRATION

Etomidate is formulated in a 0.2% solution with 35% propylene glycol. The standard induction dose is 0.3 mg/kg IV. There is virtually no accumulation of the drug. Emergence time is dose-dependent but remains short, even after repeated boluses.[16] Dose adjustments for elderly patients or those with hepatic or renal disease may be required.

ADVERSE EFFECTS

The most common side effects of etomidate are nausea, vomiting, and myoclonus during the induction phase, and injection site pain. Myoclonic activity has been reported in about one-third of cases and is attributed to interruption of inhibitory synapses in the thalamocortical tract rather than CNS excitation.[2] Pretreatment with an opioid analgesic or a benzodiazepine has been reported to diminish the frequency of myoclonic movements.[11] Vein irritation and pain at the intravenous site can be attributed to the propylene glycol diluent. Use of a large vein with simultaneous analgesic and saline infusion reduces the incidence of injection pain.[17]

Etomidate causes a dose-dependent suppression of adrenal corticosteroid synthesis by inhibiting the enzyme 11-β-hydroxylase.[74] A single induction dose of etomidate suppresses adrenocortical hormone synthesis for more than 5 hours.[75] In critically ill patients on an etomidate infusion, increased mortality has been attributed to this reduction of endogenous steroids leading to acute adrenocortical insufficiency.[18] **There is currently conflicting evidence, however, as to whether a single induction dose of etomidate has an effect on overall mortality in critically ill patients.**[76–81] Until significant randomized, controlled clinical trials can be performed, the use of etomidate for the induction of patients in early sepsis or septic shock should be cautioned.

KETAMINE

Ketamine (Ketalar™, Ketaject™) is a phencyclidine derivative that is unique among induction agents. **It produces a dissociative anesthetic state characterized by profound analgesia and amnesia.** Patients may appear awake with their eyes open, revealing a nystagmic gaze. They may make spontaneous nonpurposeful movements. **Protective reflexes are usually maintained,** which is fortunate considering that increased salivation is a common side effect. Ketamine is fast acting and has a brief duration of action. Although the likelihood of emergence delirium limits the usefulness of this drug, it has been widely used since 1970.[19]

PHARMACOKINETICS

Ketamine has a p*K*a of 7.5. Approximately 12% is plasma protein bound. Therefore, roughly half of the unbound fraction is available to accumulate rapidly in the CNS. A single induction dose produces anesthesia within 30 seconds and brain concentration peaks at 1 minute. Like barbiturates and etomidate, ketamine follows the three-compartment model, with rapid redistribution to the peripheral tissues.[19] Its CNS effects last approximately 10 to 15 minutes. Recovery of full orientation and function may take an additional 60 minutes. Ketamine is readily metabolized by hepatic microsomal enzymes to norketamine. Norketamine is one-fourth as potent as its precursor. The active metabolite may explain the prolonged recovery time. Norketamine is hydroxylated and excreted by the kidneys. Ketamine has a high extraction ratio, and its clearance is dependent on hepatic blood flow.[2]

MECHANISM OF ACTION

Ketamine acts by binding to the *N*-methyl-D-aspartate (NMDA) receptors on postsynaptic neurons. This receptor is a gated ion channel that allows depolarization and initiation of an action potential when activated by glutamate or NMDA. Ketamine blocks the flux of ions through this channel and inhibits the stimulatory effects of these neurotransmitters. Ketamine depresses neuronal activity in the cerebral cortex and the thalamus. It also stimulates the limbic system. Analgesia is produced by interrupting the association pathways responsible for the interpretation of painful stimuli that run from the thalamocortical and limbic systems.[20]

PHARMACODYNAMICS

Although ketamine produces dose-dependent CNS depression, it increases $CMRO_2$ and CBF, leading to an increase in ICP. Ketamine has a potent sympathomimetic effect. Its use often produces an increase in heart rate and arterial blood pressure. It has a direct negative inotropic effect on the myocardium, which is evident in the critically ill patient with depleted catecholamines. Ketamine produces minimal to no respiratory depression and has a potent bronchodilatory effect. It increases both bronchial and oral secretions. In contrast to other anesthetic agents, ketamine is likely to preserve protective airway reflexes. Skeletal muscle tone is also increased, resulting in the occurrence of random movements.[19]

ADMINISTRATION

Ketamine is available in 1% and 5% aqueous solutions for intravenous administration and a 10% aqueous solution for intramuscular (IM) injection. The induction dose of ketamine is 1 to 2 mg/kg IV over 1 minute or 5 to 10 mg/kg IM.[2]

In the Emergency Department, ketamine is indicated for the intubation of asthmatic patients due to its bronchodilatory properties. Ketamine may also be therapeutic for these patients, because the increase in bronchial secretions may decrease the incidence of mucous plugging.[21] Due to its cardiostimulatory effects, ketamine may be useful in the hemodynamically unstable patient. **Ketamine should not be used in those with suspected head trauma or intracranial pathology because it may increase ICP. It should not be used in patients with ischemic heart disease because it can increase blood pressure, heart rate, and myocardial oxygen demand.**

ADVERSE EFFECTS

The most significant side effect of ketamine is the occurrence of postanesthetic emergence reactions. Up to 30% of patients treated with ketamine have reported unpleasant sensations, agitation, hallucinations, restlessness, or nightmares.[2] Those most affected were elderly, females, and patients receiving more than 2 mg/kg. Children seem less adversely affected than adults. These reactions can be attenuated or eliminated by the coadministration of a benzodiazepine (midazolam) or propofol. Other side effects include hypersalivation, random movements, nystagmus, and increased intraocular and intracranial pressure. The hypersalivation may be limited by the administration of atropine or glycopyrrolate. Ketamine may activate epileptogenic foci in patients with a seizure disorder.[19]

PROPOFOL

Introduced in 1989, propofol (Diprivan™) is a sedative-hypnotic agent used for procedural sedation, induction, and maintenance of anesthesia. Although unrelated to any of the other induction agents, it has a profile similar to that of thiopental. Despite its cardiopulmonary depressant effects, the use of propofol has greatly expanded. It is well suited for ambulatory surgery performed on relatively healthy outpatients. Recovery after propofol anesthesia is rapid and is accompanied by less residual sedation, fatigue, and confusion than any other induction agent. Propofol is associated with a low incidence of postanesthetic emesis.[22] While the role of propofol as an adjunct to emergency airway management in the Emergency Department is still unfolding, it is commonly used for procedural sedation (Chapter 129) or postintubation sedation.

PHARMACOKINETICS

Propofol is an alkyl-phenol compound that is insoluble in water. It is 98% plasma protein bound. Since it is highly lipophilic, any unbound drug rapidly accumulates in the brain and liver. A single bolus produces hypnosis in as little as 15 to 45 seconds. Its duration of action, like that of thiopental, is 5 to 10 minutes and reflects a rapid redistribution to lean muscle mass. Propofol is cleared from the central compartment by hepatic metabolism. Its metabolites are water soluble and excreted in the urine.[2]

MECHANISM OF ACTION

Propofol produces CNS depression by modulating the $GABA_A$ receptor by the same mechanism as barbiturates.[2]

PHARMACODYNAMICS

Propofol produces a dose-dependent CNS depression without analgesia. It does have a strong amnestic effect. It decreases $CMRO_2$, CBF, and ICP. Since its cardiodepressant effects are greater than those of thiopental, CPP may be affected at high doses. Propofol is a myocardial depressant and potent vasodilator that lowers blood pressure and cardiac output. These effects attenuate the hemodynamic pressor response to laryngoscopy and intubation. Propofol blunts the baroreflex, so that the heart rate does not increase in proportion to a drop in blood pressure. Decreased respiratory rate and tidal volume are seen with propofol, and ventilatory response to hypercarbia is diminished. Propofol may produce bronchodilation in patients with chronic obstructive pulmonary disease (COPD).[23] Propofol appears to have a strong anticonvulsant effect and may be used to terminate status epilepticus.[24]

ADMINISTRATION

Propofol is prepared as a 1% oil-in-water emulsion that contains egg lecithin, soybean oil, glycerol, and EDTA. The adult dose for induction is 2.0 to 2.5 mg/kg IV. For sedation, an infusion rate of 25 to 75 μg/kg/min is titrated to effect. Dosages should be reduced to 1.0 to 1.5 mg/kg IV in the elderly, in high-risk patients, and in anyone premedicated with an opioid or a benzodiazepine.[23] Propofol supports bacterial growth, and any unused portion should be discarded.

ADVERSE EFFECTS

Propofol produces pain on injection in up to 75% of patients. This may be reduced or prevented by pretreatment with an opioid or the addition of 0.01% lidocaine to the emulsion. Propofol may cause mild CNS excitation in the form of myoclonus, tremors, or hiccups.[2]

BENZODIAZEPINES

Benzodiazepines are a large class of drugs with anxiolytic, sedative, hypnotic, and amnestic properties without any analgesic properties. Of these, diazepam (Valium™), lorazepam (Ativan™), and midazolam (Versed™) are most used to facilitate intubation. They have a relatively short time of onset when given intravenously. Compared to midazolam, diazepam and lorazepam have longer times of onset, less predictable dose–effect relationships, and longer elimination half-lives. They are also insoluble in water and are formulated in a propylene glycol diluent, which can produce a high rate of venous irritation as well as unpredictable absorption after intramuscular injection.[25] Midazolam, on the other hand, is water soluble at a low pH and therefore does not require propylene glycol. This decreases the incidence of erratic absorption after intramuscular injection and pain on injection.

Midazolam is the newest of the three drugs. It has become the standard choice for preinduction anxiolysis, sedation, and amnesia. Midazolam is well suited and widely used as an induction agent.[26] It may be administered alone or in combination with an opioid. There is considerable hypnotic synergy when midazolam is used in

combination with an opioid. The opioids provide excellent analgesia, which is a property lacking in midazolam.[2] When midazolam is used as the sole induction agent, recovery of consciousness takes longer than with thiopental, methohexital, etomidate, or propofol as a single agent. Midazolam is often used as a coinduction agent with ketamine or propofol, as it facilitates the onset of anesthesia without prolonging emergence times.[2] When combined with ketamine, midazolam attenuates ketamine's cardiostimulatory side effects as well as the incidence, severity, and recall of emergence reactions.[27]

PHARMACOKINETICS

Midazolam is formulated at a pH of 3.5, as it is water soluble in an acidic environment. At physiologic pH, it undergoes a molecular rearrangement that makes it highly lipophilic. It is 94% protein bound in the plasma. Unbound midazolam rapidly accumulates in the CNS, where it produces dose-dependent sedation or unconsciousness in 30 to 90 seconds. The drug redistributes less rapidly than many of the other hypnotics. This is reflected in the 10 to 30 minute duration of its CNS effects.[28] Midazolam is oxidized by the liver and excreted in the urine. Changes in hepatic blood flow can influence the clearance of midazolam.[29] Age has little effect on the elimination half-life.[29] Fentanyl has been shown to competitively inhibit the hepatic metabolism of midazolam in vitro and to decrease its clearance.[30]

MECHANISM OF ACTION

Benzodiazepines bind to a specific site on the alpha subunit of the $GABA_A$ receptor and enhance inhibitory neurotransmission. Midazolam has the greatest affinity for the receptor when compared to other benzodiazepines.[2] It has been proposed that the percentage of benzodiazepine receptor occupancy accounts for its effects. A 20% occupancy provides anxiolysis. A 30% to 50% occupancy causes sedation. Greater than 60% occupancy produces unconsciousness. It is unknown how the benzodiazepines produce amnesia.[2]

PHARMACODYNAMICS

Like thiopental and propofol, midazolam decreases $CMRO_2$ and CBF. Midazolam has a ceiling effect with respect to cerebral metabolism. The cerebrovascular response to carbon dioxide is unaffected by midazolam. It is also a potent anticonvulsant. Midazolam is a mild cardiodepressant and can decrease systemic vascular resistance.[28] The cardiac output and coronary blood flow are usually not affected by midazolam.[31] The drop in blood pressure is often masked by the sympathetic response to laryngoscopy. However, it may be pronounced in hypovolemic patients or in those who were given large doses.

Midazolam's respiratory effects also have a ceiling. It produces a mild and dose-dependent respiratory depression. In relatively healthy patients, the respiratory depression is insignificant. The respiratory depression is enhanced in patients with pulmonary disease. Hypoxemia is more frequent in patients who receive midazolam in combination with an opioid, such as fentanyl, than with either drug alone.[32]

ADMINISTRATION

An induction dose of midazolam is 0.2 to 0.4 mg/kg IV. When used as a coinduction agent, the dose of midazolam is reduced to 0.1 to 0.2 mg/kg. For sedation, the dose is 0.04 to 0.1 mg/kg IV. It can also be administered intramuscularly at a dose of 0.07 to 0.1 mg/kg when rapid onset is not required.[2] Doses may have to be lowered in older patients because sensitivity to the hypnotic effects of midazolam increases with age, independent of pharmacokinetic factors.[33]

ADVERSE EFFECTS

Midazolam has relatively few adverse effects. It is a mild cardiorespiratory depressant. When it is combined with an opioid, a synergistic respiratory depressant effect may result in hypoxemia, apnea, and death. Those patients receiving this combination should be monitored with pulse oximetry while being given supplemental oxygen.[32] Unlike diazepam, midazolam produces little venous irritation and pain upon injection. It may precipitate a psychotic episode in patients taking valproate. It does cross the placenta and is associated with birth defects, especially involving the lip and palate, when administered in the first trimester.[28]

OPIOIDS

Opioids produce dose-dependent analgesia, sedation, and respiratory depression by mimicking the effects of endogenous opiopeptins.[34] Morphine is the standard to which all opioids are compared. However, fentanyl (Sublimaze™) is the opioid of choice for use in the Emergency Department due to its rapid onset and short duration of action.[35] It has been in use since 1968 and its effects are well documented. **Unlike morphine, fentanyl is rarely associated with a significant release of histamine.**[36] Fentanyl has a remarkable hemodynamic stability profile.[36] If given in a large dose, fentanyl will produce anesthesia adequate for intubation. It is more often used as a sedative-analgesic or as a pretreatment adjuvant with one of the previously mentioned induction agents. Fentanyl is a synthetic opioid that is 50 to 100 times more potent than morphine. Structurally related to the phenylpiperidines, it is highly lipophilic and produces excellent short-term analgesia and sedation.[37]

Alfentanil (Alfenta™) is a structural derivative of fentanyl. It has a more rapid onset of action than fentanyl and half the duration of effect. Alfentanil is between one-sixth and one-ninth as potent as fentanyl. Its uses are analogous to those of fentanyl. It has been in use in the United States since 1982.[38] Recent data show alfentanil to be safe and effective for use in emergent rapid sequence intubation.[39] In cardiac patients, it was associated with a greater degree of cardiovascular depression than fentanyl.[40] Alfentanil is associated with a greater incidence of nausea and vomiting than fentanyl.[41] There are no data to suggest that alfentanil is more efficacious than fentanyl for use in the Emergency Department.

PHARMACOKINETICS

Upon intravenous injection, plasma fentanyl is 85% protein bound. Its lipophilic nature allows it to enter highly perfused tissues rapidly, including the brain, heart, and lungs. After a single bolus dose of fentanyl, effects may be seen in as little 10 seconds, and they peak in 3 to 5 minutes. Morphine's effects peak in 20 to 30 minutes. Fentanyl has a high affinity for adipose tissue and redistribution accounts for the cessation of effects, which can take up to 30 to 60 minutes. An equipotent dose of morphine has a duration of 3 to 4 hours. Redistribution of fentanyl from peripheral tissues to the central compartment after large or repeat doses may prolong its effects. Clearance of morphine and fentanyl is by hepatic metabolism. These drugs have a high extraction ratio, and changes in hepatic blood flow can influence the clearance of fentanyl.[38]

MECHANISM OF ACTION

Fentanyl binds to the μ (mu) opioid receptor found throughout the CNS. Activation of the opioid receptor causes hyperpolarization and inhibition of neurotransmitter release.[34] It has been suggested that fentanyl may also be a low-affinity NMDA receptor antagonist.[42]

PHARMACODYNAMICS

Fentanyl decreases CBF and cerebral oxygen consumption. In patients with head trauma, a relatively small dose (3 μg/kg) produced an elevation of ICP.[43] Although fentanyl has little effect on cardiac contractility, it may produce a mild reduction in the heart rate. Systemic vascular resistance and blood pressure may be slightly reduced, but they are usually unaffected in patients without cardiac pathology.[44] Respiratory depression induced by fentanyl is dose dependent. The respiratory rate first decreases, followed by the tidal volume and subsequent apnea. The patient's response to hypercarbia is blunted when sedated with fentanyl.[45]

ADMINISTRATION

Fentanyl can be used in several ways to facilitate emergency intubation. Given purely for analgesia, as little as 3 to 5 μg/kg IV over 2 minutes may allow for an awake intubation. For adults, incremental doses of fentanyl from 25 to 50 μg can be titrated to produce the desired effect.[37] Fentanyl has a more stable hemodynamic profile during rapid sequence induction than either thiopental or midazolam.[35] In hemodynamically unstable patients and those with poor cardiac reserve, 5 to 15 μg/kg of fentanyl may be used as the sole induction agent.[35]

The most prudent role for fentanyl is as an adjunct to an induction agent. Three minutes prior to intubation, premedication with 2 to 4 μg/kg of fentanyl IV over 2 minutes provides excellent analgesia and attenuates the transient hypertension and tachycardia associated with laryngoscopy and intubation.[46] Although lidocaine and β-blockers have also been shown to blunt the pressor response, opioids are more effective and reliable and do not produce rebound hypotension and bradycardia.[47,48]

ADVERSE EFFECTS

Other than the respiratory depression that is common to all opioids, fentanyl has relatively few adverse side effects. Although it may produce nausea and vomiting, this side effect is relatively uncommon when compared to other opioids such as morphine.[37] Fentanyl is not associated with a significant release of histamine, which is reflected in its hemodynamic stability. Muscular rigidity involving the chest wall and diaphragm may occur, making ventilation difficult. This happens more often at higher doses, typically greater than 15 μg/kg, and may be prevented or relieved by neuromuscular blockade or by opioid antagonism with naloxone.[49] Myoclonic movements may occur, but these do not reflect seizure activity on the EEG. As with all opioids, biliary colic and urinary retention are associated with fentanyl administration.[37]

NEUROMUSCULAR BLOCKING AGENTS

Neuromuscular blockade is an integral part of the rapid sequence induction and intubation protocol. The combination of a paralytic agent and a sedative or an analgesic is superior to the use of any single agent. The use of a neuromuscular blocking (NMB) agent to facilitate intubation provides for control of the airway and better visualization of the vocal cords than does sedation without paralysis.[50] It is also well documented that, in the Emergency Department setting, rapid sequence induction with an NMB agent allows for faster intubations with fewer complications than sedation alone.[1] **The use of a sedative without a NMB should be reserved for the awake oral intubation of a patient with a difficult airway.**

NMBs are classified as either depolarizing or nondepolarizing, depending on their action at the nicotinic acetylcholine receptor of the motor end plate. The optimal NMB agent has a rapid onset of action, a predictably short duration of action, and no side effects. As with induction agents, the optimal NMB agent has yet to be found. Until a better agent is developed, succinylcholine (Anectine™) remains the standard NMB agent for Emergency Department intubations.[51]

SUCCINYLCHOLINE

Succinylcholine is the only depolarizing NMB agent in clinical use. Introduced in 1952, it is a chemical combination of two acetylcholine molecules. **It is the most widely used NMB in the Emergency Department because its onset of action is faster and its duration of action is shorter than that of any other NMB agent. This is particularly important in patients who cannot be intubated after neuromuscular blockade and where the resumption of spontaneous respirations is vital.**

PHARMACOKINETICS

After a paralytic dose of succinylcholine, adequate intubating conditions are usually achieved in 60 seconds.[53] The duration of apnea following a single dose of succinylcholine is 3 to 5 minutes and reflects the rapid degradation of the drug by pseudocholinesterase, also known as plasma cholinesterase or butyrylcholinesterase.[53] Repeated doses or infusion of succinylcholine may produce tachyphylaxis, prolonged paralysis, and repolarization of the neuromuscular membrane, a condition referred to as phase II block.[53] If this condition develops, it can be partially reversed by administration of an anticholinesterase agent, similar to the reversal of a nondepolarizing block. **If paralysis of greater than 3 to 5 minutes is desired, a nondepolarizing agent can be administered after the patient is intubated.**

MECHANISM OF ACTION

The structure of succinylcholine allows it to bind noncompetitively to acetylcholine receptors, causing depolarization of the postjunctional neuromuscular membrane. This initial depolarization is seen as a brief period of muscle fasciculation following the administration of the drug. Unlike acetylcholine, which is hydrolyzed within milliseconds, succinylcholine remains intact for several minutes. It produces paralysis by occupying the acetylcholine receptors, and making the motor end plates refractory, so that muscle contraction cannot occur. Muscle relaxation proceeds from the distal muscles to the proximal muscles, and thus the diaphragm is one of the last muscles to become paralyzed.[52]

PHARMACODYNAMICS

Succinylcholine is rapidly hydrolyzed by plasma pseudocholinesterase to succinylmonocholine. Only a small fraction of the IV administered dose reaches the neuromuscular junction. Succinylmonocholine, which also has some neuromuscular blocking properties, is further hydrolyzed to succinic acid and choline. These end products are rapidly taken up by cells and reused in various biochemical molecules. The rapid degradation of succinylcholine provides a concentration gradient that causes the diffusion of succinylcholine away from the acetylcholine receptors and allows repolarization of the myocyte membrane.

In patients with atypical pseudocholinesterase enzyme, a genetic variant with autosomal semidominant transmission, the duration of action of succinylcholine is markedly prolonged due to decreased enzyme activity. In patients homozygous for the atypical allele, a condition that occurs with an incidence of 1 in 3200, a single intubating dose of succinylcholine may last up to 8 hours.[53]

ADMINISTRATION

The recommended dose of succinylcholine to produce optimal intubating conditions is 1.0 to 1.5 mg/kg IV bolus in adults and 1.5 to 2.0 mg/kg in infants, with the twofold increased dose in this

population explained by their higher volume of distribution.[53,83] This dose should be increased by 50% in patients who have received a defasciculating dose of a nondepolarizing neuromuscular blocker (see below under "Adverse Effects" section) prior to the administration of succinylcholine.[53] Intramuscular administration is also possible, which may become important for use in an emergency when control of the airway is necessary and the patient has no IV access. The intramuscular dose is two to four times the IV dose.[54]

ADVERSE EFFECTS

Although relatively uncommon, a number of potential adverse effects are associated with the administration of succinylcholine. These include muscular fasciculations and myalgia, autonomic stimulation, histamine release, prolonged apnea, elevated intracranial and intraocular pressure, hyperkalemia, and malignant hyperthermia.[53] **The use of succinylcholine is recommended for rapid sequence induction and intubation as the risk of a compromised airway far outweighs the potential harm from these side effects.**

The fine, chaotic muscle contractions that are often observed at the onset of paralysis are associated with several side effects, most commonly myalgia, but also increased intraocular pressure (IOP), increased intracranial pressure (ICP), and increased intragastric pressure. Muscle pain 24 to 48 hours after the administration of succinylcholine is most prominent in young, muscular men, while it is unlikely in children, the elderly, and those with undeveloped or diminished muscle mass. Muscle fasciculations may be prevented by the administration of a defasciculating dose (10% of the paralytic dose, a phenomenon known as "precurarization") of a nondepolarizing NMB agent given 3 to 5 minutes prior to the succinylcholine.[55]

Increased ICP may also occur with the use of succinylcholine. While the magnitude and clinical significance of this increase remains unclear, defasciculation with a nondepolarizing NMB agent has been shown to prevent this rise in ICP.[58]

To omit the use of a paralyzing agent entirely during the rapid sequence induction of patients with penetrating eye injuries or intracranial pathology for fear of the potential increase in IOP or ICP is a decision that must be made for each individual patient. Any attempt to intubate a nonparalyzed, lightly anesthetized patient could result in gagging or "bucking," which has been shown to increase both IOP and ICP far more than that which would be achieved from an intubating dose of succinylcholine. In most patients, muscle fasciculations are benign and precurarization is unnecessary. In patients with eye injuries or suspected intracranial pathology, however, it is prudent to either use a nondepolarizing NMB agent or utilize precurarization with succinylcholine to prevent worsening of an injury to these areas.[56] Rocuronium is a nondepolarizing agent that has been shown to significantly decrease IOP during rapid sequence induction.[57] Its use may be indicated in patients with penetrating eye injuries.[57]

Increased intragastric pressure, which is also lessened by precurarization, may increase the risk of aspiration. On the other hand, succinylcholine favorably increases the tone of the lower esophageal sphincter, which may mitigate the risk of aspiration.[59] Regurgitation of stomach contents during intubation is more likely the result of distention from overzealous mask ventilation.

Succinylcholine binds to acetylcholine receptors throughout the body, including those of the autonomic ganglia. Succinylcholine may have direct muscarinic effects on the heart. It is difficult to characterize a specific cardiovascular effect typical of succinylcholine. It may produce tachycardia, bradycardia, or dysrhythmias.[53] Children are particularly susceptible to bradycardia following succinylcholine administration. It is recommended that all children be given 0.01 mg/kg IV of atropine prior to administration of succinylcholine.[54]

Prolonged apnea following succinylcholine is a sign of decreased plasma pseudocholinesterase levels. This may occur in patients with hepatic disease, anemia, renal failure, cancer, connective tissue disorders, pregnancy, cocaine intoxication, genetically deficient enzyme activity, or taking cytotoxic drugs. In most cases, apnea rarely exceeds 20 minutes.[60]

Succinylcholine may produce an increase in serum potassium level, which is typically less than 0.5 meq/L. It should be used with caution in patients with significant hyperkalemia. Its use is not contraindicated in patients with renal failure, but caution must be taken if their serum potassium level is elevated. It has been associated with cases of massive hyperkalemia (>5 meq/L) and cardiac arrest in patients who have had digoxin toxicity, myasthenia gravis, massive muscle trauma, crush injuries, severe burns, and major nerve or spinal cord injury at least 1 week prior to receiving succinylcholine.[53] In such patients, succinylcholine should not be used starting 24 hours after the insult.

MALIGNANT HYPERTHERMIA

Malignant hyperthermia (MH) is an extremely rare and life-threatening autosomal dominant condition that can develop following exposure to certain inhaled anesthetics and/or succinylcholine in genetically susceptible individuals. It is characterized by intense, sustained skeletal muscle contraction leading to severe acidosis, rhabdomyolysis, hyperthermia, hyperkalemia, arrhythmias and, if left untreated, death. The triggering exposure is not dose-dependent, can occur following any single dose or combination of offending agents, and may occur even in individuals who have been exposed to the agents in the past without an adverse effect. The incidence of MH during anesthesia is estimated to be 1 in 15,000 in children and 1 in 50,000 in adults.[82] **Although it is most notoriously characterized by a rapid elevation in temperature, the earliest signs of the condition are usually profound tachycardia, tachypnea, and generalized skeletal muscle rigidity.** Laboratory blood analysis reveals severe respiratory and metabolic acidosis, hyperkalemia, and elevation of serum creatine kinase.

Early and aggressive treatment is the key to patient survival. This involves active cooling measures, volume resuscitation, correction of acid–base and electrolyte disturbances, and rapid administration of dantrolene (2 to 3 mg/kg IV bolus with additional increments up to 10 mg/kg).[53,82] Dantrolene sodium is a muscle relaxant that is supplied as a lyophilized powder in 20 mg vials. Prior to administration, each vial must be reconstituted with 60 mL of water.[82] **It is emphasized that rapid and early administration of dantrolene is important to abort the reaction and greatly increases the chance of survival.** Dantrolene administration should be continued until all signs of MH have stabilized. Admit the patient to the intensive care unit for observation of any recurrence following the acute phase.

Isolated masseter muscle rigidity is a benign side effect in most cases. It has been reported mainly in children receiving succinylcholine. In several reported cases of fatal malignant hyperthermia, however, masseter muscle rigidity was the first sign of an abnormal reaction.[61] **Masseter rigidity occur following the administration of succinylcholine requires the patient to be closely monitored for other signs of MH.**

Patients of families with MH, those with suspected reactions, and other selected high-risk patients can undergo a muscle biopsy test known as the caffeine-halothane contracture test, which carries a 100% sensitivity and 85% to 90% specificity for MH susceptibility.[82] Patients who develop suspected MH reactions should be referred immediately to their primary physicians for testing and follow-up, as documented positive susceptibility and patient education could prevent a future potentially lethal exposure to offending agents.

Despite the lengthy list of potential adverse effects, the benefits of intubation with a rapidly acting and short-lasting paralytic agent such as succinylcholine provide the safest conditions for

intubation in the Emergency Department. If prolonged paralysis is required in an agitated patient, a nondepolarizing agent should be administered for maintenance following intubation with succinylcholine.

NONDEPOLARIZING AGENTS

Nondepolarizing NMB agents act by competitive inhibition of the acetylcholine receptors at the motor end plate. They weakly bind to the receptor and block the binding site for acetylcholine without producing any effect on the postsynaptic neuromuscular membrane. Following the kinetics of competitive inhibition, this blockade is dependent on the relative concentrations of acetylcholine and NMB available in the synaptic cleft. As the ratio returns in favor of acetylcholine, normal neuromuscular transmission is restored. Thus, return of muscle function can be hastened by the use of a cholinesterase inhibitor such as neostigmine or edrophonium, but only after some muscular contraction can be observed. Nondepolarizing agents have not only the potential for reversal, but also for fewer side effects than succinylcholine. Their longer time to onset and much longer duration of action make them less useful for rapid sequence induction, especially in the Emergency Department.[53]

Nondepolarizing NMB agents can be grouped by chemical structure. The steroid-based agents include pancuronium, vecuronium, and rocuronium. The oldest nondepolarizing agent, d-tubocurarine, is a benzylisoquinoline, as are atracurium, cisatracurium, and mivacurium.[53] Pancuronium, vecuronium, and rocuronium have been extensively studied for use in rapid sequence intubation.[62] Of these, rocuronium (Zemuron™) has become established as the nondepolarizing NMB of choice for rapid sequence induction in situations where succinylcholine is contraindicated. For this reason, rocuronium is discussed separately from the other nondepolarizing NMB agents.

ROCURONIUM

When succinylcholine is contraindicated, rocuronium has been used at a dose of 1.2 mg/kg. This dose is twice the standard intubating dose to yield an onset of action in approximately 60 seconds and intubating conditions that are comparable to succinylcholine.[72] This has been demonstrated both in adult and pediatric populations.[72,84] It should be noted, however, that at this increased dosage, the duration of action is also prolonged to greater than 1 hour, which far exceeds the 3 to 5 minutes provided by succinylcholine.[53,63] The nondepolarizing, competitive blockade produced by rocuronium cannot be immediately reversed by anticholinesterases such as neostigmine until a partial competitive antagonism by acetylcholine has taken place naturally at the motor end plate. This may take an average of 20 minutes to occur, and must be measured by the return of muscular twitch using a neuromuscular twitch monitor, a device often used by anesthesia personnel in the operating room to monitor the level of intraoperative motor blockade.[84] Therefore, should unexpected difficulties with intubation or ventilation be encountered, it is recommended that the practice of using high-dose rocuronium during rapid sequence induction be limited in the Emergency Department as much as possible. Should all attempts at intubation and ventilation fail, staff experienced in the attainment of a surgical airway must be immediately available.

PHARMACOKINETICS

Rocuronium is eliminated primarily by the liver and <10% by the kidneys.[53] Its duration of action, therefore, is significantly prolonged in liver failure and only slightly in renal failure. There are no active metabolites, making it a good choice for prolonged infusions. Nondepolarizing NMB agents as a class are highly ionized, water-soluble compounds that cannot easily cross lipid membranes such as the blood–brain barrier and the placenta. As a result, they have no central nervous system effects and do not affect the fetus when administered to pregnant women.[53]

MECHANISM OF ACTION

Rocuronium binds nicotinic acetylcholine receptors at the neuromuscular end plate and, once bound, it is unable to induce the conformational change necessary to open the ion channels and allow subsequent depolarization. This results in a competitive and antagonistic block.

PHARMACODYNAMICS

Several drugs including volatile anesthetics, aminoglycosides, magnesium, lithium, dantrolene, and certain antiarrhythmics will augment the neuromuscular blockade produced by nondepolarizers. In contrast, corticosteroids, certain anticonvulsants, and calcium will diminish their effect. Patients with myasthenia gravis, Lambert–Eaton myasthenic syndrome, and Duchenne's muscular dystrophy exhibit varying sensitivity to nondepolarizing neuromuscular blockers. Burn patients, on the other hand, are resistant to their effects. Careful titration of dosages, dosing intervals, and infusion rates are necessary in these patient populations.

ADMINISTRATION

Rocuronium is administered at a usual intubating dose of 0.6 mg/kg, providing a clinical duration of roughly 45 minutes. Rapid sequence induction with rocuronium is most rapidly achieved with a dose of 1.2 mg/kg and is associated with an accompanying increase in duration. Following intubation, maintenance of paralysis can be achieved with intermittent 0.1 mg/kg boluses or by infusion rates of 5 to 12 mcg/kg/min, titrated to effect.

ADVERSE EFFECTS

Other than the potential for a severe anaphylactic reaction in allergic patients, rocuronium is essentially devoid of any serious side effects. This should not be taken lightly, however, as neuromuscular blocking drugs are responsible for >50% of all life-threatening anaphylactic or anaphylactoid reactions occurring during anesthesia administration.[53] While succinylcholine is the most common offending agent, the nondepolarizers are the second.

As a class, the steroidal nondepolarizers possess varying degrees of vagolytic activity and, fortunately, are not associated with histamine release. The vagolytic action of rocuronium is weak and rarely of clinical significance. This is in contrast to pancuronium, another steroidal nondepolarizer, which can cause significant tachycardia following administration. Patients may report pain on injection of rocuronium due to venous irritation. This may be reduced by prior administration of IV lidocaine, but is usually not a problem as patients are unconscious or sedated at the time of rocuronium injection.

OTHER NONDEPOLARIZING AGENTS

Pancuronium, in use since 1972, is classified as a long-acting, bisquaternary steroidal nondepolarizing agent. At a dose of 0.08 to 0.12 mg/kg, it produces paralysis in 2 to 5 minutes and lasts approximately 60 to 90 minutes. Following intubation, supplemental doses of 0.02 mg/kg can be given intermittently to maintain paralysis.[53] Its use is associated with an increased heart rate, blood pressure, and cardiac output through a postganglionic vagolytic effect. It is not associated with the release of histamine. An estimated 80% to 85% of a dose of pancuronium is eliminated unchanged in the urine. Therefore, in patients with renal failure its duration may be significantly prolonged.[53] Pancuronium's low cost and familiarity have

made it popular, but its slow onset of action and extended duration limit its usefulness in facilitating emergent endotracheal intubation.

Removing a quaternary methyl group from pancuronium yields vecuronium, a monoquaternary steroidal nondepolarizer. This small change does little to affect potency, but favorably alters the side effect profile of the drug, most notably the vagolytic action. Similar to rocuronium, the vagolytic effects of vecuronium are negligible and do not cause histamine release. This molecular change also alters the metabolism and excretion of the drug when compared with pancuronium. Vecuronium is metabolized to a small extent by the liver and depends primarily on biliary excretion and secondarily on renal excretion. Vecuronium is unstable in solution. It is prepared as a lyophilized powder that must be hydrated prior to use.

The normal intubating dose of vecuronium (0.1 mg/kg) takes 3 minutes to produce adequate paralysis for intubation, and the patient will remain apneic for 30 to 35 minutes. Although it can produce good intubating conditions within 1 minute at 2.5 times the normal dose, this unfortunately results in paralysis for 1 to 2 hours. Maintenance of paralysis can be achieved with boluses of 0.02 mg/kg. The most troublesome side effect of this drug is prolonged paralysis (up to several days) following an infusion, a side effect attributed possibly to accumulation of its active 3-hydroxy metabolite.[53]

Rapacuronium is a newer nondepolarizing NMB agent with onset times and duration of action similar to those of succinylcholine. It was developed as a replacement for succinylcholine in the rapid sequence protocol. Due to reported incidences of fatal bronchospasm in patients, rapacuronium was voluntarily withdrawn from the US market by its manufacturer in March, 2001. At present, succinylcholine is firmly in place as the muscle relaxant of choice for rapid sequence emergency intubations.[64]

MISCELLANEOUS AGENTS

LIDOCAINE

Lidocaine is a local anesthetic agent that, in low doses, has an antiarrhythmic effect on the heart. At a dose of 1 to 2 mg/kg IV, it also attenuates the increase in ICP and the hypertensive and tachycardic response associated with laryngoscopy.[65–68] It does not affect myocardial contractility in therapeutic doses. Lidocaine is usually administered to patients in which the increases in ICP, heart rate, and blood pressure associated with direct laryngoscopy are undesirable.

ATROPINE

Atropine is a rapidly acting muscarinic acetylcholine receptor antagonist with significant vagolytic effect. It is commonly used as part of the Advanced Cardiac Life Support (ACLS) protocol during resuscitation of patients in cardiac arrest and those with symptomatic bradycardia at doses of 1.0 mg and 0.50 mg IV, respectively. During rapid sequence induction of children using succinylcholine, atropine is given to prevent significant bradycardia and possibly asystole, which may occur in this population much more frequently than in adults.[73] The dose is 0.01 mg/kg IV with a minimum dose of 0.10 mg IV and a maximum dose of 0.40 mg IV. Atropine has a secondary antisialagogue effect of reducing secretions produced in the respiratory tract and the salivary glands.

Atropine crosses the blood–brain barrier and overdoses may lead to central atropine intoxication, referred to as the central anticholinergic syndrome. This is characterized by agitation, restlessness, confusion, and hallucinations that may progress to stupor, seizures, and coma. Provide supportive treatment, including seizure prophylaxis and possibly mechanical ventilation. Reversal of this life-threatening condition can be achieved with IV physostigmine, an anticholinesterase agent with the ability to cross the blood–brain barrier.

GLYCOPYRROLATE

Glycopyrrolate is a quaternary amine of the muscarinic anticholinergic class. Compared to atropine, it possesses significantly less of a vagolytic effect, but greater antisialagogue effects. This makes it the drug of choice for premedication to reduce pharyngeal and tracheobronchial secretions. Glycopyrrolate does not easily cross the blood–brain barrier due to its quaternary ammonium structure, making the occurrence of central anticholinergic side effects much less likely. It should not be administered to neonates due to the benzyl alcohol component, which can cause significant adverse effects. The recommended antisialagogue dose of glycopyrrolate is 0.004 mg/kg IM given 30 to 60 minutes prior to the procedure. It may be administered intravenously in boluses of 0.1 mg every 2 to 3 minutes as needed until the desired effect. In the Emergency Department, one or two doses are typically required during procedural sedation as an adjunct to prevent ketamine's effect of increasing respiratory tract secretions.

Glycopyrrolate is routinely administered with anticholinesterase medications during reversal of nondepolarizing neuromuscular blockade to counteract the unwanted side effects of bradycardia, bronchoconstriction, and intestinal hypermotility that accompany the ensuing increase in cholinergic activity. Specifically, it is administered along with neostigmine and pyridostigmine at a dose of 0.2 mg IV of glycopyrrolate for each 1 mg of neostigmine or 5 mg of pyridostigmine. When given IV, the onset is usually within 1 minute and the duration of the vagolytic and antisialagogue effects are 2 to 3 hours and up to 7 hours, respectively.

DEXMEDETOMIDINE

Dexmedetomidine is a new centrally acting alpha$_2$-adrenergic agonist similar to clonidine, but with more selectivity for the alpha$_2$ receptor. It causes dose-dependent sedation and anxiolysis and blocks the sympathetic response to stress and airway manipulation. For this reason, it is increasingly being used with much success as an adjunct to awake fiberoptic intubations. Its main indication, however, is for sedation of intubated and mechanically ventilated patients in the intensive care unit, especially around the time of planned extubation when other IV sedatives have been discontinued. Patients remain calm and sedated when left alone, but are readily arousable when stimulated and follow commands. Dexmedetomidine causes little to no respiratory depression.[70,71] The main side effects of the drug are hypotension and bradycardia. Dosing consists of an initial loading dose of 1 mcg/kg IV over 10 minutes followed by an infusion of 0.2 to 0.7 mcg/kg/h, titrated to the desired level of sedation.[69] Its half-life is about 6 minutes following infusion due to rapid redistribution. This short half-life has the potential for its use in the Emergency Department for awake intubations.

SUGAMMADEX

Sugammadex (Bridion™, Schering-Plough) is a novel agent that can terminate the neuromuscular block associated with rocuronium, vecuronium, and pancuronium.[85–91] It is a cyclodextrin, or a cyclic oligosaccharide carbohydrate, that is formed from the degradation of starch. It has a hydrophobic core surrounded by a hydrophilic outer rim. The hydrophobic core can trap other hydrophobic substances and solubilize them. Cyclodextrins administered intravenously are not metabolized and are excreted by the kidney.

Sugammadex is the first agent of its class. It has an affinity for the aminosteroid nondepolarizing NMB agents. Its affinity is strongest for rocuronium, followed by vecuronium then pancuronium. It binds rocuronium in a 1:1 fashion to decrease rocuronium plasma concentrations. Bound rocuronium cannot gain access to the motor endplate and cause paralysis. The reversal of the neuromuscular

block results from the binding of plasma rocuronium and the rapid movement of rocuronium from peripheral sites to the plasma to maintain an equilibrium. The sugammadex–rocuronium complex is excreted in the urine.

A variety of adverse events have been reported with the use of sugammadex.[86] These include anaphylactic reactions, back pain, bronchospasm, cough, constipation, fever, headache, hypersensitivity reactions, procedural hypotension and hypertension, prolonged QT intervals, and vomiting. It binds to bone and teeth, but the effect of this is not fully known, especially in growing children. There is the possibility that sugammadex binds to and decreases plasma levels of other drugs with a steroid-based structure such as hormones, oral contraceptives, and some antibiotics among others.

Sugammadex has the potential for significant use in the Emergency Department. The biggest concern with using rocuronium for intubation is the length of time a patient is paralyzed if they cannot be intubated. The development of sugammadex can provide a "safety net" to reverse rocuronium's effects if a patient cannot be intubated. This agent may eventually allow rocuronium to become the NMB agent of choice for rapid sequence intubation in the Emergency Department.[88,89]

Sugammadex is currently approved for use in numerous countries. Unfortunately, it is not available in the United States.[92] After an expedited review, the FDA's Anesthetic and Life Support Advisory Committee unanimously recommended approval of sugammadex in March 2008.[86] In August 2008, the FDA rejected approving this drug due to concerns regarding allergic reactions, hypersensitivity reactions, and anaphylactic reactions. At the time of this writing, sugammadex is still not approved by the FDA. Research is continuing on this drug with the hope of FDA approval in the near future.

SUMMARY

Numerous pharmacologic agents are available to sedate, relax, and paralyze a patient in preparation for intubation. These same agents are used in lesser doses to maintain postintubation sedation and paralysis as well as for procedural sedation. There is no ideal sedative or paralytic agent. The combination of lesser doses of several agents, depending on the patient's condition, will maximize the positive effects and minimize the adverse effects of each individual drug. This requires Emergency Physicians to become familiar with several drugs in each class, so that they may choose the appropriate combination for each patient.

9 Endotracheal Medication Administration

Shoma Desai

INTRODUCTION

Healthcare providers are charged with the primary goal of optimizing the oxygenation, ventilation, and the hemodynamic status of the patient during a resuscitation. In most cases, the first definitive intervention is to secure the airway through endotracheal (ET) intubation. The establishment of access to the systemic circulation soon follows. **Vascular access in certain patients can be problematic. In such cases, the ability to administer medications endotracheally can be life saving.**

Bernard first reported the ET route of medication administration in 1857, describing the alveolar absorption of curare in dogs. This discovery was followed by the observation that ET instilled salicylates appeared in the urine (Peiper 1884). In 1897, Washitzky studied the ET application of strychnine, atropine, chloral hydrate, and potassium iodide.[1]

The first suggestion for using the ET route for the therapy of pulmonary disease was in 1915.[2] This idea evolved, culminating in a study in 1937, which recommended the use of inhaled epinephrine in asthmatics.[3] The rapidity of pulmonary absorption was eventually utilized for resuscitation purposes 1967. This study demonstrated the equality of the intratracheal, intravenous (IV), and intracardiac routes of epinephrine administration in resuscitating hypoxia-induced cardiorespiratory arrest in dogs. This study began the utilization of the ET route for medication administration in emergent clinical situations.

ANATOMY AND PATHOPHYSIOLOGY

Most experiments involving ET medication administration are conducted on subjects with normal cardiovascular function. Thus, there are still many questions remaining about the utility of this route in patients with cardiopulmonary arrest. While the alveolar-capillary membrane is a highly absorptive surface, numerous factors can undermine this potential. These include reduced pulmonary blood flow (less than 30% of normal during CPR), ventilation–perfusion mismatch, and compromised alveolar absorption (e.g., pulmonary edema and pneumonia) in cardiopulmonary arrest.[5–7]

During a cardiopulmonary arrest, ET administered medications are absorbed in a protracted manner. This phenomenon, termed the "depot effect", is observed in laboratory and clinical experiments.[5] Studying ET administered lidocaine (2 mg/kg) in nonarrest patients revealed a biphasic pattern of absorption, an initial immediate peak, and a second higher peak approximately 24 minutes later.[8] Plasma lidocaine levels were still measurable 120 minutes postinstillation.[8] In addition to the altered physiologic conditions of cardiopulmonary arrest as described above, local vasoconstriction induced by epinephrine may contribute to this "depot effect."[9] The relatively low initial plasma medication levels and then the subsequent extended plateau of plasma medication levels are also exhibited by the ET administration of atropine, epinephrine, and vasopressin.[5,10]

MEDICATION DOSE

The American Heart Association (AHA) suggests an ET medication dose of 2 to 2.5 times the recommended IV dose (Table 9-1).[11] The optimal dose of ET administered medications is unknown. While there is a consensus that IV doses given endotracheally result in subtherapeutic plasma levels, the equipotent dose ranges from 3 to 10 times the IV dose in the literature.[12–42]

Many studies have noted the inadequacy of the currently recommended dose of epinephrine and atropine in cardiopulmonary arrest models.[27,31,36] Niemann and Stratton retrospectively reviewed 136 adult medical arrests, both primary and secondary asystole, with less than 10 minutes to definitive care. The rates of response (positive rhythm) and return of spontaneous circulation were significantly greater in the IV medication group than both the ET medication group and the no therapy group.[27]

TABLE 9-1 Recommended Endotracheal Medication Doses[2,11]

Medication	Adults	Pediatrics	Neonates
Atropine	2–2.5 mg	0.03 mg/kg	Unknown
Epinephrine	2–3 mg (1:10,000)	0.1 mg/kg (1:1000) (or 0.1 mL/kg)	0.01–0.03 mg/kg (1:10,000)
Lidocaine	2–3 mg/kg	2–3 mg/kg	Unknown
Naloxone	0.8–2 mg	<5 y or ≤ 20 kg: 0.1 mg/kg ≥5 y or >20 kg: 2 mg	0.1 mg/kg
Vasopressin	80 units	Unknown	Unknown

A recent discussion in the literature has drawn attention to the behavior of epinephrine when given at suboptimal doses. Epinephrine is used in arrest situations for its α-adrenergic effects. The β-adrenergic effects predominate when epinephrine is administered in small doses. This can transiently result in potentially harmful hypotension, decreased coronary perfusion pressure, and the diminished likelihood of return of spontaneous circulation.[11] Manisterski et al. documented an early drop in mean arterial blood pressure with prolonged tachycardia after ET epinephrine at doses of 0.02, 0.035, 0.1, and 0.2 mg/kg in healthy dogs.[28] Only the 0.3 mg/kg dose was effective in achieving an increase in blood pressure without a transient drop.[28] Findings such as this have prompted investigations on pretreatment with β-blockers (e.g., propranolol) prior to ET epinephrine administration, which does blunt the early β-effects.[29,30] Although more research is needed in this area, these studies do question the efficacy of the current recommended ET epinephrine dose, calling for higher ET doses.

Despite these results, concerns regarding the "depot effect" have kept the current ET medication dose recommendation at 2 to 2.5 times the IV dose. This is to avoid the prolonged side effects in the critical postresuscitation period.[5] This compromise leads to many uncertainties regarding the effectiveness and reliability of the ET route for medication administration.[9,31,32]

DILUENT

A primary goal in administering ET medications is to achieve rapid absorption. This goal can be reached with larger volumes of diluent, but is tempered by the potentially detrimental effects on pulmonary function.[4] **The current recommended volumes for ET instillation of each medication are dilution to a total volume of 10 mL in adults, 5 mL for children, and 1 mL for neonates.**[11,26]

Another controversy arises with respect to the type of diluent used. Distilled water and 0.9% saline have been utilized for ET medication administration and are currently recommended by the AHA.[11] In theory, water creates a greater osmotic gradient to potentially speed up medication absorption. This could also lead to a greater disruption of pulmonary surfactant, thereby hindering gas exchange.[5] This has been confirmed in nonarrest experiments using dogs.[33] It was later disputed utilizing much smaller volumes (2 and 10 mL) of instilled medication.[34,35] These studies found that distilled water provides more rapid and more effective absorption (higher peak serum medication levels) than 0.9% saline without a physiologically significant drop in PaO_2.

PEDIATRIC CONSIDERATIONS

Much of the debate regarding ET medication administration still exists in pediatrics. While approximately half of pediatric arrests are resuscitated without the use of medications, resuscitation drugs may be required to achieve return of spontaneous circulation. Obtaining vascular access in children, especially in neonates, can be extremely difficult. This makes the ET medication administration route a possible option for early resuscitative efforts.[37] There are no published pediatric or neonatal studies examining the type or volume of diluent, only consensus recommendations.[11,26]

A major difference between adults and children in arrest is the absorptive capacity of the immature lung. In particular, the surface area is smaller, the diffusion coefficient is larger, and there exists the potential for right to left shunts in children.[9,38] These conditions greatly affect an already unreliable absorptive process.

The indications, procedures, and complications are considered to be much the same in pediatrics as in adults. There are very few published studies focused on ET medication administration in pediatrics. Those that studied epinephrine in pediatric arrest agree that it seems to take 10 times the IV medication dose to achieve appropriate serum epinephrine levels and responses in the heart rate and blood pressure.[26,38,39] A retrospective study of neonates who received epinephrine in the delivery room underscores the difficulty of obtaining vascular access.[40] Almost all the neonates (94%, $n = 52$) received their first dose of epinephrine via the ET route. Of these, 32% obtained return of spontaneous circulation while the rest required additional epinephrine through their IV line once it was established. The authors concluded that the currently recommended ET epinephrine dose of 0.01 to 0.03 mg/kg is ineffective.

INDICATIONS

The ET administration of medications is reserved for resuscitations in which vascular access (i.e., IV or intraosseous (IO)) is delayed.[11] This may apply to the resuscitation of any patient with cardiovascular collapse. The ET route may be more frequently encountered in certain patient populations traditionally associated with difficult vascular access such as neonates, the obese, cancer patients, sickle cell patients, IV drug abusers, burn patients, and dialysis patients.[12] **The goal is to increase the probability of successful resuscitation despite a delay in obtaining definitive systemic vascular access.**

The ET route is recommended for the administration of lidocaine, epinephrine, atropine, naloxone, and vasopressin.[11] Other medications that can be administered but are not widely used include flumazenil, diazepam, midazolam, penicillins, sulfonamides, and aminoglycosides.[13–17]

CONTRAINDICATIONS

The absorption of medications given through an ET tube is unpredictable during a cardiopulmonary arrest. The only contraindication to ET medication administration is the patient having IV or IO access. The ET route may be used initially until IV or IO access is established.

EQUIPMENT

- ET tube, standard or specialty ET tube
- Bag-valve device
- Medication to be administered
- Diluent, 0.9% normal saline or distilled water
- 10 mL syringe
- 18 gauge needle
- IV adapter lock
- Water-soluble lubricant
- Optional catheters (suction, feeding, or central venous)

The patient may be intubated with a standard ET tube, an ET tube with a monitoring lumen, or a specialty ET tube with a medication injection port.[18] The EDGAR ET tube (endobronchial drug and gas application during resuscitation, Rusch, Germany) has a separate injection channel that terminates at the tip of the ET tube. This ET tube is currently available in Europe, but not in the United States. The Stat-Med ET tube (Hudson RCI, Temecula, CA) has a separate injection port and channel that terminates distal to the inflated cuff (**Figure 9-1**). These two ET tubes allow the ET administration of medications without interrupting CPR compressions or ventilation.

The LITA ET tube (Hudson RCI, Temecula, CA) is a modification of the Stat-Med ET tube. Like the Stat-Med, it has a separate injection port and channel. The channel has eight openings above the cuff and two below the cuff. This ET tube was designed for use with local anesthetic solutions to anesthetize the tracheal mucosa. It should not be used to administer resuscitation medications. They will mostly pool above the cuff in the trachea and not get properly absorbed.

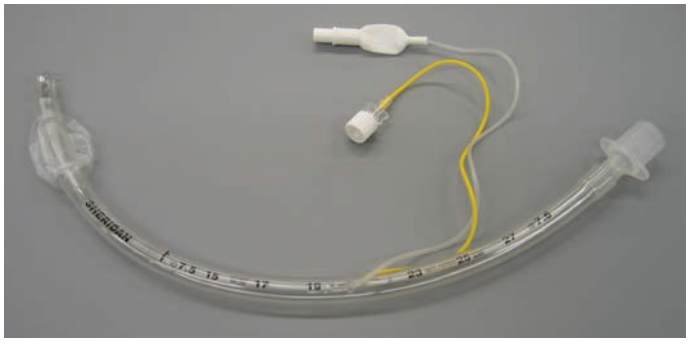


FIGURE 9-1. The Stat-Med tube (Hudson RCI, Temecula, CA).

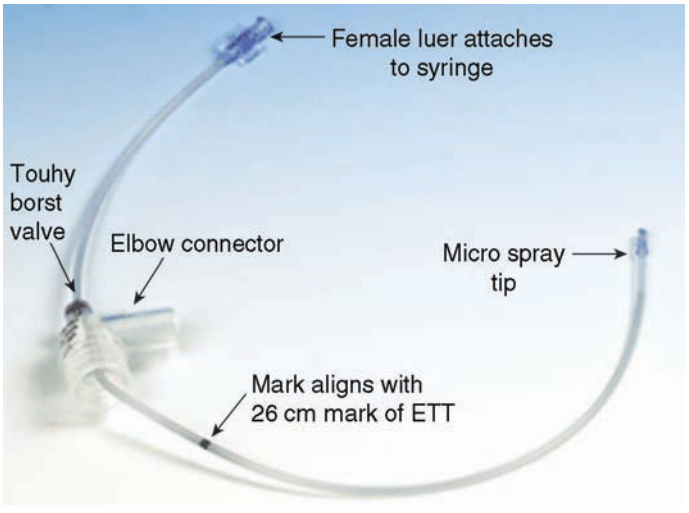


FIGURE 9-2. The MADett™ (Wolfe Tory Medical, Salt Lake City, UT).

Other, optional, equipment may be used depending on the technique used to administer the medications. A catheter may be used to administer the medication. A suction, feeding, or central venous catheter may be introduced into the ET tube to administer medications more distally. An IV adapter lock is required on the proximal end of these catheters to allow the syringe to attach to the catheter. There are no formal guidelines regarding proper catheter size. There are recommendations to use a 16 French (Fr) suction catheter in adults,[19] an 8 Fr feeding catheter in children,[20] and a 5 Fr feeding catheter in neonates.[21]

The administration of drugs through laryngeal mask airways (LMAs, Chapter 19) and combitubes (Chapter 20) as compared with ET tubes has been studied. Medication instilled through a catheter inserted through an LMA and into the trachea achieved the equivalent blood concentrations as through an ET tube.[43] Unfortunately, it is often difficult to successfully pass a catheter through an LMA and into the trachea.[22] Administration of lidocaine through LMAs was unreliable (4 out of 10 reached therapeutic plasma levels) as compared with ET tubes (10 out of 10 reached therapeutic plasma levels) in nonarrest patients.[22] Subtherapeutic plasma medication levels were noted when comparing lidocaine administration via combitubes (placed in the esophagus) versus ET tubes.[23]

The intubating LMA (ILMA) is a modification of an LMA. It is designed to allow the blind passage of an ET tube through it and into the trachea. Insertion of a catheter through an ILMA was only successful in 92% of the attempts.[44] It also required a mean time of 20 seconds (range 11–44 seconds), which is too long by AHA guidelines to discontinue CPR.[11]

An interesting device is the MADett™ or mucosal atomizer device (Wolfe Tory Medical, Salt Lake City, UT, **Figure 9-2**). This device allows ET medication administration without stopping compressions and ventilations of CPR, and no splash back into the face of the person administering the medication. The MADett™ must be used only with an ET tube size greater or equal to 7.0 mm inner diameter and a length of at least 28 cm.

TECHNIQUES

PROXIMAL MEDICATION INSTILLATION

The simplest method for ET medication administration is direct instillation. Prepare the medication or use a prefilled syringe with a needleless adapter. If drawing your own medications, use a syringe with an 18 gauge needle to draw up the medication into the syringe. Draw up sterile water or 0.9% normal saline to dilute the medication to the appropriate volume. Remove the bag-valve-mask device from the ET tube. Briefly interrupt external chest compressions. Remove the 18 gauge needle from the syringe. Inject the diluted medication in the syringe or from the prefilled syringe into the proximal end of the ET tube. Replace the bag-valve-mask device and manually ventilate five times in quick succession. The forced hyperventilation results in bilateral and distal distribution of the medication.[12] Resume chest compressions.

Always remove the needle from the syringe when injecting medication into the ET tube. Some medical personnel may choose to leave the needle attached to the syringe for convenience or to decrease any delays in medication administration. The needle, if loose, can fall off the syringe and into the ET tube. It will then "ride the tube" and can become an airway foreign body in the distal trachea or main bronchus. The needle also slows down medication injection into the ET tube, delaying restarting CPR.

PROXIMAL NEEDLE INJECTION OF MEDICATION INTO THE ET TUBE

An alternative approach is to piercing the proximal end of the ET tube with an 18 gauge needle attached to the medication-filled syringe.[24] Care must be taken to assure that the needle does not damage the ET cuff inflation tube and the tip of the needle is completely within the lumen of the ET tube. Instill the medication during inspiration, when the bag is squeezed. Detach the syringe from the needle. Attach a new medication-filled syringe or refill the used syringe to instill other medications without removing the needle from the ET tube. The remaining hole in the ET tube after the resuscitation and the needle is removed results in a negligible air leak that may be closed with a piece of tape.

DISTAL MEDICATION INSTILLATION

Medications may be administered deeper through a catheter inserted into the ET tube. This technique minimizes medication adherence to the walls of the ET tube. Prepare the medication and catheter. Draw up the appropriate medication and diluent into a syringe or use a prefilled syringe. Choose the appropriate type and size of catheter. Attach an IV adapter lock to the proximal end of the catheter. The proximal end of the catheter may have to be cut off if it is flared, tapered, or too big for the IV adapter lock to fit.[25] After cutting the proximal end, attach the IV adapter lock.

Remove the bag-valve-mask device from the ET tube. Briefly interrupt external chest compressions. Lightly lubricate the catheter with a water-soluble lubricant, so that it will advance easily through the ET tube. Insert the catheter (feeding, venous, and suction) into the ET tube until its tip extends just beyond the distal end of the

ET tube by approximately 1 to 2 cm. Attach the medication-filled syringe to the IV catheter lock if using a feeding or suction tube, or the leur lock if using a central venous catheter. Inject the medication into the catheter followed by 5 mL of air to clear the tube of any residual medication. Replace the bag-valve-mask device and manually ventilate five times in quick succession. The forced hyperventilation results in bilateral and distal distribution of the medication.[12] Resume chest compressions.

TECHNIQUES TO MINIMIZE INTERRUPTION OF VENTILATIONS AND COMPRESSIONS

The goal of CPR is to minimize interruptions of chest compression and ventilation. This can be accomplished using one of the specialized ET tubes discussed in the "Equipment" section of this chapter. These ET tubes may be placed initially in a patient with a cardiopulmonary arrest. If a standard ET tube is initially placed, it can be exchanged for one of these specialized ET tubes. Prepare the medication. Attach the medication-filled syringe to the injection port of the ET tube. Inject the medication into the ET tube injection port during inspiration with the bag-valve-mask device. The diluted drug solution may be followed by the injection of 5 mL of air to clear the tube of any residual medication.

An alternative to using these specialty ET tubes is to attach the MADett™ to a standard ET tube. The MADett™ is quick, simple, and easy to use (**Figure 9-3**). The patient should already be intubated. Stop ventilations, but not compressions, and remove the bag-valve device from the ET tube. Attach the MADett™ adapter onto the ET tube (**Figure 9-3A**). Resume ventilations by attaching the bag-valve device to the side port of the adapter. Advance the

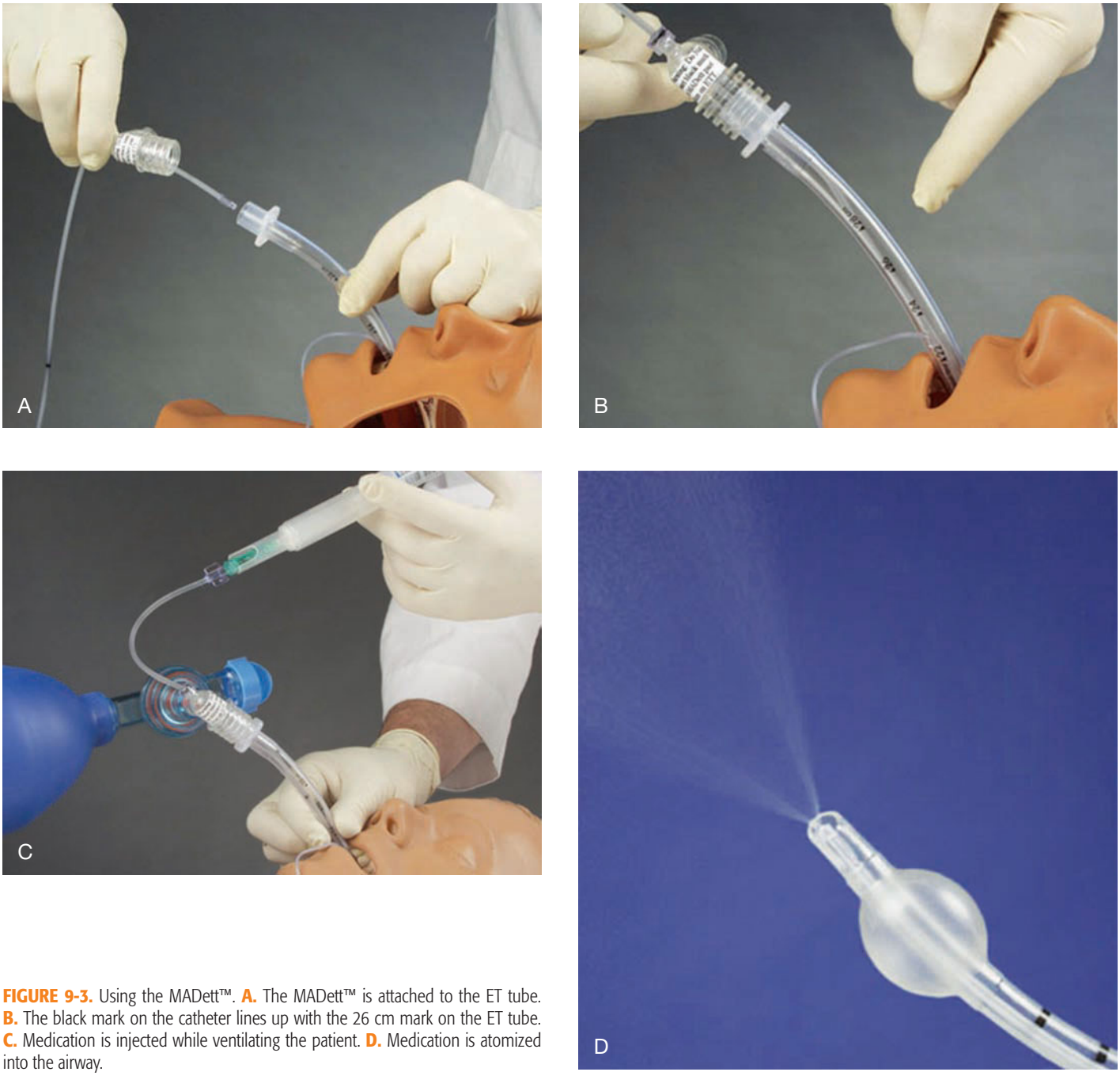


FIGURE 9-3. Using the MADett™. **A.** The MADett™ is attached to the ET tube. **B.** The black mark on the catheter lines up with the 26 cm mark on the ET tube. **C.** Medication is injected while ventilating the patient. **D.** Medication is atomized into the airway.

MADett™ catheter into the ET tube until the black mark on the catheter lines up with the 26 cm mark on the ET tube (**Figure 9-3B**). Tighten the lock nut on the MADett™ adapter to hold the catheter in place, so that it will not be advanced or withdrawn. Attach the medication-containing syringe to the luer lock attachment and inject the medication while ventilating the patient (**Figure 9-3C**). Inject the medication while bagging the patient to allow the atomized medication (**Figure 9-3D**) to penetrate deeply into the respiratory tract.

WHICH IS THE BEST TECHNIQUE?

Mielke et al. studied the time involved to perform each technique by Paramedics and Emergency Physicians.[25] These included direct injection into the ET tube, via suction catheter, via central venous catheter, and use of an EDGAR tube with an injection channel. Overall, both direct injection into the ET tube and use of the EDGAR tube were significantly faster (median 7 and 8 seconds, respectively) than the catheter techniques (median 26 and 30 seconds). In their discussion, a theoretical disadvantage of using a catheter was the instillation of medication unilaterally down one of the mainstem bronchi if the catheter was advanced too far down the ET tube. This would thereby decrease the potential absorptive surface by half. This potential negative was offset, however, by the use of larger volumes of medication and the application of postinstillation hyperventilation.[25]

Studying the same three techniques (direct ET instillation, via a suction catheter, and use of an EDGAR tube) in nonarrest patients, no difference was found in the pharmacokinetic response to lidocaine administration.[19] Specifically, there was no significant difference in serum lidocaine concentration, heart rate, blood pressure, end-tidal PCO_2, and oxygen saturation among the three groups. These findings disputed any previous assertion that using a catheter provided an advantage by instilling medications more peripherally (therefore closer to the absorptive surface). They also reported that catheter use led to a significantly longer interruption in ventilation (10.2 seconds) compared to the direct ET instillation group (3.6 seconds).[19]

These techniques were evaluated in a porcine model representing pediatric respiratory arrests.[20] Epinephrine was instilled through an ET tube, a feeding catheter, and an ET tube with a monitoring lumen. There was no significant difference in hemodynamic response or in the rate of successful resuscitation. Interestingly, by using radiolabeled epinephrine, they were also able to show that medication adherence to the ET tube was minimal and that there was no difference in bilateral pulmonary distribution among the three groups.

ASSESSMENT

There are no specific assessments related to the procedure of endotracheal medication administration. Medications instilled through the ET tube enter the respiratory tract. Large volumes of fluid in the lung may interfere with oxygen exchange, cause a pneumonitis, or cause pulmonary edema. The assessment is related to the resuscitation itself (chest compression, positive pressure ventilation, defibrillation, etc.). There is no method to determine plasma medication levels of endotracheally administered medications in a timely manner to impact clinical care.

AFTERCARE

After a successful resuscitation, there is no indication to remove one of the specialty ET tubes if used. These can be left in place and used similar to a standard ET tube. Place a piece of tape over the needle hole in the ET tube if the needle injection technique was used. Otherwise, no aftercare specific to the procedure of endotracheal medication administration is required.

COMPLICATIONS

The main complication of administering medications by the ET route arises from the "depot effect." Epinephrine, atropine, vasopressin, and lidocaine have been observed to be absorbed in a prolonged fashion, much like a continuous intravenous infusion. This phenomenon has been attributed to local vasoconstriction (epinephrine), poor lung perfusion, vascular congestion due to markedly diminished cardiac output, and comorbid conditions (e.g., pulmonary edema, atelectasis, COPD, etc.) present at the time of the arrest. However, this sustained drug effect has also been observed in nonarrest patients.[8] The result, in the case of epinephrine, is prolonged hypertension, malignant arrhythmias, and tachycardia in the postresuscitative period.[36,41] Endotracheal atropine can cause sustained tachycardia.[5,42] Endotracheal vasopressin can cause sustained bradycardia, prompting experiments with prophylactic atropine.[10] These prolonged effects may hinder both cerebral and cardiac recovery once return of spontaneous circulation is established.[42]

Another drawback to ET medication administration is the transient impairment of gas exchange. Many studies describe an early reduction in PaO_2, which is directly correlated with the volume of liquid instilled. There is a greater drop in PaO_2 after instilling water than after saline. In nonarrest dogs using large volumes of diluent (2 mL/kg), there was a decrease in PaO_2 to 61% of baseline with distilled water as opposed to 75% of baseline with saline.[33] In nonarrest humans with instilled volumes of 10 mL through the ET tube, there was a drop in PaO_2 from 157 to 95 mmHg with saline and from 157 to 103 mmHg with water.[34] Hypoxia, to a much greater extent than hypercarbia, has been reported in nonarrest models. Alterations in pulmonary gas exchange in arrest are less well understood. However, adherence to recommended volumes and the use of hyperventilation postinstillation has the potential to offset this complication.

SUMMARY

Despite concerns regarding the efficacy of ET medication administration, this route remains second line for instances when vascular access (IV or IO) is not available for the instillation of resuscitation medications. When IV or IO access is delayed, the ET route should be considered to increase the chances of successful return of spontaneous circulation. Attempts at vascular access should be continued during the administration of ET medications. The use of the ET route should be discontinued once vascular access is achieved. Despite its inherent issues, knowledge of the ET medication administration procedure can be life saving.

10 Rapid Sequence Induction

Piotr C. Aljindi, Ned F. Nasr, and Isam F. Nasr

INTRODUCTION

Rapid sequence induction (RSI) of anesthesia, sometimes referred to as "crash" induction, has become a safe and effective method of establishing emergent airway control in patients with suspected life-threatening emergencies. It ensures optimal patient compliance in a well-controlled environment. RSI involves the near simultaneous administration of a potent sedative–hypnotic agent and a neuromuscular blocking agent.[1–20] Various pretreatment drug regimens

have been advocated to prevent potentially deleterious side effects, such as aspiration of gastric contents, cardiovascular excitation or depression, and intracranial pressure elevation.

The first endotracheal tubes were developed for the resuscitation of the newborns and victims of drowning in the nineteenth century, but were not used in anesthesia until 1878.[13] Muscle relaxants were not prepared until some 60 years later. Succinylcholine was prepared by the Nobel Laureate Daniel Bovet in 1949, after which it gained the widespread usage it still enjoys today. The RSI technique did not come into modern day practice until the end of World War II.

Patients can be hypoxic, confused, uncooperative, unstable, and unknowing of their medications or medical conditions and can require airway control within minutes of arrival at the Emergency Department. **RSI is the preferred method for securing the airway in the Emergency Department, as these patients are at risk for aspiration.** These risks include vomiting from gastrointestinal obstruction, opioids, or hypotension; regurgitation from diabetic gastroparesis, gastroesophageal reflux, increased gastric pressure, or decreased lower esophageal sphincter tone; impaired laryngeal protective reflexes; and difficult airway management.[7] Conditions such as recent meal ingestion, pain, obesity, and pregnancy place patients at higher risk as well.

INDICATIONS

The primary indication for RSI is to quickly protect and secure the patient's airway. The rationale behind RSI is to create an environment in which the trachea can be intubated as quickly and with as little difficulty as possible. The clinical conditions occurring at the time of attempted intubation are therefore of great importance. During RSI, the drugs used to produce hypnosis and muscle relaxation interact together to produce the intubating conditions. A complete list of the indications for RSI appears in **Table 10-1**.

CONTRAINDICATIONS

There are few contraindications to RSI. It should not be performed by an inexperienced intubator. If the physician has doubts about his or her ability to intubate the patient, an awake intubation should be considered. The unavailability of equipment, contraindications to muscle relaxants, and critically ill patients in whom the airway can be secured by other methods (fiberoptic intubation, topical anesthesia, or minimal sedation with a benzodiazepine and/or narcotic) are also contraindications to RSI. Any contraindication to the use of succinylcholine is also a contraindication to RSI. **Table 10-2** lists the many common contraindications to the use of succinylcholine. Patients in cardiopulmonary arrest do not require RSI as they should not have any muscle tone to overcome. A relative contraindication is a patient in whom bag-valve-mask ventilation is difficult or anticipated to be difficult.

TABLE 10-1 Indications for RSI in the Emergency Department

Airway protection and risk for pulmonary aspiration (e.g., full stomach, pregnancy, and obesity)
Application of advanced cardiac life support and administration of drugs
Definitive maintenance of airway patency
Depressed level of consciousness and questionable ability to maintain a patent airway
Emergency surgery and requirement for general anesthesia
Head trauma with a decreased Glasgow Coma Scale score
Head trauma with the need for airway control
Head trauma with the need for ventilation
Potentially difficult intubation after airway evaluation
Respiratory failure, actual or impending
Uncontrolled seizure activity requiring airway control
Uncooperative or combative patient with compromised airway

Source: Adapted from Ref. 2 and 7.

TABLE 10-2 Contraindications to the Use of Succinylcholine

Cardiac arrhythmia
Children and adolescents unless no other option exists
Exaggerated hyperkalemia in susceptible patients
More than 24 h after major burns and trauma
Crush injuries
Denervation beyond 48–72 h after injury[14]
Prolonged immobilization
Paraplegia or hemiplegia
Disuse atrophy
Severe abdominal infection
Muscular atrophy
Metastatic rhabdomyosarcoma[14]
History of malignant hyperthermia in the patient or in their family history
Hypersensitivity to the drug
Increased intracranial pressure (relative)
Increased intragastric pressure (relative)
Increased intraocular pressure (relative)
Masseter muscle spasm or rigidity
Plasma cholinesterase deficiency (relative)
Skeletal muscle myopathies in the patient or in their family history

Source: Adapted from Ref. 1, 2, 8, and 14.

EQUIPMENT

- Supplemental oxygen with appropriate tubing and connectors
- Laryngoscope handle with extra batteries
- Laryngoscope blades, various sizes and types
- Endotracheal tubes, various sizes
- Wire stylet, malleable type
- Nonrebreather oxygen masks, various sizes
- Oropharyngeal airways, various sizes
- Nasopharyngeal airways, various sizes
- Alternative airway devices
- Suction source with appropriate tubing
- Suction catheters for endotracheal tubes
- Yankauer suction catheter
- Bag-valve-mask devices, various sizes
- Face masks, various sizes
- Stethoscope
- Water-soluble lubricant or anesthetic jelly
- Tape
- Benzoin adhesive
- Syringes, 10 and 20 mL
- Medications drawn up and labeled
- Pulse oximeter
- Cardiac monitor
- Automatic sphygmomanometer
- End-tidal carbon dioxide (CO_2) monitor/device
- Crash cart
- Resuscitation medications
- Personnel (respiratory technician, medication nurse, recorder, in-line stabilization assistant)

TABLE 10-3 Pharmacologic Adjuncts to Intubation in the Premedication Phase

Agent	Standard dose	Trauma dose	Blood pressure	Cerebral perfusion pressure
Fentanyl*	2.0–8.0 μg/kg	1.0–3.0 μg/kg	Stable	Stable
Sufentanil†	0.25 μg/kg	0.1–0.2 μg/kg	Stable	Stable
Alfentanil‡	5.0–25.0 μg/kg	5 μg/kg	Stable	Stable
Remifentanil¶	0.25–1.0 μg/kg/min	0.05–0.5 μg/kg/min	Stable	Stable
Lidocaine§	1.0–1.5 mg/kg	1.0–1.5 mg/kg	Stable	Stable or increased

* Minimal hemodynamic or cerebrovascular effects. Useful agents for blunting the noxious stimuli of direct laryngoscopy or intubation. The halftime of equilibration between the effect and plasma is relatively slow (5–6 minutes). May cause central vagal stimulation with resultant bradycardia and occasionally hypotension in patients with high sympathetic tone.

† Similar to fentanyl, but more potent and faster offset.

‡ Similar to fentanyl, but faster onset and duration of action. The halftime of equilibration between the effect site and the plasma is 1.5 minutes, making this opioid a very appropriate drug to provide a transient peak effect after a single bolus dose. May prevent the increase in intraocular pressure caused by succinylcholine.[8]

¶ Similar to alfentanil in terms of fast onset. Extremely rapid clearance (3–4 L/minute) due to esterase metabolism, resulting in a rapid and predictable recovery.

§ Useful adjuvant agent for blunting airway reflexes. Also blunts blood pressure, intracranial pressure, and intraocular pressure responses to intubation, involuntary muscle movements after etomidate, and injection site pain from propofol and etomidate. Topical lidocaine is also effective in blunting reflexes.

Source: Adapted from Chapter 8.

The equipment required for RSI is the same as that for any intubation.[10,13] Complete details regarding the selection of properly sized equipment can be found in Chapters 7 and 11. In addition, **backup equipment should be readily available if the patient cannot be intubated.** This can be a laryngeal mask airway, a cricothyroidotomy tray, a retrograde guidewire kit, or a percutaneous jet ventilation system to name a few.

PATIENT PREPARATION

RSI can be performed with little or no preparation. If possible, a few steps can be performed while the patient is being evaluated. Administer supplemental oxygen to the patient with a nonrebreather mask. Apply a noninvasive blood pressure cuff, continuous pulse oximetry, and cardiac monitoring. Obtain intravenous access. If time permits, pharmacologic agents can be used to increase gastric pH and motility (antacids, H_2 receptor blockers, and metoclopramide). An antisialagogue (atropine or glycopyrrolate) may also be administered to decrease excessive oral and respiratory tract secretions.

Evaluate the airway (Chapter 6). **If, after evaluation of the airway, there is sufficient doubt as to the possibility of intubating the patient successfully, a neuromuscular relaxant should not be administered.** Consideration should be given to securing the airway in another fashion (e.g., awake intubation).

TECHNIQUE

The three main characteristics of RSI are preoxygenation, application of cricoid pressure, and the avoidance of positive pressure ventilation (if possible) prior to securing the airway with a cuffed endotracheal tube. In addition, RSI requires the presence of ancillary equipment and experienced assistance. The details of timing, drug choice, and dosage are not rigidly defined. A RSI protocol is described below from start to finish.

Preoxygenate the patient with 100% O_2 by a nonrebreather mask, or ventilate with a bag-valve-mask device using cricoid pressure. This will build an oxygen reserve and prevent hypoxemia during induction. Traditionally, preoxygenation for 5 minutes is the routine practice. If this is not practical, attempt to preoxygenate the patient for 3 minutes.[6] However, four maximal inspirations are equally effective in the cooperative patient.[6] Oxygen administration via noninvasive positive pressure ventilation can improve oxygenation more rapidly than by a face mask.[21]

While an assistant is preoxygenating the patient, evaluate the airway to anticipate any difficulties during the intubation (Chapter 6). Assemble all required equipment. Connect the bag-valve device to a mask and an oxygen supply. Lubricate and place the malleable stylet into the endotracheal tube. Attach a syringe to the inflation port of the endotracheal tube cuff. Inflate the cuff to look for any air leaks. Deflate the cuff and leave the syringe attached to the inflation

TABLE 10-4 Selected Pharmacologic Properties of the Neuromuscular Relaxants

Agent	Intubation dose (mg/kg)	Average intubating time (min)	Clinical duration (min)	Comments
Succinylcholine	Children: 2 mg/kg Adults: 1 mg/kg[16] IM: 4 mg/kg	1	4–6	Agent used for rapid sequence intubation.[1,2] Associated with side effects such as exaggerated hyperkalemia in susceptible patients (>24 h after major burns and trauma, crush injury, denervation, prolonged immobilization, paraplegia, hemiplegia, muscular dystrophy) and malignant hyperthermia. Elevates intraocular, intracranial, and intragastric pressures. Use the total body weight (not the lean weight) even in the morbidly obese or pregnant patient.
Rocuronium	0.6–1.2 Children 2–12 years old: 0.9–1.2[17]	0.7–1.1	31–67	An alternative to succinylcholine provided that there is no anticipated difficulty in intubation.[4]
Vecuronium	0.08–0.10	2.5–3.0	25–40	Cardiovascular effects unlikely. Alternative to succinylcholine.
Cisatracurium	0.15–0.20	1.5–2.0	55–65	Stereoisomer of atracurium. No cardiovascular effects. Organ-independent elimination.
Atracurium	0.4–0.5	2.0–2.5	35–45	Elimination independent of liver and kidney. Releases histamine.
Pancuronium	0.06–0.10	2.0–3.0	56–100	Tachycardia and sympathetic nervous system activation.

Source: Adapted from Ref. 1, 2, 4, 5, and 9.

TABLE 10-5 Pharmacology of the Anesthetic Induction Agents

Agent	Dose (mg/kg)	Steady-state volume of distribution (L/kg)	Clearance (mL/min/kg)	Elimination half-life (h)
Thiopental	Adults: 3.0–5.0 Children: 3.0–5.0 Infants: 7.0–8.0[18]	2.5	3.4	11.6
Etomidate	0.2–0.3	2.5–4.5	10.0–20.0	2.0–5.0
Propofol	Adults: 1.5–2.5 Children: 3.0–6.0	2.0–10.0	59.4	4.0–7.0
Midazolam	0.1–0.2	1.0–1.5	7.5	1.0–4.0
Ketamine	1.0–2.0	2.5–3.3	16.0–18.0	1.0–2.0
Methohexital	1.0–3.0	0.4	6.56	22 days
Fentanyl	0.002–0.02	4.0	4.8–10.5	3.5–4.0

Source: Adapted from References 3, 7, 8, and 18.

port. Attach the laryngoscope blade to the handle and make sure that the light is functional. Simultaneously, the nurses should apply a noninvasive blood pressure cuff, continuous pulse oximetry, and cardiac monitoring to the patient. They should also draw up and label the required medications, establish intravenous access, set up the suction, record all events, and continuously observe the noninvasive blood pressure readings, cardiac monitor, and pulse oximeter.

If there is no suspicion of a cervical spine injury, position the patient in the optimum "sniffing" position. If there is suspicion of a cervical spine injury, an assistant should provide manual in-line axial stabilization of the head and neck during the intubation sequence and remove the anterior aspect of the cervical spine collar to allow for maximal mouth opening and access to the neck.

Premedicate the patient (**Table 10-3**). The mnemonic "LOAD" has been used to indicate the pretreatment drugs for RSI.[15] The mnemonic stands for lidocaine, opioid (specifically, fentanyl), atropine, and defasciculation. Lidocaine (1.0 to 1.5 mg/kg) can be given to blunt the intracranial pressure response, transient hypertension, bronchospasm, and tachycardia associated with intubation. Fentanyl (2 to 3 µg/kg) or one of its derivatives can be given to also blunt the intracranial pressure response, transient hypertension, and tachycardia associated with intubation. Atropine (0.01 to 0.02 mg/kg, minimum 0.1 mg, maximum 1.0 mg) should be given to children less than 1 year old to prevent bradycardia in response to direct laryngoscopy. Administer a defasciculating dose of a nondepolarizing neuromuscular blocking agent. This is one-tenth of the intubating dose (**Table 10-4**). Phenylephrine (50 µg) can be given to attenuate the hypotensive response to intubation. Administer an appropriate induction agent as indicated by the clinical setting and patient's hemodynamic status (**Tables 10-5 and 10-6**). Flush the intravenous line with 5 to 10 mL of 0.9% normal saline solution after each drug to ensure delivery.

Administer a neuromuscular blocking agent.[1,2,5] Numerous agents are available (**Table 10-4**). The most commonly used medications are succinylcholine (1.0 to 1.5 mg/kg) or rocuronium (1.0 to 1.2 mg/kg). **Succinylcholine is the preferred agent. Its effects are short lasting (4 to 6 minutes). This is especially useful if the patient cannot be intubated, as they will need to be ventilated with a bag-valve-mask device until the succinylcholine wears off.** Rocuronium allows the same intubating conditions as succinylcholine except that it lasts for 30 to 60 minutes. This is problematic if the patient cannot be intubated.

An assistant should apply cricoid pressure as soon as the patient loses consciousness and maintain it until successful oral endotracheal intubation has been confirmed. Avoid mask ventilation if possible. If hypoxemia or hypercarbia ensues, begin mask ventilation to a maximum pressure of 20 cmH_2O while maintaining cricoid pressure.

Intubate the trachea 60 to 90 seconds after the succinylcholine (or rocuronium) has been administered and the patient's muscles are relaxed, as noted by apnea and jaw relation. **Confirm the correct position of the endotracheal tube by visualizing the tube passing through the vocal cords, observing sustained presence of end-tidal CO_2 on the capnograph, and auscultating breath sounds at the midaxillary lines.**[11,12] Auscultate over the epigastric area to ensure that ventilation is not audible over the stomach. Release cricoid pressure. If indicated, administer a long-acting paralytic agent (**Table 10-4**). After successful intubation, administer additional sedative hypnotics and analgesics as dictated by clinical needs. Obtain a chest radiograph to confirm proper placement of the endotracheal tube.

SPECIAL CONSIDERATIONS IN PEDIATRIC PATIENTS

Rapid sequence induction is often used in the Emergency Department for securing the airway of pediatric patients. The indications and equipment, except for being smaller, are essentially not different than in the adult patient. Infants and young children have

TABLE 10-6 Cardiovascular and Central Nervous System Effects of Anesthetic Induction Agents

Agent	Blood pressure	Cardiac contractility	Cerebral blood flow	$CMRO_2$	Intracranial pressure	Cerebral perfusion pressure
Thiopental	Decrease	Decrease or no change	Decrease	Decrease	Decrease	Decrease or no change
Etomidate	Slight decrease or no change	No change	Decrease	Decrease	Decrease	Increase
Propofol	Decrease	Decrease	Decrease	Decrease	Decrease	Decrease or no change
Midazolam	Slight decrease	No change	Decrease	Decrease	Decrease	No change
Ketamine	Increase	Increase	Increase	Increase	Increase	Increase or no change
Methohexital	Decrease	Decrease	Decrease	Decrease	Decrease	Increase
Fentanyl	Slight decrease	No change	Decrease	Decrease	Increase or no change	No change

Source: Adapted from Chapter 8.

developmental differences in head and neck anatomy (Chapter 6). These differences make the Miller blade the preferred laryngoscope blade for intubation in this group. Infants and young children have a higher volume of distribution, which is why they require different doses of induction agents as reflected in **Tables 10-4 & 10-5**.

Preoxygenation is particularly important for infants and children. Compared with adults, these young patients have a higher oxygen consumption rate and a lower functional residual capacity. Consequently, oxygen desaturation occurs much more rapidly. If the child is desaturating or apneic, careful bag-mask ventilation with small tidal volumes (while maintaining cricoid pressure) should be performed to achieve adequate preoxygenation.

The use of succinylcholine remains controversial in pediatrics. Rapid sequence induction and laryngospasm are perhaps the last remaining indications for the use of succinylcholine in pediatrics. In 1994, the US Food and Drug Administration (FDA) recommended that the use of succinylcholine in children be reserved for emergency intubation and instances where the immediate securing of the airway is necessary due to the risks of hyperkalemia. This includes patients with laryngospasm, difficult airways, full stomachs, or for intramuscular use. If a child has no vascular access, succinylcholine (4 mg/kg) can be administered intramuscularly. It will provide a maximum onset of blockade in 3 to 4 minutes and last approximately 20 minutes. If there is a contraindication to using succinylcholine, rocuronium can be used for RSI. Children between 2 and 12 years old require more rocuronium than adults. The recommended doses are 0.9 to 1.2 mg/kg in this age group.

Atropine is commonly used in young children. Atropine (20 μg/kg) administered as a premedication is indicated in all children <1 year old and in all ages if a second dose of succinylcholine is required to intubate the patient.[19] There is a risk of bradycardia with the use of succinylcholine in children. This can be attenuated by premedicating the patient with atropine (20 μg/kg) or glycopyrrolate (10 μg/kg).[20]

ASSESSMENT

Confirm that endotracheal intubation is successful. This includes auscultation, fogging of the endotracheal tube with ventilations, as well as presence of persistent end-tidal CO_2. End-tidal CO_2 can be confirmed using a capnograph or a chemical (colorimetric) indicator device that consists of a pH-sensitive indicator where the dye changes its color in the presence of CO_2. A minimum of six breaths should be administered before a determination is made regarding successful endotracheal intubation. This will eliminate false-positive readings obtained by CO_2 forced into the stomach during mask ventilation, antacids in the stomach, or carbonated drinks in the stomach. False-negative results may be seen with very low tidal volumes and low end-tidal CO_2 concentrations during severe hypotension or cardiac arrest. During cardiopulmonary resuscitation (CPR), a negative result requires an alternative method of confirming the position of the endotracheal tube because compromised circulation causes low end-tidal CO_2.[12] Other methods used to confirm endotracheal intubation include fiberoptic endoscopy with direct visualization of the tracheal rings and carina, pulse oximetry (low saturation is a late sign for esophageal intubation), blood gas analysis, chest radiography, and a variety of detection devices. Please refer to Chapter 12 for more information regarding the confirmation of endotracheal intubation.

AFTERCARE

The aftercare is the same as for any intubated patient. Secure the endotracheal tube with tape or a commercially available device. Administer adequate sedation and neuromuscular relaxation as necessary. Place a nasogastric tube to decompress the stomach.

TABLE 10-7 Complications of RSI

Airway trauma
Awareness
Bradycardia
Cerebral anoxia
Complication specific to the medications administered
Corneal injury
Death
Dental damage
Hypertension
Hypotension
Hypoxia
Increased intracranial pressure
Increased intraocular pressure
Myocardial ischemia
Pulmonary aspiration
Tachycardia

COMPLICATIONS

The complications associated with RSI are numerous (**Table 10-7**), ranging from minor airway trauma to cerebral anoxia and death. These can result from the RSI or the intubation. **The technique of RSI should be performed only by experienced physicians. The availability of alternate invasive airway devices and techniques can often prevent complications if oral endotracheal intubation is unsuccessful.** A more complete discussion is contained in Chapter 11.

SUMMARY

RSI is the preferred method to secure an airway on an emergent basis and where there is a risk of aspiration of gastric contents. In experienced hands, it is a relatively safe procedure with few complications. The choice of pharmacologic agents used will vary by physician experience, physician preference, the clinical condition of the patient, and the pharmacology of the agents.

11 Orotracheal Intubation

Eric F. Reichman and Joseph Cornett

INTRODUCTION

Airway control is the first and most critical action of the Emergency Physician. The "A" in the ABC's demands that no other action may take place until the airway is secure. Endotracheal (ET) intubation inserts an artificial airway connecting the respiratory system to the outside world and provides definitive control of the airway. Once the ET tube is in place, all methods of support can be applied. If the airway is not secure, nothing can help the patient. ET intubation can be accomplished by a variety of methods. The method of choice will be dictated by physician preference and experience, the patient's condition, and the available equipment. The most common method of ET intubation is orotracheal intubation. **There are no good alternatives to intubation when oxygenation and ventilation are threatened. All actions should be focused on two objectives: to get the ET tube placed quickly and in the right location.** The proper preparation, practice, and personnel can assure that the "nightmare airway" is an extremely rare event.[1]

ANATOMY AND PATHOPHYSIOLOGY

For the purposes of intubation, our discussion of the anatomy starts at the lips and travels inward to end at the right mainstem bronchus. As you approach the patient, visualize the normal structures expected and match them with what is seen. Distortion occurs from edema or trauma. Structures may be hidden by vomit or blood. Airway structures are viewed upside down, from the position of standing over the head of the supine patient, and the potential for disorientation multiplies.

Begin at the face and move inward (**Figures 11-1 & 11-2**). The philtrum of the upper lip will be located at the 6 o'clock (bottom) position. Symmetrical swelling, carbon deposits, blistering, or signs of trauma to the lips can indicate that the inner anatomy of the airway may be altered and the intubation more difficult. Moving inward, open the patient's mouth and check the teeth for fractures, size, and the presence of removable dental devices. Large upper incisors and/or limited jaw opening will make orotracheal intubation more difficult. The tongue hangs down from the floor of the lower jaw (mandible) and ends with the tip against the upper (maxillary) incisors (**Figure 11-2**). Visualize the tongue as a hanging oval of tissue with two "tips." The first is the anterior tip of the tongue proper. The second is the epiglottis. The anatomic "floor" of this view is formed by the hard and soft palates, which end at the palatopharyngeal arch (**Figure 11-2**). The uvula is located inferiorly and in the midline. The palatoglossal arch and palatopharyngeal arch form twin vertical pillars that lie posterior to the molars of the upper teeth (**Figure 11-2**). All of these structures are potential sources of obstruction and must be evaluated for swelling, deformity, or trauma. The "back wall" is the posterior wall of the pharynx (**Figure 11-2**).

At the posterior wall of the pharynx, the airway bends 90° to run almost parallel to the bed. Visualized from the perspective of the top of the patient's head, the root of the tongue and the lingual tonsils are located at the 12 o'clock position (**Figures 11-3 & 11-4**). The tongue continues into a blind pocket known as the vallecula. Following the vallecula posteriorly, it is continuous with the epiglottis. The epiglottis hangs with its tip pointing downward. Directly behind and protected by the epiglottis is the entry to the remainder of the airway (**Figure 11-4**). The esophagus lies at the 6 o'clock position. From the viewpoint of the intubator, the hypopharynx appears like the numeral 8. The top half is the airway and the bottom half the esophagus.

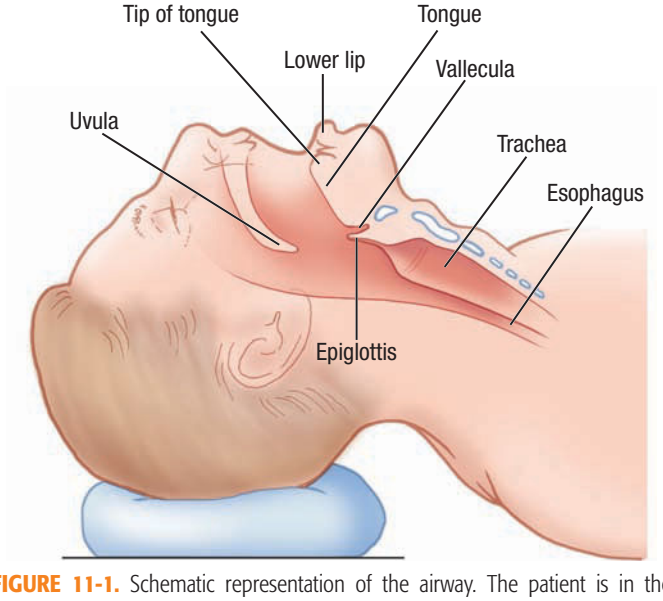


FIGURE 11-1. Schematic representation of the airway. The patient is in the "sniffing" position.

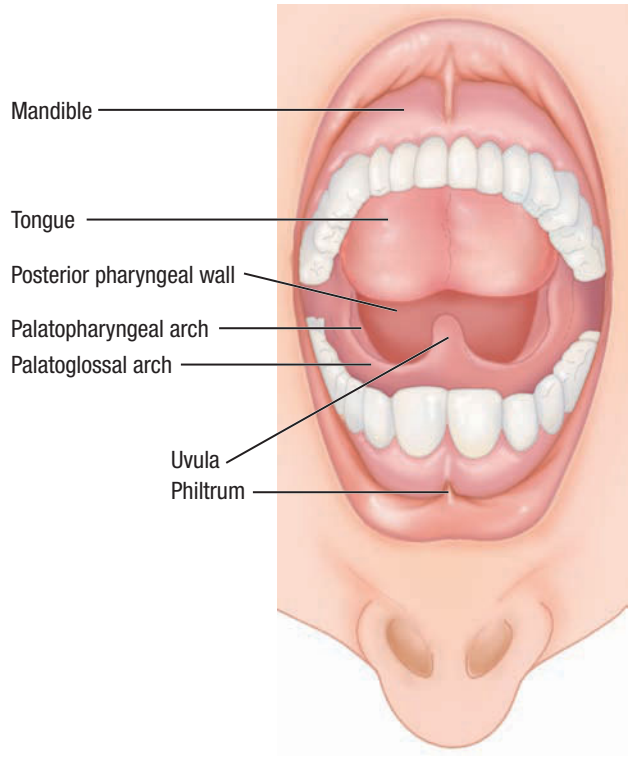


FIGURE 11-2. The oral structures as viewed from above the supine patient's head.

Under the epiglottis is the larynx (**Figure 11-5**). The vocal cords are located in the midline and form an "A" shape, with its apex superior and toward the epiglottis. **Identifying the vocal cords is important, since the visualization of the ET tube passing between the cords is proof of a successful ET intubation.** The arytenoid cartilages are paired structures. One lies at the posterior aspect of each vocal cord. The aryepiglottic folds are paired structures that span from the lateral edge of the epiglottis to the arytenoid cartilages. They contain the muscles that move the arytenoid cartilages, and subsequently open and close the vocal cords. The trachea bifurcates at the carina into the right and left mainstem bronchi. In some patients, the cartilaginous tracheal rings are visible through the vocal cords.

INDICATIONS

Any threat to oxygenation and/or ventilation is a relative indication for orotracheal intubation. If the threat is simple and easily removed, remove it. **If there is uncertainty that the patient's airway patency, respiratory drive, or oxygenation cannot be maintained without intervention, orotracheal intubation is required. Time is of the essence. The decision to intubate early can make the difference between a controlled, successful procedure and a chaotic, "crashing" nightmare.** Orotracheal intubation can be performed to administer resuscitation medications, ensure a patent airway, deliver oxygen, isolate the airway, reduce the risk of aspiration of gastric or oral contents, suction the trachea, ventilate the patient, and apply positive-pressure ventilation. Other indications for orotracheal intubation include altered mental status, head injury requiring hyperventilation, hypoxemia, hypoventilation, apnea, lack of a gag reflex, shock, and unconsciousness.

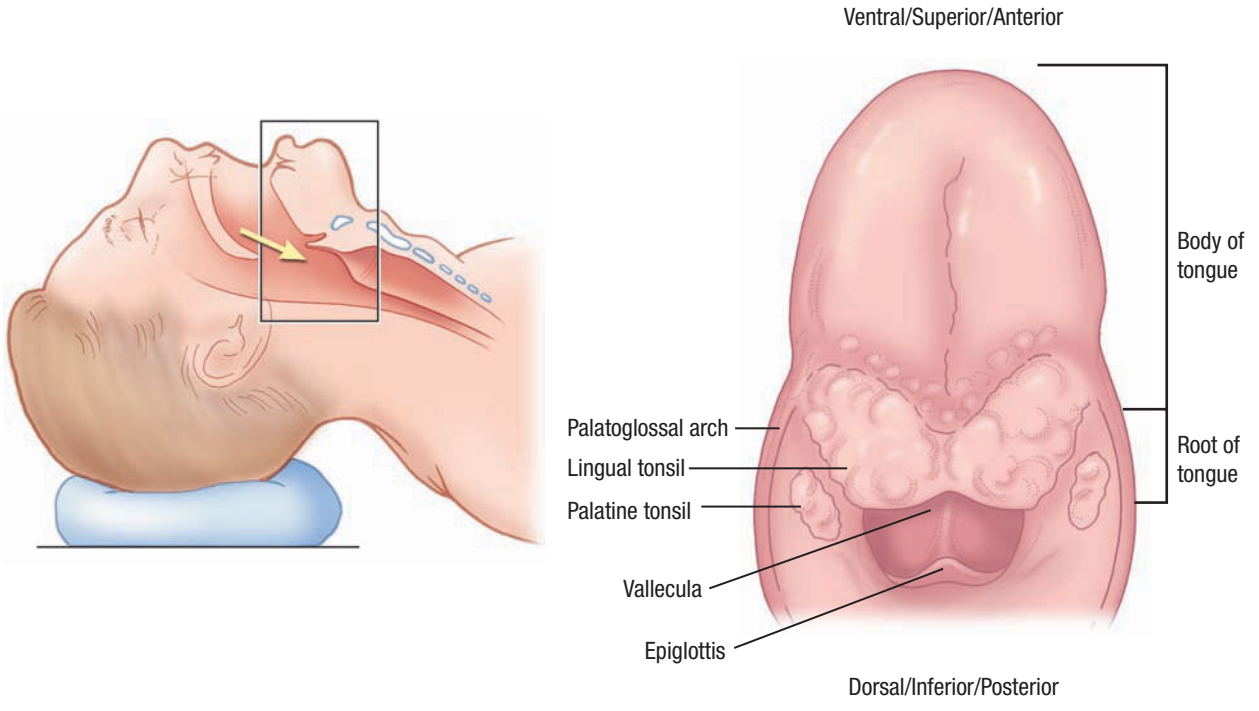


FIGURE 11-3. The tongue and adjacent structures as viewed from above the supine patient's head.

CONTRAINDICATIONS

Orotracheal intubation is relatively contraindicated in patients who do not need it, who are likely to be injured by the procedure, or whose injuries make success unlikely. Spontaneous breathing with adequate ventilation and normal mental status may allow less invasive techniques such as continuous positive airway pressure (CPAP) in patients whose medical conditions are likely to respond quickly to interventions, such as cardiogenic pulmonary edema or pneumonitis.[2] Trauma patients, with likely cervical spine injury or anterior neck wounds, as well as severely immobile arthritis patients may be injured by the manipulation required during orotracheal intubation.[3] Severe orofacial injuries, bleeding, deep airway obstruction, or gross deformity of the head and neck may make successful intubation impossible. A quickly changing obstruction, such as edema or an expanding hematoma, may require a surgical airway if orotracheal intubation is delayed. **Choose a surgical airway if the manipulation or time required for orotracheal intubation puts the patient at risk for spinal injury or hypoxia.**[4] Orotracheal intubation should not be performed by individuals unfamiliar with the equipment and technique.

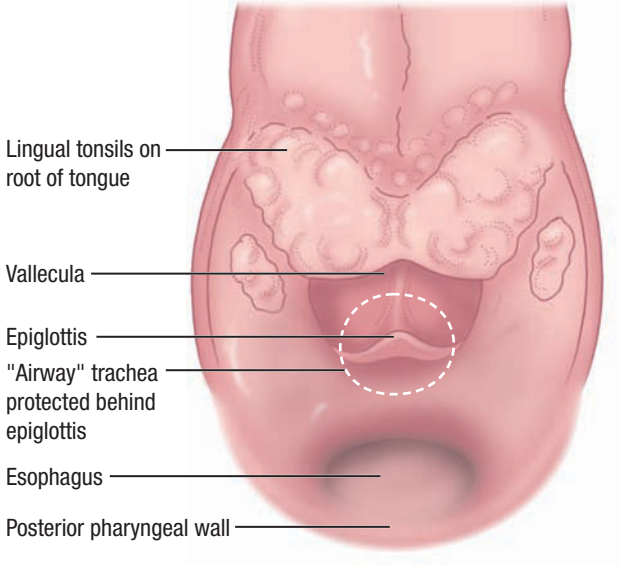


FIGURE 11-4. Structures of the hypopharynx as viewed from above the supine patient's head.

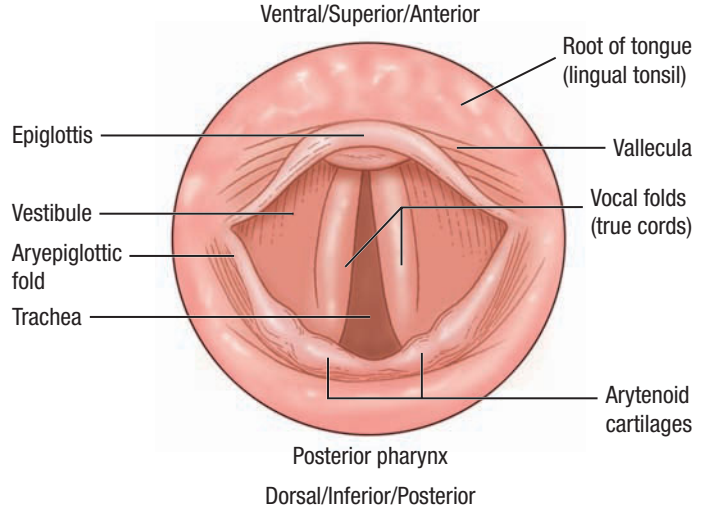


FIGURE 11-5. The structures of the glottis as viewed from above the supine patient's head.

TABLE 11-1 Oral ET Tube Sizes and Positioning Based on Patient Age

Patient's age	Size* (French)	Internal diameter (mm)	External diameter† (mm)	Distance inserted from lips (cm)
Premature	10	2.5	3.3	9–10
Full-term/newborn	12	3.0	4.0–4.2	11
1–6 months	14	3.5	4.7–4.8	11
6–12 months	16	4.0	5.3–5.6	12
1–2 years	18	4.5	6.0–6.3	13
3–4 years	20	5.0	6.7–7.0	14
5–6 years	22	5.5	7.3–7.6	15–16
7–8 years	24	6.0	8.0–8.2	16–17
9–10 years	26	6.5	8.7–9.3	17–18
11–13 years	28–30	7.0	9.3–10.0	18–20
Female ≥ 14 years	28–30	7.0	9.3–10.0	20–22
Male ≥ 14 years	32–34	8.0	10.7–11.3	22–24

* Calculated as follows: External diameter (mm) × π.
† Varies by manufacturer.
Source: Modified from Stone and Gal.[6]

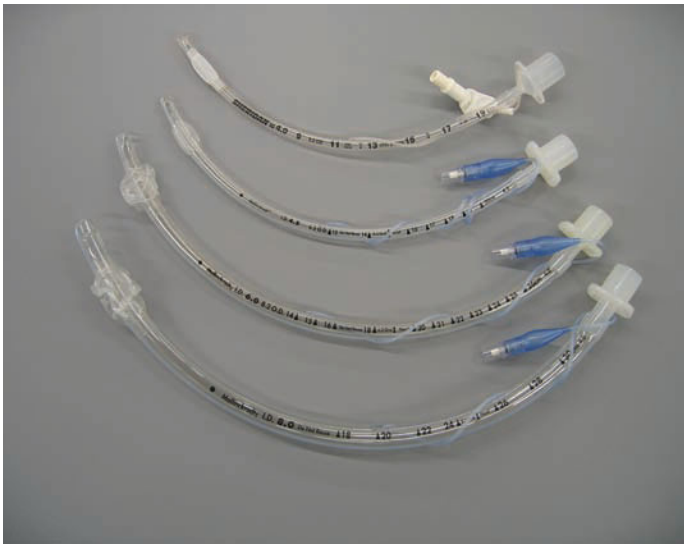


FIGURE 11-6. A variety of ET tubes.

EQUIPMENT

- ET tubes, various sizes (**Table 11-1**)
- 10 mL syringe
- Water-soluble lubricant or anesthetic jelly
- Wire stylet, malleable type
- Laryngoscope handle
- Fresh batteries for the laryngoscope
- Laryngoscope blades, various sizes and shapes
- Supplemental oxygen with appropriate tubing and connectors
- Nonrebreather oxygen masks, various sizes
- Wall suction with appropriate tubing
- Yankauer suction catheter
- Bag-valve device, sizes: infant, child, adult small, adult medium, adult large
- Oral airways, sizes: infant, child, adult 3 to 5
- Nasal airways, various sizes
- Benzoin adhesive
- Tape
- Pulse oximeter
- Cardiac monitor
- Automatic sphygmomanometer
- End-tidal carbon dioxide (CO_2) monitor/device
- Cricothyrotomy backup tray
- Crash cart
- Resuscitation medicines
- Personnel (respiratory technician, medication nurse, in-line stabilization assistant, and recorder)
- Medications (premedications, induction, anesthetics, paralytics), see **Tables 11-1 to 11-2**

Many institutions make their own "intubating/airway kit." It contains all the commonly used equipment in a portable container or cart that can be moved wherever required in the Emergency Department. While differences will exist between institutions, the kit commonly includes adult and pediatric laryngoscope handles, various sizes and types of laryngoscope blades, various sizes of oropharyngeal airways, various sizes of nasopharyngeal airways, tongue blades, malleable stylets, various sizes of ET tubes, syringes, tape, and commercially available devices to secure the ET tube. Some institutions may have a single kit, or separate kits for adult and pediatric patients.

ET TUBES

The ET tube is a clear polyvinyl chloride disposable tube that is open on both ends (**Figure 11-6**). The proximal end contains a standard size (15 mm) connector that will attach to the bag-valve device, a ventilator, and other sources of positive-pressure ventilation. The distal end is beveled. It has a perforation, located approximately 0.5 to 0.75 cm from the tip and opposite the bevel, known as the Murphy eye. Printed on the tube are the size, a radiopaque line to aid in radiographic visualization, and 1 cm incremental marks beginning at the tip. An inflatable cuff is positioned proximal to the Murphy eye. A pilot balloon with an inflation port, to inflate the cuff, hangs from the proximal third of the ET tube. A syringe, filled with air, attaches to the inflation port to inflate and deflate the cuff.

The ET tube cuff is a high-volume, low-pressure balloon. It is designed to accommodate a high volume of air before the intracuff pressure rises. This is an extremely important feature. If the intracuff pressure rises, it is transmitted to the delicate tracheal mucosa where it can cause pressure necrosis and ischemia.

The choice of ET tube size will vary based on the patient's age, anatomic anomalies, body habitus, and airway anatomy (**Table 11-1**). **The ET tube is sized based on the internal diameter (ID) measured in millimeters.** The size is printed onto the surface of the ET tube for reference. The sizes begin with 2.5 mm and increase in 0.5 mm increments. Some generalities hold true in most patients. Adult males usually require a size 7.5 to 9.0 cuffed ET tube. Adult females usually require a size 7.0 to 8.0 cuffed ET tube.

ET tube selection in children can be made by one of several methods. A Broselow tape will identify the proper size tube. Visually select a tube with an ID that matches the size of the width of the nail of the patient's little finger, the width or diameter of the fifth finger, the diameter of the distal phalanx of the third finger, or the external nares luminal diameter. All these visual methods

will approximate the same size ET tube. The following formula may be used to confirm the uncuffed ET tube size: (16 + child's age in years)/4. Tables based on the child's age, length (Broselow tape), or weight may be used to estimate the proper ET tube size. An uncuffed ET tube should be used in children under 28 days of age to prevent the complications of subglottic and tracheal stenosis. After determining the proper size ET tube, also select and prepare a tube that is one size smaller in case the patient's airway is smaller than expected.

Traditional teaching holds that cuffed ET tubes increase the risk of ischemic damage to the tracheal mucosa due to compression between the cuff and the cartilaginous rings, resulting in the old mandate to use uncuffed ET tubes in children younger than 8 years of age. There have been numerous advances in modern ET tubes that are changing this orthodoxy.[41] Current American Heart Association Guidelines now recommend, but do not require, a cuffed ET tube for children older than 28 days of age. In the first 28 days of life, the cricoid narrowing functions as a cuff. For children over 28 days of age, the cuffed ET tube is just as safe as an uncuffed ET tube.[25,26] The high volume, low pressure cuffs found on new ET tubes allow the cuff to produce a seal at much lower pressures. The use of cuffed ET tubes is becoming more common in pediatric ICUs and Emergency Departments. Several studies have shown no increase in postintubation stridor or reintubation when cuffed ET tubes are used in controlled settings with regular cuff pressure monitoring.

In addition to providing some protection from aspiration, other potential benefits resulting from the use of cuffed ET tubes in children include allowing ventilation at higher pressures, maintenance of more consistent ventilatory parameters, and fewer changes of inappropriately sized ET tubes. Cuffed ET tube size can be calculated using the equation (age in years/4) + 3, or by use of an ET tube one-half size smaller than the calculated uncuffed ET tube size.[7,21]

All ET tubes should be examined for defects before use. Attach a 10 mL syringe filled with air to the pilot balloon inflation port. Inject the air to inflate the cuff. The cuff should inflate symmetrically and have no air leak. Deflate the cuff completely. Leave the syringe attached to the pilot balloon in order to inflate the cuff after the ET tube has been inserted into a patient's airway. If an ET tube is defective, discard it and open a new ET tube.

LARYNGOSCOPES

The laryngoscope is a handheld device that is used to elevate the tongue and epiglottis to expose the glottis. **It is a device that is held in the left hand regardless of which hand of the user is dominant.** It consists of a handle (**Figure 11-7**) and a blade (**Figures 11-8 & 11-9**). The handle contains the battery for the light source. The distal end of the handle has a fitting where the handle connects to the blade. A transverse bar indicates where the indentation on the proximal blade attaches to the handle. There are many types of laryngoscope handles. They all have the same basic design, but are available in a variety of diameters and lengths (**Figure 11-7**). Smaller diameter (thinner) laryngoscope handles may be better suited for use with the smaller sized pediatric laryngoscope blades. Shorter, "stubby" laryngoscope handles may offer an advantage when proceeding with intubation of obese or barrel-chested patients, especially in cases where the neck cannot be manipulated. The shorter handle will not catch on the chest wall during attempts to place the laryngoscope blade in the patient's mouth.

The laryngoscope blade may have a removable bulb attached to its distal third. A fiberoptic bundle within the blade transfers power from the handle to the bulb. Other laryngoscope blades



FIGURE 11-7. A variety of laryngoscope handles.



FIGURE 11-8. The Macintosh laryngoscope blades.



FIGURE 11-9. The Miller laryngoscope blades.

only contain fiberoptic bundles which transmit light, with the light source located within the handle. The choice of the type and size of laryngoscope blade will vary with physician experience and preference. **The best blade is one that the intubator feels comfortable and confident using.** The curved Macintosh blade is most commonly used (**Figure 11-8**). It is the easier blade to use for those with little experience with orotracheal intubation. Many feel that it requires less forearm strength to use as compared to the straight blade. The large flange allows for easier control of the tongue and the flat curved shape of the spatula fits the natural curve of the tongue. The straight Miller blade is often reserved for those experienced with the blade and with orotracheal intubation (**Figure 11-9**).

The tip of the curved Macintosh blade fits into the vallecula and indirectly lifts the epiglottis to expose the vocal cords (Figure 11-10). A size 2 blade is used for 3 to 6 year olds. A size 3 blade is used for children starting at about age 6, for women, and for small to average-size males. A size 4 blade is usually reserved for large males.

The tip of the straight Miller blade goes directly under the epiglottis to lift it and the tongue to expose the vocal cords (Figure 11-11). Use the straight blade, if possible and the intubator is familiar with its use, to intubate patients under 2 years of age. A straight blade makes controlling the epiglottis and tongue easier than with a curved blade. It also makes visualization of the vocal cords easier due to its smaller flange profile. A size 0 blade is used for premature babies and neonates up to approximately 1 month of age. A size 1 blade is used for children from approximately 1 month of age to toddlers up to 2 years of age. A size 2 blade is used for children 3 to 6 years of age. Children between 6 and 12 years of age may require either a size 2 or 3 blade depending on their body size. A size 3 blade is used for adolescents, women, and average-size males. A size 4 blade is rarely used, and then primarily for large males.

If one cannot remember the proper blade size, it can be determined based on patient anatomy.[20] Place the base of the blade, excluding the handle insertion block, at the level of the patient's upper incisor teeth. The tip of the blade should be located within 1 cm proximal or distal to the angle of the patient's mandible. Correct blade size allows for approximately 90% of first attempt intubations to be successful versus 57% if the blade is too small.[20]

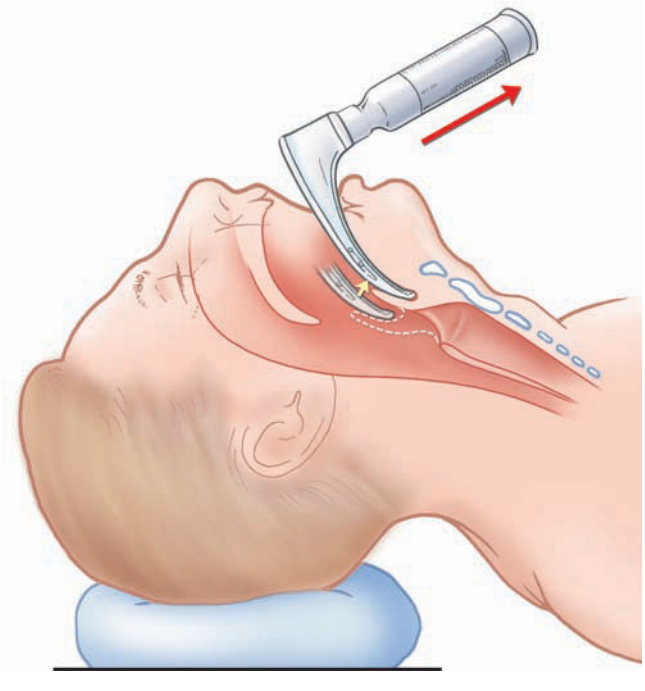


FIGURE 11-10. Use of the Macintosh blade. It is inserted into the vallecula to elevate the mandible, tongue, and epiglottis as a unit.

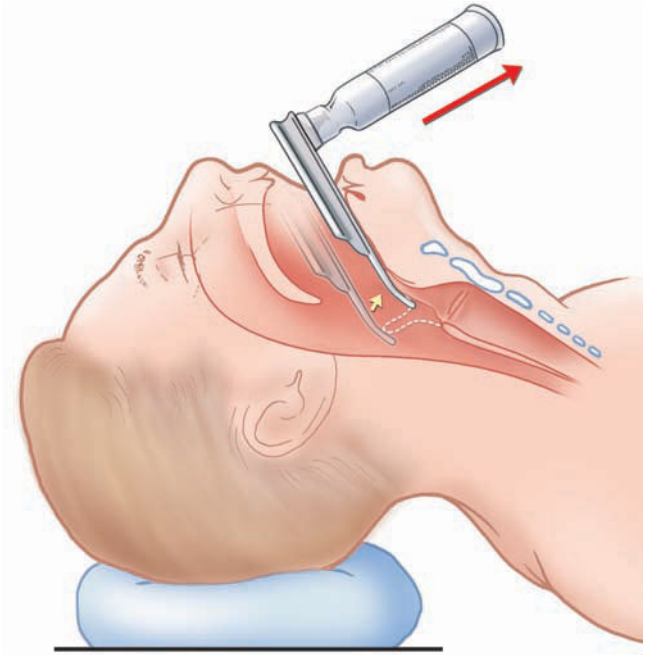


FIGURE 11-11. Use of the Miller blade. It is inserted below the epiglottis to elevate the mandible, tongue, and epiglottis as a unit.

There are a wide variety of laryngoscope blades commercially available. They tend to be variations of the curved Macintosh or Straight Miller blades. The McCoy blade is a curved blade with a hinged tip. The tip can be flexed by depressing a lever on the laryngoscope handle. This flexion augments indirect elevation of the epiglottis by stretching the hypoepiglottic ligament. The Flexiblade (Arco-Medic Ltd., Omer, Israel) laryngoscope also has a levering blade. The extra lift provided by these blades may improve visualization of the vocal cords.[8,9] The Propper Flip-Tip laryngoscope blade (Propper Manufacturing Co., Long Island, NY) has a lever that elevates its tip up to 90° to lift the epiglottis. Other variations of the Macintosh blade include the incorporation of a variety of prism or mirror systems. These modifications allow for indirect visualization of otherwise obscured vocal cords. The Belscope (International Medical Inc., Burnsville, MN), Truvue EVO2 (Truphatek International Ltd, Netanya, Israel), Lee-Fiberview (Anesthesia Medical Specialties, Beaumont, CA), and Viewmax (Rusch, Duluth, GA) blades are examples of these types of modifications.[8,10,11]

There have also been many variations of the straight laryngoscope blade. Today, the Miller is the most popular straight blade. Other variants include the Phillips and Henderson blades. These modify components such as the cross section, the blade channel width, tip style, and light source placement. These modifications represent efforts to avoid such problems as dental trauma, laceration of the ET tube cuff, improve tongue displacement, minimize tip trauma, and obscuration of the light source by secretions.

In addition to traditional metal laryngoscope blades, plastic single-use blades are also available. These single-use plastic blades were developed, in part, to concerns regarding possible transmission of infectious agents by incompletely sterilized metallic blades. A study comparing plastic versus metallic Macintosh laryngoscope blades

in 1177 patients found that metallic blades had higher first attempt intubation rates, fewer cases of difficult intubation, and used alternative airway interventions less often than when intubation was attempted with a plastic blade.[12] Plastic blades cause less dental trauma when used on dental models.[16] The rates of dental trauma in patients when compared to metal blades are not known. The use of single-use disposable plastic blades cannot be recommended at this time unless circumstances do not allow proper cleaning of metallic laryngoscope blades.

STYLETS

The stylet is a semirigid piece of metal that is bendable (**Figure 11-12**). It is often plastic coated. It inserts into the lumen of the ET tube. It should be lubricated with a water-soluble lubricant or an anesthetic jelly prior to insertion into the ET tube. **The tip of the stylet should be 1 cm proximal to the tip of the ET tube to prevent injury to the patient's airway.** The ET tube, with a stylet, can be bent to maintain a specific shape. The stylet is used to facilitate passage of the ET tube through the vocal cords. It is commonly bent into a "hockey stick" or "J" shape for most intubations. A greater curvature is often used for intubations when the larynx is "anterior," in difficult intubations, and in "blind" intubations.

A modification of the traditional stylet is the Parker Flex-It™ Directional Stylet (Parker Medical, Highlands Ranch, CO). This is a plastic articulating stylet that requires no prebending. The stylet has a built-in gentle curve. It has a button on its proximal end that extends from the ET tube. When pushed with the thumb, it allows the curvature of the ET tube to be continuously adjusted during intubation attempts.



FIGURE 11-12. The intubating stylet. It may be bent into any required shape. When inserted into an ET tube, it will form the ET tube into the desire shape. The most common shapes are the "J" and the "hockey stick."

PREPARATION

PHYSICIAN

Once the decision to intubate has been made, the Emergency Physician must use their training and experience to begin leading the team toward a successful intubation. Although the process must move quickly, the Emergency Physician must, by example, ensure a calm and orderly environment. Making the decision to intubate earlier allows the team to follow a shorter and easier time line. The Emergency Physician must visualize this time line and identify actions and potential problems before they occur. **A backup plan should also be available in case orotracheal intubation is impossible.** Any Emergency Department patient about to be intubated is a high priority, so do not be afraid to use resources liberally. Obtain assistants to help as soon as the decision to intubate is made.

PERSONNEL

Shortly before the procedure begins, assemble the entire team near the bed and go over "the game plan" calmly and quickly. All personnel involved with the procedure should be gloved, gowned, and masked. Eye protection should be worn by all personnel to protect against splash injury from blood and secretions. **Explicitly identify assistants and assign their roles early.** Give instructions clearly and calmly before the procedure begins. It is helpful to write down medications and doses in the order that they will be given and to review them quickly with the medication nurse. Emphasize that it will be the nurse's job to draw up, label, and administer the medications, followed by a saline flush. Reinforce that during the procedure this will be a particular nurse's only job. The respiratory assistant has three important tasks: helping to ventilate the patient, applying cricoid pressure, and handing the ET tube to the intubator so that visual contact with the vocal cords is not lost. If cervical spine immobilization is needed, a third assistant should be explicitly instructed as to how and when the team leader would like the patient's neck secured.

EQUIPMENT

The mnemonic "SOAPME" can be used to help review the equipment required for intubation: Suction, Oxygen, Airway, Pharmacology, Monitoring, Equipment.[13] Check that the room is ready and all equipment is within arm's reach. Turn on the suction and the oxygen. Confirm that both systems work. Attach the suction tip and check to see whether there is a small finger hole in the barrel that must be covered for the suction to work. If so, close it with a piece of tape so that the suction is "always on." This is not a concern if a Yankauer suction catheter is being used. Ensure that the suction tubing is long enough to reach the center of the bed. Place the suction catheter under the mattress to the right of the patient's head and within easy reach. Place the spare suction tip nearby. Set the oxygen flow regulator to 15 L/min. Apply a nonbreather mask to the oxygen and the patient. Place the bag-valve device near the head of the bed and within easy reach. Confirm that the noninvasive blood pressure cuff, cardiac monitor, and pulse oximeter are working and attached to the patient. Confirm that the end-tidal CO_2 monitor is nearby and working. If such a monitor is unavailable, a disposable in-line monitoring device should be available. Ensure that the patient has at least one working intravenous line.

Assemble the intubation equipment. Place the proper size laryngoscope blade on the handle. Open the blade and confirm that the light works. Close the blade into the ready position, flat against the handle, to keep the bulb cool and not drain the batteries. Take the ET tube and the backup smaller one and prepare them. Insert the 10 mL

syringe into the inflation port of the pilot balloon for the ET tube cuff. Inject enough air to inflate the balloon. If there is no leak, deflate the balloon until it is completely flat against the ET tube. **Leave the syringe attached.** Liberally lubricate the stylet with a water-soluble lubricant. Insert the stylet into the ET tube until its tip is 1 cm proximal to the distal tip of the ET tube. Place a bend in the stylet as it enters the proximal end of the ET tube to keep the stylet from advancing. Bend the stylet/ET tube assembly into a curve roughly approximating a "hockey stick" or "J" (**Figure 11-12**). Lubricate the tip of the ET tube and the collapsed cuff. This prevents the ET tube from getting caught on the epiglottis and making its advancement through the vocal cords difficult. Place the assembly back into the ET tube package. Place the ET tubes, laryngoscope, backup laryngoscope handle and blades, oral airways, and tape on a tray within easy reach of the bed. Check the room lighting. Raise the bed to minimize excessive bending and better visualize the patient's airway.

PATIENT PREPARATION

If the patient is competent and awake, explain the procedure, clarify advance directives, and obtain consent. If time permits, a history is especially helpful. The mnemonic AMPLE can help to provide quick information: allergies, medications, past medical history, last meal, and events leading to the current problem.

Confirm again that the appropriate monitoring sources are working and attached to the patient. Confirm adequate intravenous access. Place the patient, with a normal neck, in the "sniffing" position, with the head extended at the atlantooccipital joint while the neck is relatively flexed. A folded towel under the occiput helps to gently raise and tilt the head back into the proper position (**Figures 7-1, 11-1, & 11-13**). **Correct positioning is probably the most important preparation of the patient.** Dentures should be left in place temporarily, as they help to stabilize the mouth and prevent occlusion during preoxygenation and bag-valve-mask ventilation.

To intubate the obese patient, place them into the head-elevated position using a ramp or pile of sheets under their head and shoulders (**Figure 7-2**). This position facilitates spontaneous ventilation, mask ventilation, and laryngoscopy.[22–24] It also prolongs the patients oxygen saturation during and after rapid sequence induction.

If the patient is breathing spontaneously, begin preoxygenation for 5 minutes before the procedure (if time permits). Use a well-fitting nonrebreather mask with the oxygen flow regulator set at 15 L/min. This displaces nitrogen from the lungs and gives the patient a physiologic reservoir of oxygen for approximately 5 minutes while apneic. **Remember: 5 minutes of preoxygenation provides 5 minutes of protection.**[5] If bag-valve-mask ventilation is required, have an assistant apply posteriorly directed cricoid pressure to minimize gastric distention and decrease the chance of vomiting and aspiration. Have assistants ready to turn the patient onto his or her left side to minimize the risk of aspiration if vomiting occurs. Monitor the pulse oximeter to assure good oxygenation and ventilation. It should rise to the high 90s and remain there. If not, check the O_2 circuit from the wall to the patient and confirm that spontaneous breathing is still occurring.

TECHNIQUE

The evaluation and preparation for orotracheal intubation are complex and essential. If done well, the intubation will hopefully be quick and anticlimactic. Position the respiratory assistant to the right side near the patient's head. The intubator should stand at the head of the bed. Adjust the bed to place the mattress level with the intubator's umbilicus. Pull the bed away from the wall at least 2 feet and clear a "maneuvering space" of tubes, lines, and equipment to prevent distractions. If in-line cervical immobilization is needed, the assistant should stand at the intubator's left hip, ready to remove the collar and hold the neck in position.

Grasp the laryngoscope with the left hand. **It is a left-handed instrument regardless of the handedness of the intubator.** Pull it open and lock the blade onto the handle. Confirm that the light is functioning. The tip of the laryngoscope blade should be pointed toward the patient's chin. Pass the prepared ET tube and suction catheter to the respiratory assistant, who will place them into your right hand when asked. This allows the intubator to maintain constant visual contact with the patient's airway during the procedure.

Induction of anesthesia is the final preparation for orotracheal intubation. The choice of drug sequence is based on the physician's experience and the patient's condition (**Table 11-2**). A typical sequence begins with a defasciculating dose of a nondepolarizing neuromuscular blocking drug. After 2 to 3 minutes, induce anesthesia with a sedative followed immediately by a paralytic agent (i.e., succinylcholine). Apply cricoid pressure. Once the patient's muscles are relaxed, perform the intubation as described below. Please refer to Chapters 8 and 10 regarding the complete details of the pharmacology of the induction agents and rapid sequence induction. **Some patients, especially the old and sick, may stop breathing earlier than anticipated. Be prepared to intubate before the expected time of drug onset.**

Observe the patient's chest. Watch it rise. When it stops, note the time. Place your right thumb on the patient's jaw. Gently pull down the lower lip and open the mouth. Reinspect the oral cavity. Remove any dentures or foreign bodies. Compare what you see with what you expect to see. Fix any problems as you go further into the airway. If blood or vomit is seen, ask for the suction catheter. **Apply the suction catheter without removing your gaze from the patient's airway.** When done suctioning, hold the suction catheter up for the assistant to take.

INTUBATING WITH THE (CURVED) MACINTOSH BLADE

Firmly grasp the laryngoscope in the left hand (**Figure 11-13A**). Insert the tip of the Macintosh laryngoscope blade into the right side of the patient's mouth. Smoothly advance the blade inward while keeping slight upward pressure against the tongue. Use the blade to trap and push the tongue to the left as the blade is simultaneously moved to the midline, "clearing a path" for your gaze. Keep the left wrist firm. **Use the forearm, wrist, and hand as a single unit and avoid bending or flexing the wrist. It is essential to move the patient's tongue up and to the left.** The tongue will protect the mandibular teeth from being injured by the laryngoscope blade. It allows the laryngoscope blade to be moved away from the maxillary teeth. It also opens a path to visualize the patient's airway.

When the blade has been inserted all the way, lift the patient's airway up and forward exactly along the long axis of the laryngoscope handle, which should be aimed toward a point directly above the patient's chin (**Figures 11-10, 11-11, & 11-13B**). **Do not "cock" or "crank back" on the laryngoscope handle with your wrist, or the back of the laryngoscope blade may break the patient's incisors.** The epiglottis should be seen at the base of the tongue.

A variable amount of force is required to lift the mandible, tongue, and soft tissues to visualize the vocal cords. More force is required to visualize the vocal cords in patients who have a large tongue, are obese, have redundant pharyngeal soft tissue, or have trismus. Grasp the laryngoscope handle as close to its base as possible in these patients. The lower grasp provides more control of the laryngoscope and a mechanical advantage to apply more force without dental trauma.

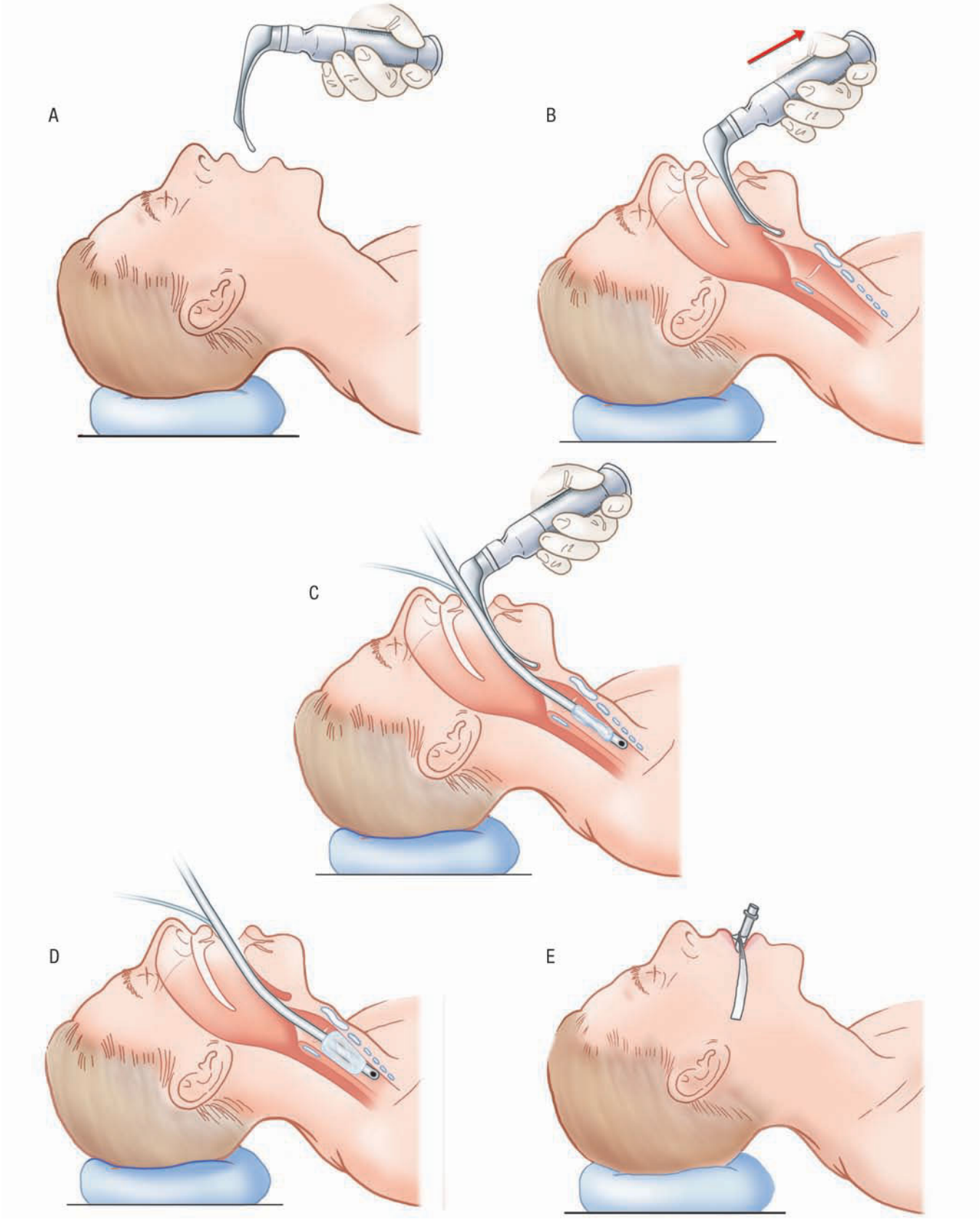


FIGURE 11-13. Orotracheal intubation with the Macintosh blade. The patient is in the "sniffing" position. **A.** Proper positioning of the laryngoscope blade above the patient's mouth. **B.** The blade is inserted into the vallecula. The handle is lifted anteriorly and inferiorly to elevate the mandible, tongue, and epiglottis (*arrow*). The glottis will be visible. **C.** The ET tube is inserted into the trachea until the cuff is below the vocal cords. **D.** The laryngoscope has been removed and the cuff inflated. **E.** The ET tube is secured.

TABLE 11-2 Rapid Sequence Induction Medications for Specific Patient Profiles

Patient type	Premedication*	Induction and paralysis†
"Normal adult"	Vecuronium (0.01 mg/kg)	Etomidate (0.3 mg/kg) or propofol (1–2.5 mg/kg) or thiopental (3 mg/kg) and succinylcholine (2 mg/kg)
"Normal child"	Vecuronium (0.01 mg/kg) and atropine (0.02 mg/kg, min dose 0.1 mg)	Thiopental (5 mg/kg) and succinylcholine (2 mg/kg)
Asthma, adult	Lidocaine (1.5 mg/kg) and atropine (0.5 mg)	Ketamine (1–2 mg/kg) and succinylcholine (2 mg/kg)
Asthma, child	Lidocaine (1.5 mg/kg) and atropine (0.02 mg, min 0.1 mg)	Ketamine (1–2 mg/kg) and succinylcholine (2 mg/kg)
Head injury, adult	Vecuronium (0.01 mg/kg) and lidocaine (1.5 mg/kg) and fentanyl (3–5 μg/kg)	Etomidate (0.3 mg/kg) and succinylcholine (2 mg/kg)
Head injury, child	Vecuronium (0.01 mg/kg) and atropine (0.02 mg/kg, min 0.1 mg) and lidocaine (1.5 mg/kg) and fentanyl (3–5 μg/kg)	Thiopental (5 mg/kg) and succinylcholine (2 mg/kg)
Head injury, adult, hypotensive	Vecuronium (0.01 mg/kg) and fentanyl (3 μg/kg) and lidocaine (1.5 mg/kg)	Etomidate (0.2 mg/kg) and succinylcholine (1.5 mg/kg)
Head injury, child, hypotensive	Vecuronium (0.01 mg/kg) and atropine (0.02 mg/kg, min 0.1 mg) and lidocaine (1.5 mg/kg) and fentanyl (2–3 μg/kg)	Midazolam (0.15 mg/kg) or etomidate (0.3 mg/kg) and succinylcholine (2 mg/kg)
Hyperkalemia or renal failure, adult	None	Etomidate (0.3 mg/kg) or propofol (1.0–2.5 mg/kg) or thiopental (3 mg/kg) and rocuronium (0.6 mg/kg) or vecuronium (0.01 mg/kg)
Hyperkalemia or renal failure, child	None	Thiopental (5 mg/kg) and rocuronium (0.6 mg/kg) or vecuronium (0.01 mg/kg)
Status epilepticus, adult	None	Thiopental (3 mg/kg) and succinylcholine (2 mg/kg)
Status epilepticus, child	None	Thiopental (5 mg/kg) and succinylcholine (2 mg/kg)
Pregnancy	Atropine (0.5 mg)	Ketamine (1–2 mg/kg) and rocuronium (0.6 mg/kg) or vecuronium (0.01 mg/kg)

* Given 3 minutes before intubating ($T = 3$).

† Given simultaneously at the beginning of intubation ($T = 0$) and wait for 45 to 60 seconds for onset of paralysis.

Advance the tip of the laryngoscope blade into the vallecula—the space between the base of the tongue and the body of the epiglottis (**Figures 11-10 & 11-13B**). Lift the laryngoscope handle to raise the tongue, jaw, and epiglottis as a unit (**Figure 11-10**). Observe carefully as the epiglottis pivots upward and uncovers the glottis (**Figure 11-5**). The vocal cords should be visualized. Cricoid pressure (Sellick's maneuver) may make intubation more difficult. If the cricoid pressure is adversely impacting the view, it should be relaxed or even removed.[14] The application of cricoid pressure by an assistant pressing the cricoid cartilage back, upward, rightward, and posteriorly (in this sequence) can help bring the vocal cords into view when the intubator cannot apply more lifting force due to lack of strength or reluctance to lift the airway, as in a suspected neck injury. **This is known as the BURP maneuver.**[27]

Another anterior neck manipulation maneuver known as **optimal external laryngeal manipulation (OELM) or bimanual laryngoscopy** may be applied.[28] They differ from the BURP maneuver in that the intubator uses their right hand to manipulate the larynx into the optimal position while simultaneously viewing the patient's airway and controlling the laryngoscope with their left hand. An assistant then assumes control of the larynx, maintaining the same position as the intubator proceeds to insert the ET tube. Alternatively, to limit laryngeal movement during the hand-off, the intubator can use their right hand to manipulate an assistant's hand on the patient's larynx. When properly positioned, instruct the assistant to keep their hand still while the intubator removes their hand off the assistant's hand. A third variation uses the assistant to manipulate the patient's larynx while the intubator verbally directs them.

When the vocal cords are visualized, instruct the assistant to pass the ET tube into your right hand. This allows you to keep a "visual lock" on the vocal cords. Insert the ET tube into the right side of the patient's mouth. Advance the ET tube so that the tip reaches the vocal cords without letting the body of the tube block the view. Continue to advance the ET tube through the vocal cords until the cuff passes through them and into the trachea (**Figure 11-13C**). Advance the tube an additional 2 to 3 cm. **The tip and cuff of the ET tube must be visualized passing through the vocal cords to assure placement in the trachea.**

The fit of the ET tube through the vocal cords always seems to be tight, even in larger patients. A well-lubricated tip with the cuff completely collapsed is essential. Rolling the tube gently between the thumb and the index finger at the moment of insertion can also help pilot the tip between the vocal cords. If the ET tube is too large or the vocal cord opening narrow, ask the assistant to pass the smaller ET tube, which has already been prepared.

The average depth of insertion (in cm) of the ET tube starting from the patient's lips is listed in **Table 11-1**. It can also be calculated using one of the following formulas: ET tube ID (in mm) × 3, (age in years/2) + 12 for patients over 2 years of age to a maximum of 18 years of age, or age + 10 for children less than 8 years of age.

Once the ET tube has been inserted, the intubator's right hand must hold the tube in place continuously until it is properly secured. The assistant should inflate the ET tube cuff with the attached 10 mL syringe of air (**Figure 11-13D**) and then remove the syringe and stylet. **The intubator must hold the ET tube firmly to make sure that it does not become dislodged when the stylet is removed.** The assistant should attach the end-tidal CO_2 monitor and the bag-valve device to the ET tube. If symmetrical lung sounds are heard on auscultation and if pulse oximetry and CO_2 monitoring appear appropriate, secure the ET tube in position in the right corner of the patient's mouth (**Figure 11-13E**).

INTUBATING WITH THE (STRAIGHT) MILLER BLADE

Intubating with the straight blade is similar to the curved blade with a few differences. Insert the laryngoscope blade completely. If the epiglottis is seen, insert the tip directly under and slightly beyond it. Lift the epiglottis and airway as above by raising your hand along the long axis of the laryngoscope handle toward a point above the patient's chin (**Figure 11-11**). **If neither the epiglottis nor the vocal cords are seen, the tip of the laryngoscope blade is in the esophagus.** Locate the airway by lifting as above while slowly withdrawing the laryngoscope blade. As the tip slides back, it will "catch" the epiglottis and the airway should "fall down" into view. The BURP or OELM maneuver may now be applied if necessary. Some physicians use a variation of this to localize the epiglottis by inserting the blade

deeply and lifting, then withdrawing while feeling for the "give" as the epiglottis tip falls off of the retreating blade, and then readvancing a small distance to "scoop up" the epiglottis, exposing the airway. The remainder of the technique is the same as described above.

ASSESSMENT

In the Emergency Department, simple common-sense methods will quickly and accurately assess ET tube placement. The confirmation of ET intubation is briefly described in this section. Please refer to Chapter 12 for a more detailed discussion. **The assessment must be made quickly!** An ET tube in the wrong place, the esophagus, is as quickly dangerous as a properly placed one is lifesaving. **Was the ET tube visualized passing through the "A frame" of the vocal cords? This is the most important assessment.** If it was directly visualized being placed and continuously held in place, it is properly positioned. Is the pulse oximeter reading in the high 90s and steady or rising? Is the CO_2 monitoring appropriate? Be familiar with the monitor in your institution. Electronic monitors will show a respiratory waveform and a numerical value. In-line colorimetric monitors connected between the ET tube and the respiratory circuit will change color with inspiration and expiration to indicate the flow of CO_2 passed the device.

Evaluate the patient. Symmetrical upper chest rise without increasing abdominal size suggests proper placement. Persistent "fogging" or condensation inside the ET tube with each breath for at least six ventilations will also confirm proper placement. Auscultate lateral to the nipples for strong and symmetrical breath sounds during positive-pressure breaths. Avoid auscultating in the midline, where "normal" breath sounds can be heard from a misplaced ET tube in the esophagus. Auscultate at the lateral apices and bases of the lungs. Auscultate over the epigastrium. Correct placement will give strong, symmetrical breath sounds except in the epigastrium. If epigastric sounds are strongest or "gurgling" or vocalization is heard, assume incorrect ET tube placement. Breath sounds that are asymmetrical and stronger on the right indicate a right mainstem intubation. Deflate the cuff and gently withdraw the ET tube in 1 cm increments while auscultating. Continue to withdraw the ET tube until equal breath sounds are heard. Secure the tube and reinflate the cuff.

Obtain a chest radiograph after clinically confirming the placement of the ET tube. The tip of the radiopaque stripe of the ET tube should be over the third or fourth thoracic vertebra and 3 to 4 cm above the carina of the trachea. Always inspect the radiograph for any signs of a pneumomediastinum, pneumothorax, or hemothorax.

Clinical assessment of the ET tubes position should take less than 15 seconds. If you are unsure of the ET tube position, leave the first tube in place while applying cricoid pressure. If the patient's pulse oximetry reading is in the mid- to high 90s, reinsert the laryngoscope and look to see if the ET tube is passing between the vocal cords. Alternatively, the ET tube can be removed and intubation reattempted. If the pulse oximetry is low, remove the ET tube and ventilate the patient with a bag-valve-mask device for 30 to 60 seconds to allow the pulse oximetry to rise into the high 90s before making a second attempt at intubation. **Do not ventilate the patient by a bag-valve-mask without the application of cricoid pressure. The stomach can inflate with air and increase the risk of aspiration.**

Some physicians prefer to leave the misplaced ET tube in place. Leaving the first tube might seem to complicate subsequent intubation attempts but can serve to vent gastric vomit out of the oropharynx as well as to locate the esophageal entrance during the next attempt at direct visualization of the airway.

As long as ventilation is possible with the bag-valve-mask device and pulse oximetry can be maintained above 92% ($PO_2 = 60$ mmHg), two or three attempts can be made at orotracheal intubation. If 30 seconds elapse or pulse oximetry falls to 92%, stop the intubation attempt and ventilate the patient for 30 to 60 seconds, as above. In training programs, the third attempt should be made by the most skilled person available. Three failed attempts define a "failed airway" and call for rescue intubation by an alternative method. **Any patient in whom bag-valve-mask ventilation becomes impossible must be given a surgical airway.**

AFTERCARE

The ET tube must be secured to prevent it from migrating distally or proximally. The traditional method of wrapping tape around the ET tube then around the patient's head is rarely used today. If used properly, tape functions just as well or better than commercially available ET tube holders.[19] A variety of disposable, relatively inexpensive, and single patient use ET tube holders are commercially available. They are easy to apply, adjust, and reposition if necessary. The basic unit is a nonlatex plastic ET tube holder that positions over the patient's mouth, a cushioned neckband, and Velcro closures for a snug fit. There are many variations of this basic unit.

A nasogastric tube or orogastric tube is often placed after orotracheal intubation to remove air, fluid, and gastric juices from the stomach. This tube must also be secured. It is either taped to the patient's face or to the ET tube to prevent it from migrating distally or proximally. One specific ET tube holder is a novel device that deserves mention. The Intubix™ (Intubix LLC, Houston, TX) is an ET tube holder with a built-in bite guard and orogastric tube side port (**Figure 11-14**). It allows the blind passage of the orogastric tube through the side port as well as securing it in position.

Postintubation management should include pain control, sedation, and paralysis if indicated. The patient should be sedated, and possibly paralyzed depending on the situation, so they do not fight the ET tube and extubate themselves. **The patient should never be paralyzed and not sedated so they are aware and but unable to respond. This is considered cruel.** Administer an opioid analgesic as required for pain control. The patient may require repeated bolus dosing of these medications or a continuous infusion for analgesia, sedation, and/or paralysis depending on their condition.

COMPLICATIONS

HYPOXEMIA AND MISPLACED ET TUBES

Hypoxia is the most destructive complication. It often results from prolonged intubation attempts, with or without proper preoxygenation, and unrecognized misplaced ET tubes. Without adequate oxygenation, irreversible brain injury begins to occur within 2 to 3 minutes. Hypoxia can result in cardiac arrhythmias.

An unrecognized esophageal intubation will result in significant morbidity and mortality. After intubation, the proper ET tube placement should be confirmed by auscultation, chest rise, fogging in the ET tube, end-tidal CO_2 monitoring, and chest radiography. **Any manipulation or movement of the ET tube or the patient's upper body (head, neck, and torso) should be followed by an assessment of the ET tube position. It can easily become dislodged and migrate into the hypopharynx and esophagus.** Other methods to confirm ET tube placement include inserting a fiberoptic bronchoscope through the ET tube and visualizing the tracheal rings and carina (Chapter 21) or inserting a lighted stylet and following the illumination into the trachea (Chapter 17).

CARDIOVASCULAR COMPLICATIONS

Bradycardia can be produced by pharyngeal manipulation. It may be especially pronounced in children because of their higher vagal

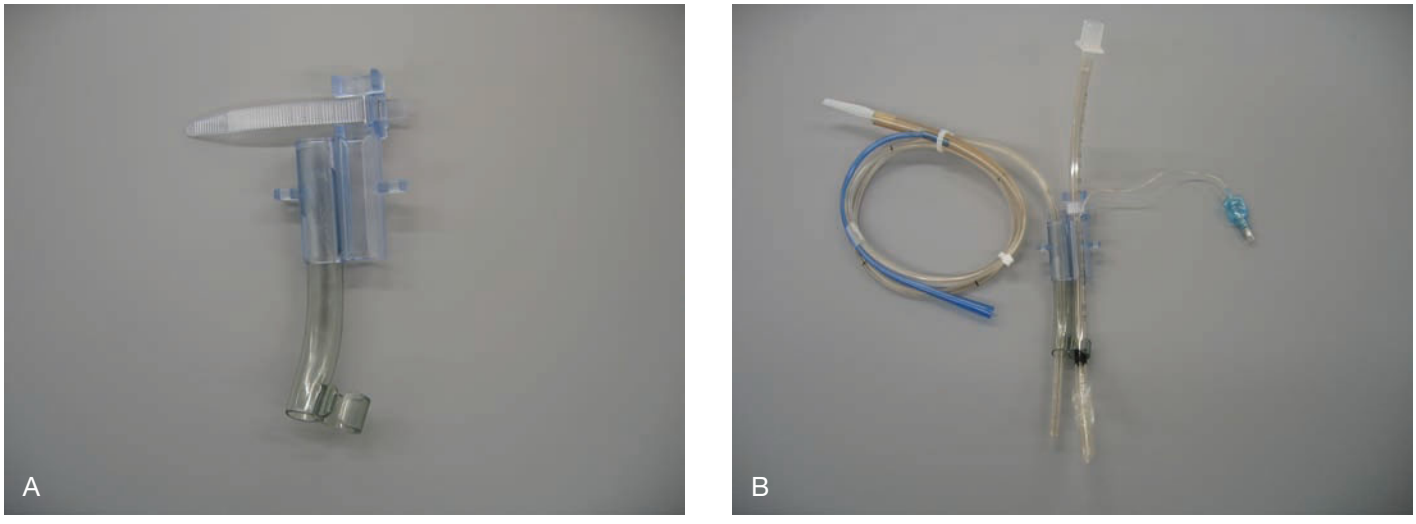


FIGURE 11-14. The Intubix ET tube holder. **A.** The unit. **B.** The unit with an ET tube and an orogastric tube attached.

tone. Pretreatment with atropine (0.02 mg/kg with a minimum dose of 0.15 mg) in children under 6 years of age can avoid this. It will also serve to decrease airway secretions.

Increased intracranial pressure can occur as a result of the direct laryngoscopy. The exact cause of this transient rise is unknown. Lidocaine has been postulated as being of benefit in blunting this but is so far unproven. A dose of 1.5 to 2.0 mg/kg IV may be used as a premedication if time allows and the patient's condition warrants its use.

MECHANICAL COMPLICATIONS

Direct mechanical complications from the laryngoscope include lacerations of the lips, trauma to the pharyngeal wall, broken teeth, or dentures that may be aspirated and require later removal. Vomiting can cause subsequent chemical and bacterial pneumonitis. A pneumothorax is a rarely seen complication of laryngoscopy. It is more often associated with positive-pressure ventilation. Laryngoscopy may cause apnea, bronchospasm, and/or laryngospasm due to prolonged stimulation of the pharynx.

Laryngospasm may result from insertion of the laryngoscope blade or attempts to advance the ET tube through the vocal cords. This occurs more often in patients who are awake, semiconscious, not paralyzed, and not anesthetized. It may be prevented by the application of nebulized lidocaine, topical anesthetic spray, transtracheal injection of lidocaine, or laryngeal nerve blocks. If laryngospasm occurs during intubation, remove the laryngoscope and begin positive-pressure ventilation. **Positive-pressure ventilation will often overcome the laryngospasm. If not, consider paralyzing the patient immediately with succinylcholine or performing a surgical airway.**

The ET tube and stylet can be a source of mechanical complications.[15,17,18] A sore throat is a common and self-resolving nuisance. Uvular necrosis occurs when it is compressed between the ET tube and palate. This rare complication is self-limited and often heals within 2 weeks. Treatment includes antihistamines, steroids, and possibly antibiotics. The stylet protruding from the distal end of the ET tube can cause soft tissue contusions and lacerations, perforation of the vocal cords, hemorrhage into the airway, and perforation of the trachea. Proper stylet placement with its tip within the ET tube will prevent these complications. ET tube cuff overinflation can result in mucosal sluffing, pressure necrosis, and hemorrhage. Tracheal rupture is a rare but life-threatening complication.[17,18] It may be due to cuff overinflation, a protruding stylet, intubation using more rigid and less pliable stylets, pushing through a weakness or defect, or from multiple intubation attempts. The complications associated with cuff overinflation can be prevented by using manometry, which is seldom used.

AIR LEAKS

A "leak" of air out from the patient's mouth or nose during ventilation signifies a mechanical problem with the ET tube. If the cuff is damaged, the ET tube must be removed and replaced. Check the position of the ET tube by direct laryngoscopy. If the cuff is located between or above the vocal cords, it will not secure the airway properly. Deflate the cuff, advance it through the vocal cords, and reinflate the cuff. If the cuff slowly deflates, there may be a leak in the pilot balloon. Reinflate the cuff and apply a hemostat to the tubing attached to the pilot balloon or attach a closed stopcock to the inflation port.

ASPIRATION

The risk of aspiration increases in patients with difficult airways or full stomachs. This includes obese and pregnant patients. The use of an awake ET intubation or rapid sequence induction with cricoid pressure may minimize the risk of aspiration. **A properly placed ET tube with the cuff inflated will decrease, but not totally eliminate, the risk of aspiration.**

THE UTILITY OF THE SELLICK MANEUVER

The use of cricoid pressure was introduced in 1774 in its use to prevent gastric distention during artificial ventilation of drowning victims.[29] Sellick reintroduced the application of cricoid pressure in 1961.[30] Cricoid pressure theoretically causes an occlusion of the upper esophagus by trapping it between the cricoid cartilage and the vertebral bodies. It has since been used on a daily basis for rapid sequence induction by Anesthesiologists and Emergency Physicians. This maneuver was thought to prevent regurgitation and gastric insufflation during positive-pressure ventilation. The application of cricoid pressure was later termed the "Sellick maneuver."

Sellick's original publications were small observational studies self-reporting on his technique. These studies were not blinded, controlled, or randomized. Several subsequent studies determined the amount of force required to occlude the esophagus on cadavers

and patients. It is not practical or possible to measure the cricoid force applied during clinical care in the Emergency Department.

Multiple studies have found adverse effects associated with the Sellick maneuver.[28,31–35] It can worsen the laryngoscopic view of the airway. Other complications include bruising, airway obstruction, cricoid cartilage fracture, goiter hemorrhage, subconjunctival hemorrhage, and esophageal rupture. Cricoid pressure decreases lower esophageal sphincter tone and may explain in part the cases of pulmonary aspiration prior to intubation.

Although the Sellick maneuver is considered a "standard of care," very little evidence supports its use to prevent aspiration.[33–35] This does not mean that the Sellick maneuver should not be performed! It may be of benefit to prevent aspiration, especially in the Emergency Department where patients often have "full stomachs." If intubation or ventilation is difficult using the Sellick maneuver, slowly release cricoid pressure in an attempt to improve ventilation or airway visualization.

ENDOTRACHEAL CUFF PRESSURE

Inflation of the ET tube cuff is required to adequately ventilate a patient without an air leak, provide positive-pressure ventilation, and prevent aspiration. There can be a fine line between proper cuff inflation and overinflation. One of the goals of any procedure is to prevent complications from the procedure itself. Overinflation of the ET tube cuff can result in mucosal necrosis, mucosal sloughing, hemorrhage, tracheal rupture, or subsequent tracheal stenosis. Physicians have traditionally palpated the pilot balloon to estimate cuff pressure and prevent any complications from overinflation. This method is not accurate.[36,37]

Measurement of the cuff pressure is a simple, quick, and inexpensive procedure. It should be considered whenever a patient is intubated.[38] Cuff pressure should be measured if a patient is transported by air as the cuff pressure changes at elevated altitudes.[39,40] A pressure of up to 20 cmH_2O provides an adequate seal, without compromising mucosal blood flow and lowers the risk of subsequent subglottic stenosis. Tracheal mucosal blood flow shows a decline at 30 cmH_2O, and is completely blocked at 45 cmH_2O. An ET tube cuff pressure manometer is needed to measure these pressures accurately.

There are numerous methods to quickly assess cuff pressure. Palpation is not accurate and should not be used. The simplest method is to use a manometer. These devices (Cufflator, Posey Corp., Pasadena, CA or Rusch Endotest, Teleflex Medical, Research Triangle Park, NC) allow the simultaneous inflation of the cuff while monitoring the cuff pressure on a dial. These devices function similarly to those used to inflate a car tire. While simple to use, they can be cumbersome due to their shape and weight. An in-line device that attaches to the cuff inflation port is available (PressureEasy Cuff Pressure Controller, Smiths-Medical, Dublin, OH). The device has an indicator window that signals when the cuff pressure is maintained between 20 and 30 cmH_2O. A third novel device is the Pressure Alert Endotracheal Tube (www.jamesdysonaward.org/projects/project.aspx?ID=598). This device is not yet commercially available. It incorporates a "pop-up" button into the pilot balloon that alerts the user when the cuff pressure is too high.

SUMMARY

Orotracheal intubation is both common and lifesaving. It is the primary and preferred method of airway management. Every Emergency Physician must master this skill. With proper preparation, definitive control of the airway can be obtained. This assures that patients can be oxygenated and ventilated when they cannot do this on their own. Good team leadership skills are nearly as important as physical dexterity and assure an orderly and quick procedure. Rapid patient assessment is important to prevent complications. If orotracheal intubation is unsuccessful, another form of intubation or a surgical airway should be performed.

12 Confirmation of Endotracheal Intubation

Tarlan Hedayati and Leonardo Rodriguez

INTRODUCTION

This chapter will review the various methods utilized to confirm appropriate endotracheal (ET) intubation. **Direct visualization of the ET tube passing through the vocal cords is the preferred method for the initial assessment of a properly placed airway.** Unfortunately, this is not always feasible. Rates for incorrect ET tube placement have been noted to be up to 25%.[1,2] **The verification of correct ET tube placement is as or more important than the intubation procedure. Lack of proper confirmation of ET tube placement has the potential for serious patient harm and catastrophic outcomes if unrecognized and uncorrected.**

For approximately 20 years, there has been ongoing research and development to improve upon the basic techniques of physical examination confirmation of ET intubation. Physical examination with auscultation has been found to be inadequately sensitive (94%) and specific (83%) as an independent method for confirmation of correct ET tube placement.[3] This chapter discusses the use of physical exam findings, esophageal detection devices (syringe and bulb), carbon dioxide (CO_2) detection devices (a qualitative detector and a continuous quantitative monitor), and imaging techniques (radiography and ultrasound). Each method is described for a patient with normal anatomy and the absence of any pathology (e.g., neck or chest trauma). While all these methods can be used in all patients, certain patient conditions or pathology may affect the accuracy of some methods. **No single method is universally or completely reliable, obviating the need for a multiple method approach.** This multiple method approach to confirmation of ET intubation is now the accepted practice according to The American College of Emergency Physicians (ACEP) Board of Directors policy statement as of April 2009.[4]

PHYSICAL EXAMINATION

Since the advent of ET intubation, the use of physical examination methods has been the mainstay for the initial evaluation of proper ET tube placement. Direct visualization of the insertion of the ET tube through the vocal cords and into the trachea is the first method to confirm proper ET tube placement. Postintubation direct visualization of the ET tube using laryngoscopy or bronchoscopy, noting tracheal rings past the end of the ET tube, is the next best method of assessing correct ET tube placement.

Secondary methods for confirmation of ET intubation are an absolute requirement. Auscultate the chest and abdomen to assess for delivery of air to the lungs via either a bag-valve device or a mechanical ventilator (**Figure 12-1**). First, auscultate over the epigastrium to assess for the absence of sounds in the stomach. The presence of an enlarging abdomen or audible air inflation into the stomach with each positive-pressure ventilation may be the initial sign of an ET tube in the esophagus or an esophageal intubation. The next auscultation points are located at the chest wall lateral to the nipples. Auscultate bilaterally from top to bottom for the presence and equality of breath sounds. **Avoid auscultating over the**

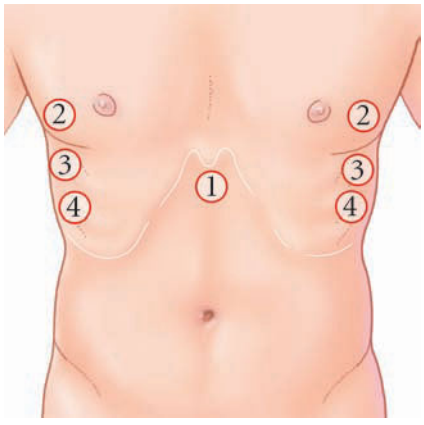


FIGURE 12-1. The order of auscultation after intubation to confirm ET tube placement begins at the epigastrium[1] listening for the absence of air sounds, then down both sides of the chest wall, just lateral to the nipple line.[2–4]



FIGURE 12-2. Examples of the bulb and the syringe esophageal detector device (Photo courtesy of Wolf Tory Medical, Salt Lake City, UT).

central portion of the chest. This may lead to the misinterpretation of the transmission of esophageal or gastric inflation.[5] These sounds may mimic airway breath sounds and lead to failure in detecting an esophageal intubation.

The final note pertaining to auscultation involves equality of breath sounds. The anatomy of the left and right mainstem bronchi allow for a preferential right mainstem bronchial intubation when the ET tube is placed too deep. As a general rule, insertion in centimeters to a depth three times the diameter size of the ET tube (e.g., 21 cm for a 7.0 mm size ET tube) at the level of the incisor teeth is preferred. This will generally place the ET tube approximately 3 to 4 cm above the carina in an adult.[6] If breath sounds are stronger over the right lung fields, deflate the ET tube cuff and gradually withdraw the ET tube in 1 cm increments until the bilateral breath sounds are equal. This will prevent complications from inadequate ventilation and oxygenation as well as resultant pulmonary edema in the nonventilated lung.[7] Please refer to Chapter 11 for a more complete discussion of ET tube size, insertion depth, and placement for adults and children.

The next assessment involves taking a step back and visualizing the chest wall and ET tube characteristics with each breath. Unequal or a lack of chest rise and fall with each instilled breath may indicate a misplaced ET tube either in a mainstem bronchus or in the esophagus, respectively. Condensation and/or fogging in the ET tube with each breath has been used frequently in the past to confirm proper ET tube placement. This has been proven to be an unreliable source of confirmation.[8] It should only be used in conjunction with auscultation and visualization of bilateral chest wall movement. The presence of vomit in the ET tube, in the absence of an aspiration event, may be a sign of an esophageal intubation.

The final postintubation physical assessment is an evaluation of oxygenation via skin signs and, more reliably, pulse oximetry. Cyanosis and a downtrending oxygen saturation seen on a pulse oximeter are delayed findings. The patient may experience significant hypoxemia before cyanosis appears or before there is a significant drop in the pulse oximetry. **Do not rely upon cyanosis and pulse oximetry as a first-line assessment to confirm proper ET tube placement.**

ESOPHAGEAL DETECTOR DEVICES

Esophageal manometer devices utilize the structural differences between the trachea and esophagus in determining correct ET tube placement. The semicircular tracheal cartilaginous rings provide a constant open passage for the flow of air. The tubular esophagus with its lack of a luminal support structure collapses and prevents movement of air when suction is applied.[9] The two types of ET tube confirmation devices that rely on this anatomical variance are the syringe and the manometer or bulb methods (**Figures 12-2 & 12-3**).

The syringe method relies on a gradual and constant retraction of the plunger, while its tip is attached to the proximal end of the ET tube utilizing a manufactured connector (**Figure 12-3**).[10] The plunger will draw back easily and without resistance if the ET tube is correctly placed in the trachea (**Figure 12-3A**). The volume of aspirated air should be greater than 30 mL over a period less than 4 seconds.[11] Resistance when drawing back the plunger is seen when the distal end of the ET tube is incorrectly placed in the esophagus (**Figure 12-3B**). An airtight seal must be created between the syringe and the ET tube to prevent any air leak that would lead to a false-positive test and result in the assumption that the ET tube is in the trachea.

Similarly, the manometer or bulb method relies on the collapse of the esophageal wall. Compress the bulb to remove any air contained within. Firmly and securely apply the bulb to the proximal end of the ET tube while still compressing the bulb. Release compression on the bulb. If the bulb inflates fully and easily, the ET tube is presumably in the trachea. If the bulb does not inflate fully and easily, the ET tube is presumably in the esophagus.

There are numerous circumstances with which an esophageal detector device has repeatedly failed to identify an improperly placed ET tube.[9–14] Most notably is after bag-valve-mask ventilations in the absence of cricoid pressure. The stomach and esophagus can inflate with air and allow for easy flow of air into the device simulating airflow from the airway. The device may fail to detect a misplaced ET tube when the distal end of the ET tube is just above the vocal cords. In this instance, there is no resistance to airflow and the bulb or syringe device easily fills with air.

This method has been shown to falsely identify an esophageal intubation when the ET tube is placed into a mainstem bronchus or the tip of the ET tube is pressed against the tracheal wall. The subsequent resistance to back flow of air into the syringe or bulb mimics that of the collapsed wall of the esophagus. If this should occur, withdraw the ET tube 1 cm and attempt using the esophageal detector device again. Repositioning should continue to result in resistance to aspiration or bulb inflation if the ET tube is in the esophagus. The presence of heavy or thick pulmonary secretions or fluid in the lungs can plug the airways and reduce the flow of air to prevent air aspiration by the syringe or bulb inflation.[12] Care must be taken so

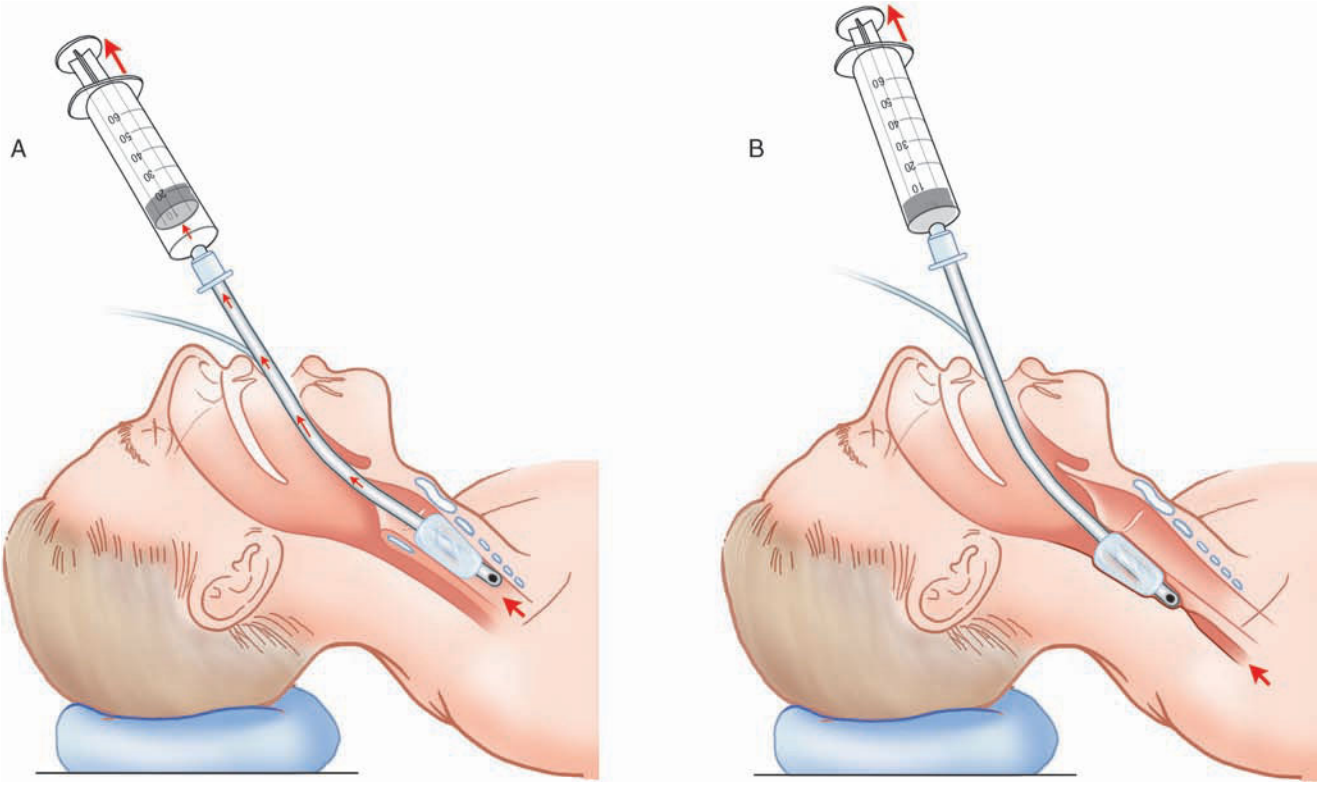


FIGURE 12-3. Using the syringe esophageal detector device. **A.** Correct placement of the ET tube in the trachea allows for aspiration of air. **B.** Placement of the ET tube in the esophagus will result in resistance to aspiration due to collapse of the esophageal wall.

as not to rapidly aspirate and potentially draw the tracheal mucosa into and obstructing the ET tube yielding a false-negative result.[11] In the obese patient, the posterior noncartilaginous segment of the tracheal has been shown to collapse into the trachea and prevent the flow of air.[13–16]

When taking into account the limitations of esophageal detection devices and their use as an adjunct to other methods, they can provide a rapid and inexpensive method for confirming ET tube placement.[17–19] This is especially evident in the patient with circulatory collapse, hypotension, cardiac arrest, or a pulmonary embolism where other devices are limited.[18]

CARBON DIOXIDE DETECTORS AND CAPNOGRAPHY

Since 1985, the utility of end-tidal CO_2 detection as a means for confirming proper ET intubation has been studied and recently confirmed to be the "most accurate" modality according to ACEP.[20] The premise of end-tidal CO_2 detection devices requires the presence of exhaled CO_2 passing through and exiting the ET tube. Adequate circulation is required for CO_2 to be produced and transported from the lung parenchyma. The accuracy of this modality relies on its use in the noncirculatory collapsed/cardiac arrest patient. The April 2009 ACEP Board of Directors statement goes further to state that end-tidal CO_2 detection, using either qualitative or quantitative methods, approaches 100% sensitivity and specificity in the patient with an inflated cuffed ET tube and spontaneous circulation. Nearly every case of a false-negative detection of a correct ET tube placement (i.e., correct ET tube placement in the absence of end-tidal CO_2 detection) has been discovered in the cardiac arrest patient.[15,16,21–25]

End-tidal CO_2 detection devices can be utilized either qualitatively as a one-time spot check using a colorimetric detector or can be monitored continuously via capnography. Both are utilized in a similar fashion. They are in-line devices that have two connectors, one of which attaches to the proximal end of the ET tube and the other attaches to the oxygen delivery device (bag-valve device or mechanical ventilator tubing).

The colorimetric end-tidal CO_2 detector utilizes a piece of pH-sensitive material that lies beneath a clear plastic window. The presence of CO_2 flowing through the device, typically using six manual breaths as the maximum number needed and the minimum amount to clear any gastric CO_2, causes a color change from purple to yellow that then changes back to purple in the absence of CO_2 (**Figure 12-4**). The minimum concentration of end-tidal CO_2 required for a color change is 0.5%. This is one reason that the recent literature has focused on whether newborns and children produce sufficient quantities of end-tidal CO_2 for accurate detection.

Capnography, or continuous quantitative graphical demonstration of end-tidal CO_2 detection, involves placement of an infrared



FIGURE 12-4. Colorimetric end-tidal CO_2 detectors before (left) and after (right) exposure to exhaled CO_2. Note the change in the color of the pH paper from purple to yellow when exposed to CO_2.

detector in-line between the end of the ET tube and the oxygen delivery device (bag-valve device or ventilator tubing). The infrared detector is then connected with a cable to the electronic monitor that interprets the reading and generates a waveform representation of the end-tidal CO_2 levels. One of the advantages of this method over the qualitative approach is the ongoing monitoring of CO_2 production. This allows a continuous assessment of the airway as well as the overall quality of resuscitative efforts with some determination of outcome.[3]

The main disadvantage CO_2 detectors for confirmation of ET intubation are false-negative results in poor perfusion states, cardiopulmonary arrests, and the presence of secretions on the device. In the noncardiac arrest patient with adequate cardiac output and pulmonary flow, sensitivities approach 100% (76% in cardiac arrest) for ruling out esophageal intubation have been found in patients of all ages.[26–28]

If the distal end of the ET tube is located just above the vocal cords in the hypopharynx, a false-positive result may lead the physician to believe the airway is secure. The device may detect adequate levels of CO_2 without a properly secured and definitive airway in the trachea. False-positive results from an improperly placed ET tube erroneously believed to be in the trachea may occur when the device is used a short time after the patient has consumed a carbonated beverage. The device cannot recognize that the CO_2 is actually coming from the stomach.

The universal presence of capnography is not yet a reality. Its utility in most circumstances with few exceptions is undeniable. The colorimetric end-tidal CO_2 detector is equally reliable to capnography. It is a disposable, rapid, less expensive, and more widely available means to assess proper ET tube placement in the noncardiac arrest patient.[20]

RADIOGRAPHY

Although there may be a lack of availability of capnography in most Emergency Departments, this is far less an issue with either radiography or ultrasonography.[29] These methods, unlike those mentioned previously, are unique in that they rely on anatomic relationships for confirmation of ET tube placement. Radiography and ultrasonography may be particularly useful in the cardiac arrest patient.

The main utility for radiography in the confirmation of ET intubation lies in its ability to detect whether the ET tube is placed too deeply into the trachea. Locating the end of the ET tube approximately 3 to 4 cm above the carina may prevent some of the complications associated with a right mainstem intubation. The postintubation chest radiograph can assist in identifying any complications that may have resulted during the intubation. This includes aspiration, tracheal injury, a pneumomediastinum, or a pneumothorax. **The postintubation chest radiograph does little to distinguish between esophageal versus tracheal intubation. The delay in obtaining a radiograph to confirm ET tube placement puts the patient at significant risk.**

ULTRASONOGRAPHY

The use of ultrasound (US) in the Emergency Department has gained significant popularity in the diagnosis of various diseases and pathology. There are multiple methods for utilizing US guidance to assess for proper ET tube placement. Two common methods of confirming proper ET tube placement are described below. The benefits of these two methods are that ventilation is not required for ET tube placement confirmation and, in the case of an accidental esophageal intubation, there is no risk of inflating the stomach, or its resultant emesis and aspiration of gastric contents.

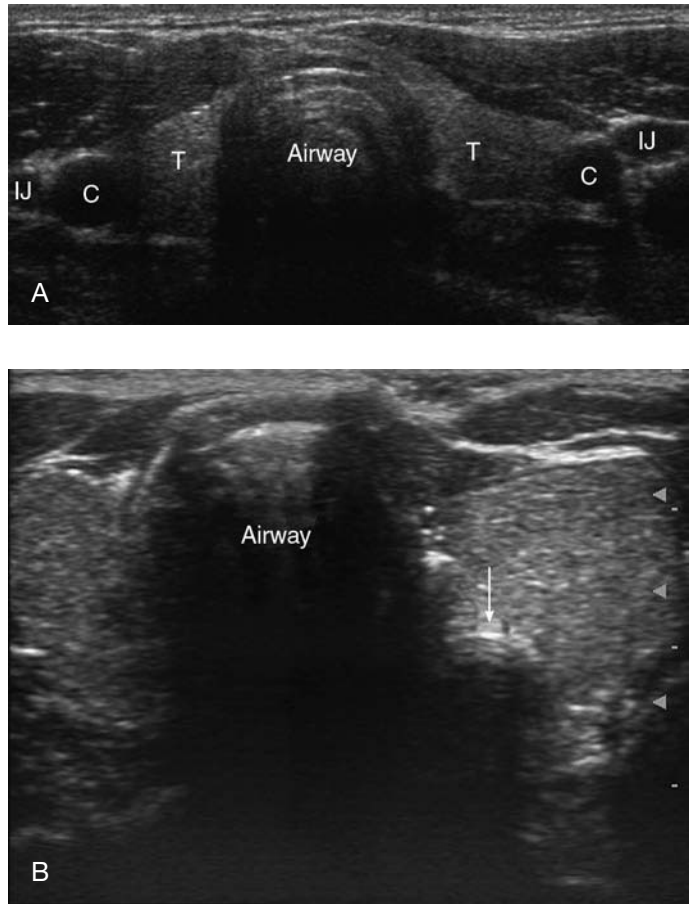


FIGURE 12-5. Ultrasound images at the level of the sternal notch to confirm proper ET tube placement. **A.** Endotracheal intubation. The signature double echo of the plastic ET tube can be seen in the airway or trachea. (C, carotid artery; IJ, internal jugular vein; T, thyroid gland). **B.** Esophageal intubation. The ET tube (*arrow*) is in the esophagus. It is positioned deep and lateral to the airway (Ultrasound images courtesy of Sam Hsu, MD).

The first method uses a high frequency linear US transducer. Place the US probe horizontally at the level of the suprasternal notch. A properly placed ET tube in the trachea will show the shadowing of the ET tube posteriorly without direct visualization of the esophagus (**Figure 12-5A**). In the event of an esophageal intubation, the trachea appears similarly to the previously described image but the esophagus will be visualized just to the left of the trachea with posterior shadowing due to the presence of the ET tube (**Figure 12-5B**). A small, prospective, randomized, controlled study found 100% sensitivity and 100% specificity in the accuracy of US as a modality to confirm ET tube placement.[30]

The second technique uses similar methodology over the cricothyroid membrane. Place the US transducer longitudinally over the cricothyroid membrane to identify and the hyperechoic anterior and posterior laryngeal walls are identified. The appearance of a "snowstorm" pattern between the two lines indicates correct ET tube placement.[31]

Foreign bodies are often hyperechoic and appear bright white on US. One study looked at using US to confirm ET tube placement both with and without a stylet within the ET tube.[34] The basic idea being the addition of the stylet would increase the sensitivity and specificity of identifying correct ET tube placement. It would add additional hyperechoic shadows to those of the ET tube. The use of a stylet did not improve the US localization of the ET tube within the trachea.

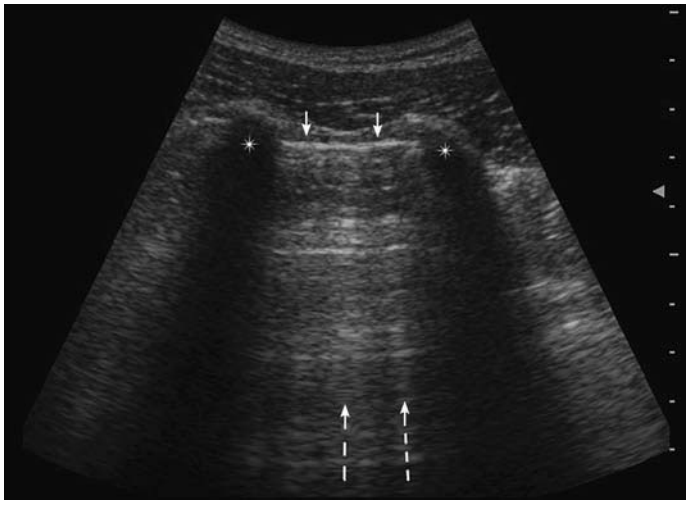


FIGURE 12-6. Ultrasound through the chest wall demonstrating the bright interface (*solid arrows*) of the visceral and parietal pleura generating the "sliding lung sign" during ventilation. The dashed arrows demonstrate echogenic bands moving side-to-side with ventilations. The asterisks (*) identify the ribs (Ultrasound image courtesy of Sam Hsu, MD).

Ultrasonography of the chest wall has been studied as a method of confirming ET tube placement.[32] This method does require ventilation of the patient in that it utilizes the visceral–parietal pleural interface of the lungs to confirm inflation of the lung. Apply the US probe to the anterior-superior chest wall. Orient the US probe vertically over the second and third ribs in the midclavicular line. The visceral and parietal pleural interface can be seen and appreciated as the so-called "sliding lung sign" (**Figure 12-6**). The hyperechoic interface will be seen moving back and forth with each respiration.[32]

TRACHEAL TUBE INTRODUCERS

The tracheal tube introducer (TTI) or gum elastic bougie has long been used by Anesthesiologists to intubate in difficult conditions. The TTI is a flexible rod-like device whose distal end is slightly angled. It is inserted through the patient's vocal cords with the angled tip facing anteriorly during direct laryngoscopy. It is then advanced into the trachea. Advancement of the TTI causes the tip to slide along the anterior tracheal cartilage rings. A "click" is palpable as the tip crosses each tracheal ring. Eventually, the TTI will stop or "hang-up" as it passes into smaller bronchi. The ET tube is then advanced over the TTI and into the lung.

Intubate the patient using direct laryngoscopy. To verify proper positioning of the ET tube, insert the lubricated TTI into the ET tube with the angled tip facing anteriorly. Advance the TTI through the ET tube. The tip should catch on each tracheal ring and "click" to verify proper ET tube position. The lack of any "clicks" or "hang-up" suggests an esophageal intubation. Like all other methods of confirming ET intubation, this method is not 100% perfect.[33]

SUMMARY

Insertion of an ET tube always requires verification that it is properly placed. No one tool or technique is sufficient for any or all situations or circumstances. The best method to confirm proper ET tube placement involves utilizing multiple methods, keeping limitations in mind, and ongoing repeat assessments. Any change in a patient's clinical condition requires reverification that the ET tube is still properly positioned. The ongoing research and development of improved methods obviates the critical importance of rapid and accurate confirmation of ET intubation.

13 Video-Assisted Orotracheal Intubation Devices

Pholaphat Charles Inboriboon

INTRODUCTION

Direct laryngoscopy was introduced in 1895 by Afred Kirstein. Since that time, physicians have developed instruments to improve visualization of the larynx while limiting tissue trauma. The Macintosh and Miller laryngoscope blades were developed in the 1940s and have been the primary tool for endotracheal (ET) intubation.[1] Although they have been effectively used for most ET intubations, there are limitations to their ability to allow direct visualization of the glottis and surrounding structures. Numerous adjuncts have since been developed to assist in ET intubation.[1]

The recent development of video laryngoscopy marks a new era in airway management. Traditional direct laryngoscopy requires alignment of the oral, pharyngeal, and laryngeal axes to visualize the glottis (**Figure 6-5**). Despite mechanical manipulation, it is not always possible to align these three axes. **The major advantage of video laryngoscopy is that it does not require the Emergency Physician to align the three airway axes, reducing the need for manipulation and potential traumatic forces on the airway.[2] Through the use of a video camera, video laryngoscopes provide a superior view of the glottis when compared to traditional direct laryngoscopy. The eye of the video laryngoscope camera is within centimeters of the glottis and provides a wider angle of vision than the 15° of traditional direct laryngoscopy. The video monitor magnifies the view of the airway making structures easier to visualize.** This chapter reviews a representative number and types of devices currently available and used in Emergency Departments.

PENTAX AIRWAY SCOPE

The Pentax Airway Scope (Pentax Medical CO., Montvale, NJ), also known as the Pentax AWS or the AWS, is a rigid video laryngoscope (**Figure 13-1**). It incorporates the blade, camera, and an ET tube targeting mechanism into one device. It is designed for use in the prehospital setting, Emergency Department, and operating room.[3,4]

INDICATIONS AND CONTRAINDICATIONS

The AWS can be used for elective and emergent intubations. Patients with their head and neck immobilized can benefit from intubation with this device. It provides better visualization of the glottis, decreased cervical movement, and a higher success rate in comparison to traditional direct laryngoscopy.[5,6] Intubation with the AWS produces less airway stimulation than either the Glidescope or traditional laryngoscopes, thus minimizing the hemodynamic changes associated with intubation.[6,7] There are no contraindications to the use of the AWS.

EQUIPMENT

The AWS incorporates an imaging system and a targeting system into one portable tool. It is ergonomically designed to minimize tissue trauma. Its use does not require the alignment of the three airway axes. The imaging system provides an illuminated 90° field of view.[3] The AWS produces better glottic visualization than



FIGURE 13-1. The Pentax AWS (Photo courtesy of Pentax Medical Co., Montvale, NJ).

traditional direct laryngoscopy.[32] The external shell is composed of a water-resistant plastic making it suitable for use in the prehospital setting and the Emergency Department.

The body is an integrated 12 cm long cable attached to a charge-coupled device camera and a 2.4 in full-color LCD monitor (**Figure 13-1**). The monitor is hinged and allows a 0° to 120° angle for optimal viewing. The monitor screen incorporates a target symbol used to facilitate intubation. External monitoring and recording can be utilized with the external output. The device is battery operated utilizing two AA alkaline batteries for 1 hour of continuous operation.

The PBLADE is a plastic, single-use, disposable, and transparent laryngoscope blade that attaches to the body of the AWS (**Figure 13-1**). It is designed to follow the natural curvature of the upper airway and minimize the need for manipulation of the three airway axes. The PBLADE is composed of Lexan plastic that resists fogging, but not to the extent of the Glidescope antifogging mechanism.[8] The fiberoptic cable and camera rest inside the cavity of the PBLADE. An ET tube is loaded into a track located on the right side of the PBLADE. It accommodates a size 6.0 to 8.5 ET tube. Through the use of this guided track, intubation is performed without the use of a stylet. Suctioning can be performed under direct visualization with a 4.0 mm (12 Fr) or smaller suction catheter inserted through the PBLADE's suction port.

PREPARATION

Prepare and check the AWS before each use. Turn on the device. The video image and target symbol should appear on the monitor. The power lamp below the monitor should illuminate. Immediately replace the batteries if the monitor displays a flickering battery image. Check the light source. Place a hand below the tip of scope to ensure that it is illuminating. **Do not look directly at the light source.**

Attach the PBLADE to the AWS. Loosen the lock ring on the scope by rotating it in a leftward direction. **Align the triangular marks on the PBLADE and on the AWS body to ensure proper positioning prior to connection.** Insert the flexible fiberoptic tube through the scope insertion port on the PBLADE. Realign the triangular marks. Keep the connector ring pressed in the direction of the scope body and push in the connector of the PBLADE. Release the connector ring. Confirm that the PBLADE is firmly attached and that the tip of the AWS comes into close contact with the scope window. Secure the connection by turning the lock ring in the rightward direction.

Load the ET tube. Liberally lubricate the ET tube with a water-soluble lubricant. Insert the ET tube by sliding it along the ET tube-guide groove. Fix the ET tube onto the hooks located on the proximal end of the PBLADE. Adjust the ET tube so that the tip is aligned with the inferior edge of the PBLADE tip (**Figure 13-1**). Apply medical grade antifogging to the outside of the PBLADE's scope window.

TECHNIQUE

Gently insert the PBLADE into the patient's mouth similar to a traditional laryngoscope blade. Insert it along the right side of the mouth. Gently and slowly advance the PBLADE. Always visually observe the blade as it is inserted to prevent damage to the patient's lips, teeth, and other soft tissues during insertion. **Do not put pressure on the teeth and make sure that the tongue is not pushed inward while inserting the PBLADE.** Once inserted, reposition the device to the midline.

Observe the monitor to visualize the airway and epiglottis. Secretions can be suctioned by introducing a 12 French suction catheter through the suction catheter insertion port. Perform suctioning while observing the location of the suction catheter tip on the monitor. Visualize the epiglottis. Slide the epiglottis lifting blade underneath the epiglottis. Gently elevate the device to elevate the epiglottis. Gently manipulate the device until the glottis is aligned with the target symbol on the monitor screen. Gently advance the ET tube through the glottis until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Detach the ET tube from the hooks. Gently remove the PBLADE from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

ALTERNATIVE TECHNIQUES

In rare circumstances, the Emergency Physician cannot be positioned above the patient's head. An inferior or lateral approach can be utilized. Insert the PBLADE as described above. Adjust the position of the screen using the hinge to obtain an optimal viewing angle. Once the epiglottis is visualized, the remainder of the technique is exactly as described previously. It may feel awkward to manipulate the device and the ET tube from a position inferior or adjacent to the patient's head.

Insertion of the fully assembled AWS may not be possible in obese patients and others with large chests.[9] Separate the PBLADE loaded with the ET tube from the AWS. Insert the PBLADE into the oropharynx under direct visualization. Gently and carefully reattach the AWS to the PBLADE. Be careful not to traumatize the patient's lips, teeth, or airway soft tissues. Once the device is reassembled, proceed with intubation as described above.

This technique can be used for patients in which deep sedation and induction are contraindicated. An off-label technique for awake intubation has been described.[10] Assemble the device. Attach a Bodai connector to the proximal end of the ET tube. Insert a 14 French suction catheter into the lumen of the ET tube via the Bodai connector. Attach the breathing circuit to the other branch of





FIGURE 13-2. The McGrath Laryngoscope. **A.** The device. **B.** The blade has been inserted and the ET tube is advanced through the vocal cords (Photos courtesy of LMA North America, San Diego, CA).

the Y-connector to administer oxygen at a rate of 10 L/min. Insert a tracheal spray tube, smaller than 12 French, through the original suction channel. Attach a syringe loaded with topical anesthetic solution to the proximal end of the tracheal spray tube. Suctioning can be performed through the ET tube as the PBLADE is advanced. The topical anesthetic agent can be delivered via the spray tube. Once the glottis is visualized, the local anesthetic solution can be delivered to and through the vocal cords prior to advancing the ET tube through the glottic opening.

COMPLICATIONS

Placement of the AWS may not be possible in patients with limited mouth opening.[4] The diameter of the PBLADE is approximately 2.5 cm. An alternative airway device should be readily available if paralysis does not improve mouth opening. Visualization of the vocal cords can be limited by secretions.[11] A suction catheter should always be readily available. Insert the PBLADE slowly to prevent it from being inserted into pooled secretions. Visualization may not be possible despite aggressive suctioning in the case of particulate matter or severe bleeding. If this occurs, be prepared to use an alternative airway device. Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

Since the ET tube is loaded onto the PBLADE, its maneuverability is limited. Employ a bougie in cases where visualization of the glottis is possible but intubation is not successful. Align the PBLADE and ET tube as much as possible with the glottis. Pass a bougie through the ET tube. Advance and direct the bougie through the vocal cords. Slowly and gently advance the ET tube over the bougie under video guidance.[11]

Despite a quicker time to visualization and insertion of the ET tube, the time from initiation of intubation to ventilation is not significantly different from traditional direct laryngoscopy.[8] It is speculated that this is due to the increased time it takes to remove the ET tube from the AWS postintubation. The time to ventilation can be reduced by beginning manual ventilation before removal of the PBLADE from the oropharynx. This technique should be considered in patients that are hypoxic postintubation.[4]

McGRATH LARYNGOSCOPE

The McGrath Laryngoscope (LMA North America, San Diego, CA) is a video laryngoscope that is designed to provide a clear video view of the glottis with minimal changes in the traditional direct laryngoscopy technique. It is the most portable video laryngoscope and modeled after the traditional Macintosh laryngoscope blade (**Figure 13-2A**). It is a refinement of the "smart scope" laryngoscope developed by Matt McGrath. As a British university student, he won the 1999 Royal Society of Arts student design competition for outstanding design achievement for his portable laryngoscope with a small video monitor attached to the handle.[8]

INDICATIONS AND CONTRAINDICATIONS

The McGrath laryngoscope is indicated for elective and emergent intubations. It is useful in difficult intubations in which the three airway axes may be difficult to align.[2,12–14] This includes patients with cervical spine immobilization, limited mouth openings, tongue edema, and high Cormack and Lehane grade airways. It is indicated for use in pediatric patients weighing 15 kg or more.[15] The McGrath laryngoscope is not indicated for use in awake intubations.[16]

EQUIPMENT

The McGrath laryngoscope consists of three main components: the handle module, the camera stick, and the blade (**Figure 13-2A**). The handle module houses the power source and the video monitor. The nonslip rubberized handle contains a single AA battery and the power switch. At the crown of the handle module rests the 1.7 in color LCD monitor. The monitor can rotate around the handle 360° and can be tilted to adjust the viewing angle. The camera stick houses the camera and light source. Its length is adjustable to produce a blade length ranging from a Macintosh size 3 to 5 blade. The disposable single-use plastic blade fits over the distal camera stick to protect the camera and to assist in lifting of the epiglottis.

PREPARATION

Preparing the McGrath laryngoscope for use is quite simple. Unscrew the cap on the top of the handle and insert the AA battery. The top of the handle is opened by turning it counterclockwise and closed by turning it clockwise. Apply the camera stick onto the handle. Pull out the release safety catch at the base of the handle and rotate it so that it is aligned parallel to the long axis of the camera stick. Slide the camera stick into the base of the handle. Return the safety catch to its original position. Firmly attach the disposable sterile laryngoscope blade to the camera stick. Slide it over the camera stick until it firmly latches. Adjust the blade length by sliding the camera stick through the clamp handle. A click will be heard for

each adjustment in the blade size. Turn the power on by pressing the power switch on the top of the handle. The LED light on the LCD monitor will be continuously lit if there is adequate battery power. If it blinks, the battery power is low and the battery should be changed prior to using the device.

TECHNIQUE

The intubation technique using the McGrath laryngoscope is similar to that used in traditional direct laryngoscopy.[16] Insert the tip of the blade in the midline and superior to the tongue. Slowly advance the blade and rotate its tip toward the larynx in the sagittal plane until the epiglottis is visualized via direct visualization or via indirect visualization using the camera monitor. Further advance the blade until its tip rests in the vallecula. Gently lift the blade until the glottis is visualized. Gently elevate the device to elevate the epiglottis. The monitor should show the vocal cords as well as the surrounding structures (**Figure 13-2B**). If only a portion of the vocal cords is visible, slightly withdraw the blade until the desired view is obtained (**Figure 13-2B**). Gently manipulate the device until the glottis is centered on the monitor screen. Insert and advance the proper size ET tube through the vocal cords with the assistance of either a malleable stylet or a bougie. The ET tube with a stylet should ideally be hockey stick shaped 5 cm from the tip of the ET tube to optimize maneuverability.[12] Gently advance the ET tube through the glottis until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Withdraw the stylet or bougie. Gently remove the blade from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

ALTERNATIVE TECHNIQUE

An alternative technique can be performed in those patients with limited mouth opening or chest anatomy that prevents placement of the device into the oropharynx using the traditional laryngoscopic technique.[13] Disarticulate the camera stick from the handle to facilitate placement of the blade into the oropharynx. Insert the camera stick and blade similar to introducing a tongue depressor into the oral cavity. Attach the handle to the camera stick. Intubate the patient as previously described.

COMPLICATIONS

If the epiglottis obstructs visualization of the glottic opening, apply greater upward force to lift the epiglottis. If this is not successful, the plastic blade may be used in the same manner as a miller blade. Redirect the blade to lift the epiglottis, visualize the glottis, and intubate as previously described. Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

If the monitor image is unclear, check for fogging. Apply an antifog solution as needed.[8] A blurred image can result from the blade not being latched onto the camera stick. The video lens should be flush with the viewing window of the blade. If neither of these maneuvers is successful, remove the blade from the device and clean the camera lens with a gentle soft wipe.

A grade I view may be obtained of the glottis yet the ET tube cannot be advanced into the trachea. This may be due to the acute bend and long flange of the blade.[30] The device provides a view of the glottis without the alignment of the three airway axes. This requires the ET tube to have a more acute bend than normally used for direct laryngoscopy. Place an acute bend in the styletted ET tube approximately 7 to 10 cm from the tip. Another option is to advance the ET tube into the glottis while simultaneously withdrawing the stylet, thus not inserting the styletted ET tube into the glottis.



FIGURE 13-3. The Berci–Kaplan DCI Video Laryngoscope (Photo courtesy of Karl Storz Endoscopy-America, El Segundo, CA).

BERCI–KAPLAN DCI VIDEO LARYNGOSCOPE

The Berci–Kaplan DCI video laryngoscope is a video Macintosh intubating laryngoscope developed by Drs. Kaplan, Ward, and Berci (Karl Storz Endoscopy-America, El Segundo, CA).[17] It incorporates micro video imaging technology into a traditional laryngoscope blade. This reduces the learning curve in operating this device for those experienced with traditional direct laryngoscopy. It is ideal for use when training the novice in the traditional direct laryngoscopic technique.[17,18] A fiberoptic bundle extends from the proximal end of the laryngoscope blade allowing for a larger angle of viewing and a magnified view of the airway. This video laryngoscope has been marketed for use as part of an "all-in-one" video intubation system (**Figure 13-3**).

INDICATIONS AND CONTRAINDICATIONS

The video laryngoscope is indicated for normal and difficult intubations, in both pediatric and adult patients. The large video screen makes this device particularly useful for difficult intubations requiring external manipulation of the airway by an assistant. There are no contraindications to the use of the video laryngoscope.

EQUIPMENT

The video laryngoscope device consists of various laryngoscope blades, the DCI camera head, and the control unit. The video laryngoscope blade houses the camera optics. It is available in Macintosh (sizes 3 and 4), Miller (sizes 0, 1, and 3), and the Doerges universal blade styles. The lens provides a viewing angle of 60° to 80°, depending on the type of laryngoscope blade. The laryngoscope blade is

integrated into the ergonomic handle (**Figure 13-3**). The handle attaches to the camera head, the interface between the control unit and the video laryngoscope. Other interchangeable airway devices can be attached to the control unit including the Bonfil's scope, Brambrinck scope, and fiberoptic scope. The control unit incorporates the light source, an image processing module, imaging memory, power supply, a keyboard, and a color LCD monitor.

PREPARATION

Attach the selected laryngoscope blade to the camera head. Turn on the control unit. The laryngoscope blades can be changed with the control unit powered on. Apply medical grade antifogging solution onto the camera lens.

TECHNIQUE

An advantage of this video laryngoscope is that the intubation technique does not differ from that of traditional direct laryngoscopy. The added benefit of indirect visualization is that less force is needed to visualize the glottis. An assistant can view the monitor to facilitate external manipulation of the larynx to bring the glottis into view. The ET tube can be passed through the glottic opening under either direct or video-assisted visualization. Gently advance the ET tube through the glottis until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Withdraw the stylet or bougie. Gently remove the blade from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

ALTERNATIVE TECHNIQUE

A limitation of this video laryngoscope is its relatively large handle with cables protruding from its proximal end. This can impede intubation in patients with large chests, short necks, or cervical spine immobilization.[19] Insert and advance the laryngoscope blade into the patient's mouth from the side. Gently rotate and return the laryngoscope handle into the midline once the blade is deep enough and the handle can clear the chest. Proceed with intubation as previously described.

COMPLICATIONS

A known issue with this video laryngoscope is lens fogging. This is particularly problematic in patients that are not fully paralyzed. This can be prevented by applying a medical grade antifogging solution, a thin layer of water-soluble lubricant, or the patient's saliva on the lens.[19] Blood and other secretions can obscure the view. This can be reduced by not inserting the laryngoscope blade into pooled secretions and by the use of suctioning.[19] Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

Common barriers to purchasing this device are its cost and its large size. The large size of the control unit limits its portability unless it is placed on a rolling cart. Despite this, the control unit can be used in conjunction with several other of the companies airway devices. This makes it a worthwhile investment in Emergency Departments that utilize other compatible airway devices.[19]

C-MAC VIDEO LARYNGOSCOPE

The C-Mac (Karl Storz Endoscopy-America, El Segundo, CA) is a video laryngoscope system released in 2009 (**Figure 13-4A**). It replaces the original video laryngoscope by Karl Storz. It has numerous advantages including being more compact and portable, the blade width is decreased, and the video technology has been



FIGURE 13-4. The C-Mac Video Laryngoscope. **A.** The C-Mac system. **B.** The C-Mac. **C.** The C-MAC PM (Photos courtesy of Karl Storz Endoscopy-America, El Segundo, CA).

improved. The original video laryngoscope incorporated a fiberoptic camera and video system into a traditional laryngoscope blade. The C-Mac abandons this technology for a CMOS micro video camera. This allows the video system to be incorporated within the laryngoscope blade. The CMOS micro video camera provides an enhanced area of view and does not have the issue of fogging.

INDICATIONS AND CONTRAINDICATIONS

The C-Mac video laryngoscope is indicated for normal and difficult intubations, in both pediatric and adult patients. There are no contraindications to the use of the video laryngoscope.

EQUIPMENT

The completely handheld portable C-Mac consists of three main components: the blade, the electronic module, and the monitor (**Figure 13-4B**). The blade reproduces the curvature of the traditional Macintosh blade and is composed of stainless steel. The proximal end has been flattened to reduce the amount of mouth opening required for intubation and to reduce the risk of oral trauma. The lens is located approximately one-third of the distance from the tip of the blade and provides a 60° field of vision. The CMOS chip housed in the blade provides lens antifogging and an optimal image quality. The blade is available in several sizes.

The electronic module is the interface between the laryngoscope blade and the monitor unit. The module permits easy operator-controlled video documentation. Images can be recorded as still shots or video sequences using the incorporated key pads.

The 7 in, high-resolution monitor is housed in an impact-resistant and splash-protected plastic body. The top of the monitor has an integrated secure digital (SD) memory card and an USB port for video recording and transfer. The monitor automatically white balances when it is turned on. The monitor image can be further modified using the touch key controls to the right of the monitor screen. The monitor device also houses a lithium ion battery with a 2 hour operating time when fully charged.

Several new attachments make the C-Mac quite versatile (**Figure 13-4A**). The C-Mac PM incorporates a 2.4 in LCD monitor that inserts into the laryngoscope handle (**Figure 13-4C**). This eliminates the electronic module, cord, and base unit. The LCD monitor unit can be used with all the C-Mac laryngoscope blades. The C-Cam is a camera head that attaches to the monitor unit. Through this, numerous other airway devices can be attached including all Storz airway devices, the Bonfil's scope, and other fiberoptic scopes (**Figure 13-4A**).

PREPARATION

Preparing the C-Mac for use is quite simple.[20] Insert the electronic module into the video laryngoscope blade receptacle. The blade can later be changed while the monitor is on. Insert the yellow connection cord of the electronic module into the yellow socket on the back of the monitor. If the battery symbol turns red, connect the power cord into the blue socket on the back of the monitor and plug in the power supply. The battery sign will indicate that the unit is charging. Insert an SD card into the monitor for recording and image capture. An alternative is to connect an external video recording source into the USB port.

Turn on the C-Mac using the power switch located at the left lower corner of the display monitor. Check the camera for proper functioning by focusing the lens under the laryngoscope blade on your hand. The camera's light source should be visible on the hand. The light intensity, color saturation, and contrast can all be adjusted using the key pads located on the monitor. Wipe the lens with a soft cloth or lens tissue if the video image is blurry. If this does not improve the image, clean the contacts of the electronic module. Recording can be performed by pressing the record button located on the laryngoscope blade handle.

TECHNIQUE

The intubation using the C-Mac is exactly the same as using traditional direct laryngoscopy.[20] Insert the laryngoscope blade into the oral cavity under direct visualization. Advance it past the oropharynx and into the vallecula. Lift the laryngoscope handle upward to improve visibility. Visualization can be performed by either direct visualization or via the monitor. Gently advance the ET tube through the glottis until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Withdraw the stylet or bougie. Gently remove the blade from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

COMPLICATIONS

Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

GLIDESCOPE

The Glidescope (Verathon Inc., Bothell, WA) combines a video camera with a patented antifog system into a portable laryngoscope blade and monitor system. The blade design modifies the traditional Macintosh blade curvature to provide a more anterior view of the larynx. The Glidescope was developed by a Canadian surgeon.[8] Modifications in the basic design have resulted in several models (**Figure 13-5**). The Cobalt Glidescope utilizes a single-use disposable blade for a rapid turnaround without sterilization between uses.[21] The Ranger Glidescope models provide a compact, high impact device originally intended for military and prehospital use.[22]

INDICATIONS AND CONTRAINDICATIONS

The Glidescope is indicated for routine and difficult intubations. It is particularly useful for patients requiring cervical spine immobilization. It has been demonstrated to have a significant advantage over the Macintosh blade in the patient with tongue edema.[23] It can be used in pediatric patients that weigh as little as 1.8 kg. There are no reported contraindications for using this device.

EQUIPMENT

The primary components of the Glidescope are the blade and the video monitor. In the traditional Glidescope and the traditional Ranger Glidescope, all of the blade models incorporate an auto focusing CMOS camera, a LED light source, and a patented antifogging mechanism housed inside of a medical grade plastic shell. The Glidescope blade begins with the traditional Macintosh blade and adds a 60° curvature at the midpoint. This allows for a more anterior view of the airway with less lifting force required.[8] The camera lens lies at the distal aspect of the blade's curve to protect it from secretions while providing a close-up view of the glottis. The Glidescope produces better glottic visualization than traditional direct laryngoscopy.[31,33–35]

The traditional Glidescope blade is a reusable integrated blade and handle. It is available in four sizes. The traditional Ranger blade consists of a reusable integrated blade, a handle, and a video cable that cradles into the body of the Glidescope monitor. It is currently available in two sizes. The Ranger single-use blades are available in six sizes.







FIGURE 13-5. The Glidescope Video Laryngoscope. **A.** The Glidescope GVL system. **B.** The Glidescope AVL system. **C.** The Glidescope Ranger system (Photos courtesy of Verathon Inc., Bothell, WA).

The Glidescope cobalt and Ranger single-use blade consists of a video baton and a STAT blade. The video baton houses the CMOS camera, LED light, and antifogging mechanism. The baton is inserted into a onetime use STAT blade constructed of medical grade plastic. The STAT blade is shaped like the traditional Glidescope blade and provides the protective cover for the baton, reducing the risk of transmitting an infection.[23] This dramatically reduces Glidescope turnaround by eliminating the 30 minutes required to clean traditional blades prior to re-use.[21,23] The baton is available in two sizes and four blade sizes.

The blades are connected to the video monitor through a video cable. The traditional Glidescope and the Cobalt Glidescope have a 7 in, nonglare, color LCD monitor. Housed within the monitor are the battery and the power source. The monitor includes the power switch and control pads that allow adjustment of the video image. The Ranger versions have a rugged shell for field use and a 3.5 in color, nonglare LCD. The body of the monitor incorporates a cradle for the blade. The Ranger Glidescope utilizes a rechargeable lithium ion battery. When fully charged, it can be used for 90 continuous minutes or approximately 20 intubations.[22] Many of the Glidescope models come with the GlideRite rigid stylet, though it is not required for intubation. It is a rigid stylet designed to complement the angle of the Glidescope blades. Intubation with the GlideRite rigid stylet offers no advantages over the standard malleable stylet.[36]

PREPARATION

Preparing the Glidescope for use is quite simple. Attach the Glidescope blade to the monitor using the video cable. Turn on the device and it is ready for use. For the Cobalt and single-use Ranger models, insert the baton into the STAT blade. A click will be heard to confirm that the blade has been securely attached. It is not required to use the GlideRite rigid stylet. It is recommended to curve the malleable stylet 90° to model the shape of the Glidescope blade to facilitate manipulation of the ET tube.[8,21,22,24–26]

TECHNIQUE

The intubation technique using the Glidescope is similar to that of traditional direct laryngoscopy.[21,22] Insert the blade into the midline of the oral cavity. Advance the blade under direct visualization until its tip reaches the pharynx. Continue to advance the blade while observing the monitor to identify the epiglottis. Advance the blade into the vallecula. Lift the blade, if necessary, to elevate the epiglottis. Under direct visualization, insert the ET tube until its tip nears the tip of the laryngoscope blade. Guide the ET tube toward the glottic opening. Pull the GlideRite stylet back approximately 2 cm and advance the ET tube through the vocal cords. This will facilitate passage of the ET tube through the vocal cords while reducing the potential for injury. Gently advance the ET tube through the vocal cords until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Withdraw the stylet. Gently remove the blade from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

COMPLICATIONS

Use of a Glidescope for intubation can increase the time to advance the ET tube through the vocal cords when compared to intubation using direct laryngoscopy.[6] This difference in time decreases with increased use and familiarity with the device.[27] It is strongly recommended that novice operators use the Glidescopes on mannequin models and for "routine" intubations prior to using it as a rescue device for difficult intubations.

Intubation with the Glidescope can be difficult in patients with small mouths or large tongues due to the limited area for both the blade and ET tube. In these cases, it may be difficult to pass the ET tube into the larynx. Do not blindly insert the ET tube as it may cause injury to the oropharyngeal tissues.[28] If space is a problem, insert the Glidescope under direct visualization and then move it to the left. The ET tube can then be inserted under direct visualization. The view on the monitor of the larynx may appear deviated.[28] Manipulate the Glidescope to obtain an optimal view on the monitor. An additional technique is to shape the ET tube into a hockey stick or j-curve to facilitate advancement and manipulation from the lateral aspect of the mouth.[6] Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

CLARUS VIDEO SYSTEM

The Clarus video system (Clarus Medical LLC, Minneapolis, MN) is a device that can be modified with various accessories for use as a video laryngoscope, an ET tube exchange catheter, a flexible scope, and a malleable stylet.[29] It incorporates the video, lighting, power, and monitor system into one handheld product (**Figure 13-6**). The malleable video stylet shaft and the disposable video laryngoscope blade are designed for intubation.[29] The optional flexible scope is detachable for use as an ET tube exchange catheter.



FIGURE 13-6. The Clarus Video System (Photo courtesy of Clarus Medical LLC, Minneapolis, MN).

INDICATIONS AND CONTRAINDICATIONS

The Clarus Video System is intended for use in performing and confirming placement of an ET tube. It is indicated for use alone or as a video stylet in conjunction with a standard laryngoscope. It can be used for routine and difficult intubations. There are no contraindications to using this device.

EQUIPMENT

The handle of the video system houses the rechargeable power unit. The color LCD display monitor attaches to the handle. The monitor viewing angle can be adjusted with an easy to reach thumb control. The light intensity can be adjusted using controls on the handle. The handle also contains the external video connector and the battery charger port. The distal lens, light LED, and camera are housed in the distal tip of the video stylet shaft.

A disposable tube stop fits on the malleable video stylet to hold the ET tube at the desired height on the stylet. An oxygen port can be connected to the tube stop to supply supplemental oxygen through the ET tube. A detachable and flexible video scope is available for use during ET tube exchange.

PREPARATION

Preparing the Clarus video scope for use requires the device to be assembled. Place the disposable tube stop over the stylet shaft.

Attach the oxygen port to the matching circular receptacle on the tube stop. Attach oxygen tubing to this port if desired. The oxygen flow rate and pressure must be monitored to prevent barotrauma.[29]

Apply an ET tube with a minimum diameter of 5.5 mm and a maximum length of 34.3 cm over the distal tip of the stylet and fitted to the tube stop. Consider applying a water-soluble lubricant onto the stylet to facilitate this process.[29] Consider applying a medical grade antifogging agent to the lens on the stylet tip. Adjust the tube stop so that the stylet tip rests just proximal to the distal end of the ET tube in order to provide optimal visualization and reduce the potential for tissue trauma. Tighten the clamp screw on the tube stop to fix the position of the ET tube onto the stylet shaft. The image on the monitor screen should automatically focus when the device is turned on. The illumination can be adjusted using the dial on the monitor.

TECHNIQUE

Once the device has been properly assembled, it can be used for intubation with a traditional laryngoscope. Insert the laryngoscope and attempt to visualize the vocal cords and other surrounding structures. If visualized, insert the ET tube on the Clarus stylet similar to performing traditional direct laryngoscopy. Visualization of the airway structures may not be possible in patients with difficult airways or those requiring cervical spine immobilization. Use the monitor on the Clarus Scope to direct, manipulate, and advance the styletted ET tube through the glottis. Gently advance the ET tube through the glottis until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Withdraw the Clarus stylet. Gently remove the laryngoscope blade from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

COMPLICATIONS

Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

KING VISION VIDEO LARYNGOSCOPE

The King Vision Video Laryngoscope (King Systems Inc., Noblesville, IN) is a battery operated, rigid, and portable digital video laryngoscope (**Figure 13-7**). It is simple to use and understand. The King Vision is significantly less expensive than most other video laryngoscopes. The device uses newer organic light emitting diode (OLED) technology.



FIGURE 13-7. The King Vision Video Laryngoscope (Photo courtesy of King Systems Inc., Noblesville, IN).

INDICATIONS AND CONTRAINDICATIONS

The King Vision is indicated for routine and difficult intubations. It can be used in both adolescent and adult populations. The laryngoscope blade is equivalent to a Macintosh #3 size blade. There are no contraindications to using this device as long as a Macintosh #3 blade is appropriate for intubation.

EQUIPMENT

The King Vision has a two-piece design consisting of the color OLED monitor base unit that attaches to a disposable laryngoscope blade (**Figure 13-7**). The two pieces snap together. The monitor unit houses three AAA batteries as the power source, the on/off switch, and a mini USB port for video output to a display monitor or recording device. The batteries provide at least 90 minutes of "on time". The OLED monitor offers increased contrast at a lower cost than LCDs and LEDs. In addition, the monitor is brighter, faster, lighter, thinner, and uses less power than LCDs.

The blades are plastic, single use, and disposable. They are available in two styles, with and without an ET tube channel. The channelled blade accommodates a 6.0 through 8.0 ET tube. The blade is currently only available in a Macintosh #3 size. It differs from the standard Macintosh #3 blade in that it is slightly shorter and wider than the Macintosh #3 blade. The blade is smaller than most video laryngoscopes. It requires a minimum mouth opening of 13 mm for the standard blade and 18 mm for the channelled blade. A CMOS camera and a LED light source are mounted on the disposable blade. The lens has an antifog coating.

PREPARATION

Preparation of the King Vision is quick and simple. Ensure that the power is off. Applying a blade with the unit powered on will result in image distortion. Choose a laryngoscope blade either with or without a channel. Slide the blade onto the monitor piece and snap it in place. The front and back of both the blades and the monitor unit are color coded to facilitate proper orientation. The blade with a channel can be used with or without an ET tube inserted into the channel. If desired, load an appropriate size ET tube (size 6.0 through 8.0) without a stylet into the well-lubricated channelled blade. Use only water-soluble lubricants. Avoid placing lubricant over the lens. Align the distal tip of the ET tube with the end of the channel. Turn on the device. Replace the batteries if the battery indicator light is flashing red. Observe the monitor to ensure that an image is present and clear. The image will be distorted if the unit was powered on when the blade was attached. Simply turn the unit off and then back on to obtain a clear image. The tip of the ET tube, if using the channelled blade, should not be visible on the monitor. If it is visible, pull the ET tube back until the tip is aligned with the tip of the blade and no longer visible in the monitor.

TECHNIQUE

The technique for intubation is similar to traditional direct laryngoscopy if using the standard blade or the channelled blade without loading an ET tube. Insert the blade in the midline and advance it into the oropharynx. Continue to advance the blade toward the vallecula while observing the monitor. The blade can be placed into the vallecula like a Macintosh blade or can be used to elevate the epiglottis like a Miller blade. Use the monitor to direct, manipulate, and advance the styletted ET tube through the glottis. Gently advance the

ET tube through the glottis until the ET tube marker line reaches the glottis. Inflate the ET tube cuff. Withdraw the device. Gently remove the laryngoscope blade from the patient's mouth while securely holding the ET tube in place. Confirm proper ET tube position.

A slight technique modification is required if mounting an ET tube into the channelled blade. Insert the blade as described previously. Center the glottic opening on the screen. Slide and advance the ET tube along the channel and through the vocal cords. Minor manipulation of the blade may be required to align and advance the tip of the ET tube through the vocal cords.

COMPLICATIONS

As with all video intubation devices, imaging can be compromised by excessive secretions or blood in the oropharynx. Incorrect or forceful insertion can result in dental trauma and soft tissue injuries. The other complications associated with this device are similar to those of direct laryngoscopy.

SUMMARY

There is a growing array of video intubation devices available with varied designs. This includes those that embed the camera into the laryngoscope blade, those that embed the video camera into a scope or a stylet for use inside an ET tube, and those that utilize an ET delivery device. For the Emergency Physician, they represent a simple method for routine intubation as well as promising rescue devices for the difficult airway. These devices have varied learning curves. Regardless of which device one uses, it is important to use these devices in both simulation and routine intubation prior to use as a rescue device. These devices are useful for training healthcare personnel in the technique of orotracheal intubation in the prehospital and hospital setting. The use of a video laryngoscope to intubate is much easier than using traditional direct laryngoscopy, especially for novices.

14 Fiberoptic-Assisted Orotracheal Intubation Devices

Michael Lutes and Olga Pawelek

INTRODUCTION

Recent years have seen a rapid expansion in optical devices used to aid in endotracheal intubation. All of these devices use fiberoptics that begin near the distal end and transmit an image to be viewed at the proximal end. Many of these devices are variations on the "optical stylet" concept. They consist of an eyepiece or other viewing mechanism attached to a stylet of varying degrees of flexibility. A standard endotracheal tube can be jacketed onto each device. The stylet can then be used as an adjunct to standard endotracheal intubation or as a stand-alone device.

Traditional direct laryngoscopy requires alignment of the oral, pharyngeal, and laryngeal axes to visualize the glottis. Despite mechanical manipulation, it is not always possible to align these three axes. The major advantage of fiberoptic laryngoscopy devices is that they do not require the Emergency Physician to align the three airway axes, thus reducing the need for manipulation and potential traumatic forces on the airway. Fiberoptic devices provide a superior view of the glottis when compared to traditional direct laryngoscopy. The lens of these devices is within centimeters of the glottis and provides a wider angle of vision than the 15° of traditional direct laryngoscopy. The viewing port magnifies the view of the airway making structures easier to visualize.

A generalized approach to using optical stylet-type devices will first be discussed, followed by the unique features of each selected instrument. This chapter reviews a representative number and types of devices currently available and used in Emergency Departments. The last two devices covered in the chapter, the Airtraq and Bullard laryngoscope, function quite differently than an optical stylet.

INDICATIONS AND CONTRAINDICATIONS

Fiberoptic intubation devices can be used for adult and pediatric difficult (actual or anticipated), elective, emergent, and routine intubations. These devices can be used as "rescue devices" in cases of failed direct laryngoscopy. Patients with their head and neck immobilized, limited mouth opening, morbid obesity, or those requiring awake intubation or intubation while in a sitting position can benefit from intubation with these devices. It provides better visualization of the glottis, decreased cervical movement, and higher success rates in comparison to traditional direct laryngoscopy. These devices can be used to aid in the localization and removal of airway foreign bodies. There are no contraindications to the use of these devices.

USING FIBEROPTIC INTUBATION DEVICES

There are some general guidelines to using fiberoptic intubation devices that will improve the Emergency Physician's success in their implementation. First, it is useful to understand the limitation of these devices. Fogging is a common problem. Fogging can be minimized by applying a medical grade antifog solution to the lighted end of the instrument or warming the distal tip by placing it in a warm blanket or warmed saline solution. Any fluid (e.g., blood, secretions, or vomitus) in the oropharynx will limit the usefulness of these devices. First, suction any fluid and debris from the oropharynx prior to device insertion. Second, care should be taken to avoid touching any mucosal surface with the distal tip of the device. Encountering the mucosa can cause "pink out" and promote fogging of the device; both of which will impair visualization. Fiberoptic intubation devices cannot be used to separate tissues, rather they should follow an open channel created either by a standard laryngoscope or by manual distraction of the patient's jaw.[1] Lastly, small movements are magnified by these devices. Proceed slowly and identify known landmarks as the device is navigated from the mouth to the glottic opening. Getting lost in a field of pink mucosa is best overcome by slowly backing the device out until known landmarks are visualized and identified, and then slowly re-advancing the device along a path of familiar anatomy.

LEVITAN SCOPE

The Levitan Scope (Clarus Medical, Minneapolis, MN) was created by Dr. Richard Levitan (**Figure 14-1**). He is an Emergency Physician, a noted airway educator, and an innovator. The Levitan Scope differs from other devices in this chapter in that it is shorter and requires the endotracheal tube to be cut to a length of approximately 28 cm. While cutting the tube is an inconvenient step, doing so makes the working length of the scope shorter and makes wielding the device easier. The scope is equipped with a side port that allows for oxygen insufflation. The distal end of the device is flexible, allowing it to be bent to the specific needs of the scenario. It is powered by a detachable battery-operated light source or with a standard green-line fiberoptic laryngoscope handle. It is relatively



FIGURE 14-1. The Levitan Scope (Photo courtesy of Clarus Medical, Minneapolis, MN).

affordable compared to some other devices. Much of the intubation strategy described for the Levitan Scope is generalizable to other optical stylets. The techniques and strategies are summarized from a publication by the inventor.[2]

PREPARATION

Prepare the scope for use. Liberally lubricate the scope with a water-soluble lubricant. Do not get lubricant on the lens. Apply an endotracheal tube (6.0 mm or larger) over the shaft. The tip of the scope should be approximately 1 cm from the end of the endotracheal tube. Connect the side port to oxygen tubing. Turn on the oxygen source to provide a flow rate of 5 to 10 L/min. This flow rate allows for oxygen insufflation and aids in keeping the lens clear. The manufacturer recommends bending the distal tip to about 35° in the straight-to-cuff fashion. Attach the light source, either a miniature LED light source or a green-line fiberoptic laryngoscope handle.

TECHNIQUE

The Levitan Scope was designed with the intent of incorporating the option of fiberoptic assistance into every intubation attempt. In the majority of cases, where landmark visualization is feasible with standard laryngoscopy, the scope will simply act as a stylet. Once endotracheal intubation is achieved, additional confirmation can be made by visualizing the tracheal rings via the eyepiece.

When endotracheal intubation is not possible by direct laryngoscopy, the Levitan Scope jacketed with an endotracheal tube can be used for fiberoptic intubation. Obtain the best visualization of the airway anatomy possible using the traditional laryngoscope. Ideally, at least the epiglottis should be visible. Introduce the scope into the mouth under direct vision. Advance it until the tip of the scope is positioned approximately 1 cm superior to the epiglottis. To maintain this position, it may be helpful to rest the device against the patient's dentition at the right corner of the mouth. Avoid touching the distal tip of the scope against the mucosa to prevent "pink out" and fogging.

Switch from direct visualization to fiberoptic viewing via the device's eyepiece. Identify the airway structures. Slowly advance and direct the tip of the scope under the epiglottis. Continue to advance the tip of the device into the glottic opening. If the device is resting at the right corner of the patient's mouth, pivoting the device toward the Emergency Physician will direct the tip of the scope anteriorly toward the glottic opening. Confirm proper placement by visualizing the trachea rings through the eyepiece.

Once the tip of the scope with the jacketed endotracheal tube has been advanced through the vocal cords and into the trachea, remove the laryngoscope. Advance the endotracheal tube by rotating it off the stylet in a counterclockwise fashion. Rotating the endotracheal tube while advancing it helps to prevent the beveled edge from catching on the tracheal rings. Securely hold the endotracheal tube. Remove the Levitan Scope and secure the endotracheal tube.

The Levitan Scope can also be used without a laryngoscope, though it may require more practice to become adapt at this technique. Prepare the scope as described above, with the exception that the distal 3 to 4 cm should be bent to approximately 70°. Grasp the patient's jaw and tongue in the left hand and lift to create an open channel for the scope. Insert and advance the scope in the midline while avoiding contact with the mucosal surfaces. Look through the eyepiece and advance the device through the glottic opening.

VIDEO RIFL

The Video Rigid Intubating Fiberoptic Laryngoscope or Video RIFL (AI Medical Devices Inc, Williamston, MI) is unique among the optical stylets in that it has a flexible tip that can be manipulated with a trigger at the handle-end of the device (**Figure 14-2**). There were originally two models available, the Airway RIFL and the Video RIFL. The Video RIFL replaced the eyepiece of the Airway RIFL with a small LCD screen. The newer Nasal RIFL stylet attaches to the device and allows nasal intubation. The high resolution LCD



FIGURE 14-2. The Airway RIFL (Photo courtesy of AI Medical Devices Inc., Williamston, MI).

screen rotates 180° to provide visualization from any angle. The Video RIFL has a unique tip that articulates up to 135° to navigate obstructions. The device can be used as a stand-alone device or as an adjunct to standard laryngoscopy. It can be used to facilitate intubation through many supraglottic airway devices such as the Air-Q or I-gel. The primary disadvantages of this device are the cost, the relative length of the device, and that it is top-heavy. The length may prove cumbersome for users of shorter stature.

The two-sided RIFL blade can be used in conjunction with the Video RIFL. It is a disposable, single use, plastic blade. Its use is optional. The RIFL blade is inserted into the midline of the patient's mouth and lifted to elevate the tongue, open the airway, and provide a path to the glottis.

PREPARATION

Inspect the Video RIFL for any damage. Turn it on. Liberally lubricate the stylet portion of the device with a water-soluble lubricant. Place a 6.5 mm or larger endotracheal tube onto the stylet. The current model does not accommodate endotracheal tubes less than 6.5 mm. A smaller pediatric version is being developed. Set the tube stop so that the tip of the stylet is just inside the distal end of the endotracheal tube.

TECHNIQUE

The Video RIFL can be used as an adjunct to standard direct laryngoscopy. If the glottic opening can be easily visualized using a standard laryngoscope, the device can simply be used as a stylet to introduce the endotracheal tube into the trachea. If the laryngeal structures are not well visualized with direct laryngoscopy, insert and advance the device as described for the Levitan Scope. Attempt to visualize the epiglottis through the eyepiece or on the LCD screen of the Video RIFL. Advance the device under the epiglottis and through the vocal cords. The trigger-like handle of the Video RIFL can be squeezed to direct the tip of the instrument. Release the handle once the tip of the device passes through the vocal cords in order to facilitate advancement of the endotracheal tube off the device. Advance the endotracheal tube into the trachea. Withdraw the device and secure the endotracheal tube. Confirm proper endotracheal tube placement.

The Video RIFL can be used as a stand-alone device without the aid of a laryngoscope. Grasp the patient's mandible and tongue in the left hand and manually distract it. Insert the Video RIFL into the patient's mouth with the long axis of the device parallel to the palate. Look into the eyepiece or at the LCD screen and attempt to visualize the airway structures. Flex the tip of the device to visualize the vocal cords. Advance the Video RIFL through the vocal cords. Complete the remainder of the procedure as described above.

AIR-VU PLUS FIBER OPTIC SCOPE

The Air-Vu Plus Fiber Optic Scope (Mercury Medical, Clearwater, FL) is an optical stylet designed specifically for aiding in fiberoptic endotracheal tube placement through the Air-Q supraglottic airway (Mercury Medical, Clearwater, FL). It is a rigid device with a curved tip designed to fit the shape of the Air-Q (**Figure 14-3**). The Air-Vu Plus can be used with either a compact LED light source or a standard green-line fiberoptic laryngoscope handle. The device can be used as an optical stylet or as a stand-alone device in the same fashion as the Levitan Scope. The primary advantage of the Air-Vu plus versus other devices is its compatibility with the Air-Q. The primary disadvantage is the rigidity of the device and the fixed curve of the shaft, both of which can make advancement of the device and the endotracheal difficult.



FIGURE 14-3. The Air-Vu Plus Fiber Optic Scope (Photo courtesy of Mercury Medical, Clearwater, FL).

SHIKANI OPTICAL STYLET

The Shikani Optical Stylet or SOS (Clarus Medical, Minneapolis, MN) is unique among the optical stylets in that it comes in both pediatric and adult sizes (**Figure 14-4**). The SOS can be used with a variety of light sources. This includes its own specific handle, a green-line laryngoscope handle, or a fiberoptic cable attached to a remote light source. The SOS is malleable, allowing it be shaped to a 70° to 80° angle at the tip for use as a stand-alone device or a 30° angle when used as an adjunct to standard direct laryngoscopy. The SOS can be attached to oxygen tubing to allow insufflation of oxygen at 5 to 10 L/min. Intubation is achieved in a manner similar to other optical stylets. Advantages of the Shikani Optical Stylet include the availability of adult and pediatric sizes, its malleability, and the option of providing insufflation of oxygen. There are also



FIGURE 14-4. The Shikani Optical Stylet (Photo courtesy of Clarus Medical, Minneapolis, MN.



FIGURE 14-5. The Bonfils Retromolar Intubation Endoscope (Photo courtesy of Karl Storz Endoscopy-America, El Segundo, CA).

several case reports of its successful use in children.[3] The disadvantages are primarily related to its length, which can make coordination of intubation difficult for some users.

BONFILS RETROMOLAR INTUBATION ENDOSCOPE

The Bonfils Retromolar Intubation Endoscope (Karl Storz Endoscopy-America, El Segundo, CA) is simple in appearance (**Figure 14-5**). It can accommodate a 6.5 mm or larger endotracheal tube and has an adjustable tube stop. It can be equipped with either an eyepiece or an adapter to couple with a monitor. It also allows for oxygen insufflation via a side port. The curvature at the tip of the scope is fixed.

Intubation with the Bonfils Retromolar Intubation Endoscope can be achieved in the same fashion as described for other optical stylets in this chapter, either with or without the aid of a standard laryngoscope. In a study in the anesthesiology literature, 103 of 107 patients with unanticipated difficult airways were successfully intubated with this device, with 80% intubated without the aid of a laryngoscope.[4] The other 20% were intubated with a Macintosh blade and the Bonfils scope. A more recent study reports the device's success in the awake intubation of five patients with challenging airways.[5] Despite having higher success rates than traditional direct laryngoscopy, it can be difficult to maneuver this device into proper position under the epiglottis.[6]

AIRTRAQ OPTICAL LARYNGOSCOPE

The Airtraq (Prodol Meditec S.A., Vizcaya, Spain) differs from other devices in this chapter in that it is not an optical stylet, but rather an optical laryngoscope (**Figure 14-6**). It also differs from video laryngoscopes, such as the Glidescope, in that it is portable, completely handheld, battery operated, and does not require an external monitor for viewing. The Airtraq is disposable and designed for single patient use. The guide channel on the side of the Airtraq is anatomically shaped to deliver the endotracheal tube into the glottic opening. The Airtraq is available in four sizes, each with a required minimal mouth opening (**Table 14-1**). An optional reusable wireless

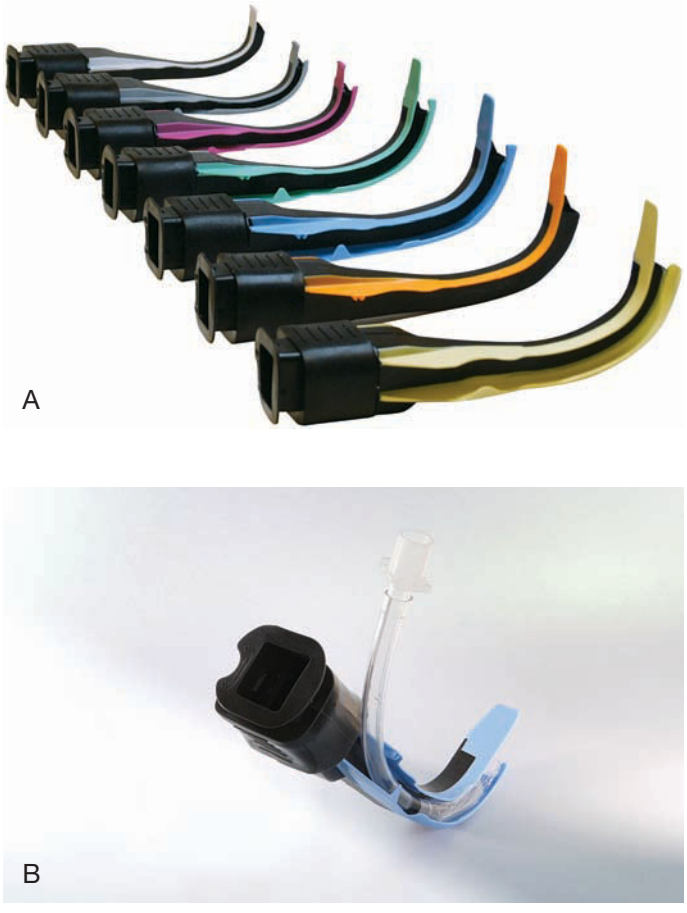


FIGURE 14-6. The Airtraq. **A.** The devices. **B.** An endotracheal tube loaded onto the device (Photos courtesy of Prodol Meditec S.A., Vizcaya, Spain).

video camera can be attached to the viewing window. It will transmit the viewing image to a wireless display monitor and recorder.

The Airtraq has proven to be effective and easy for even novice practitioners to learn to use.[7,8] The prehospital community favors the Airtraq for its compact size, portability, disposability, and being useful in less-than-standard patient positions.[9] The use of an Airtraq results in less cervical spine motion, less hemodynamic stimulation, and a decreased time required to intubate when compared to direct laryngoscopy.[10–12]

PREPARATION

Select the appropriate size Airtraq (**Table 14-1**). Confirm that the patient's mouth can be opened enough to accommodate the Airtraq. Turn on the Airtraq with the switch on the left side of the handle. Turning the Airtraq on early (i.e., at least 30-45 seconds before it is used) in the setup phase allows it to warm up, which also helps to prevent fogging. If the Airtraq is stored in a cold environment (e.g., storage room or ambulance in winter), allow it to warm up for at least 60 to 90 seconds before it is used. Select the appropriate

TABLE 14-1 Airtraq Sizes

Size	Endotracheal tube size	Minimal mouth opening (mm)
#0: Infant	2.5–3.5	12.5
#1: Pediatric	3.5–5.5	12.5
#2: Small	6.0–7.5	16
#3: Regular	7.0–8.5	18

size endotracheal tube. Test the endotracheal tube to ensure that the cuff inflates properly. Liberally lubricate the endotracheal tube and insert it into the channel of the Airtraq (**Figure 14-6B**). The patient can either be left in the neutral position or placed in the sniffing position. Lubricate the Airtraq to prevent it from catching and pushing the tongue posteriorly.

TECHNIQUE

Grasp the prepared device with the left hand. Insert the tip into the midline of the patient's mouth, with the long axis of the Airtraq parallel to the patient. Advance the Airtraq into the hypopharynx by lifting and rotating the viewing end upward. The curved shape of the Airtraq will follow the patient's normal anatomic curvature of the pallet and hypopharynx. When the device is just about upright and perpendicular to the patient, look into the eyepiece and attempt to visualize the epiglottis. Once the epiglottis is visualized, the Airtraq can either be advanced into the vallecula similar to a Macintosh blade or used to directly lift the epiglottis similar to a Miller blade. In either case, the Airtraq must be lifted up to elevate the epiglottis and center the glottic opening on the viewing screen.

Visualize the vocal cords. Advance the endotracheal tube with the right hand while securely holding the Airtraq with the left hand. Visualize the endotracheal tube passing through the vocal cords. If the vocal cords and airway structures are seen but the endotracheal tube will not advance, the vocal cords are probably not in the center of the viewing screen. Slowly withdraw the Airtraq, lift it slightly until the vocal cords are positioned in the middle of the viewing screen, and then advance the endotracheal tube.[13] Once the proper insertion depth is reached, securely hold the endotracheal tube. Gently distract the Airtraq toward the patient's left side while holding the endotracheal tube in its current location to release the endotracheal tube from the side channel. Withdraw the Airtraq from the mouth and inflate the cuff of the endotracheal tube. Confirm proper endotracheal tube position and secure it with tape or a commercial device.

The two most common mistakes are inserting the Airtraq too deep and not lifting it to elevate the epiglottis. Either of these will result in a view of the arytenoid cartilages and the vocal cords, with the viewing screen having the arytenoids centered in the view rather than the vocal cords. This will result in the advancing endotracheal tube hitting the arytenoid cartilages, thus not advancing through the vocal cords. Simply withdraw the Airtraq slightly and lift it upward to center the vocal cords in the viewing screen.

BULLARD LARYNGOSCOPE

The Bullard laryngoscope (Gyrus ACMI, Southborough, MA) is a rigid laryngoscope that combines a curved blade with fiberoptic visualization into a simple and easy-to-use handheld unit (**Figures 14-7 & 14-8**). The proximal handle contains an 11 French (3.7 mm) working port, a site to attach the light source such as a traditional laryngoscope handle or a fiberoptic, and a visualization port (**Figure 14-7**). The port allows oxygen insufflation, suctioning, administration of pharmaceuticals, or the passage of a guidewire to promote tracheal intubation.[14,15] The curved blade is similar in shape to a Macintosh blade. A fiberoptic bundle allows visualization of the vocal cords and tracheal intubation without a direct line of sight.

The Bullard laryngoscope is available in three sizes (**Figure 14-8**). The device is handheld, readily portable, self-contained, and is operated as quickly as a traditional laryngoscope with a Macintosh blade. The ability to visualize the vocal cords without aligning the oral, pharyngeal, and laryngeal axes allows successful intubation with a minimum of cervical spine movement.[14–19]

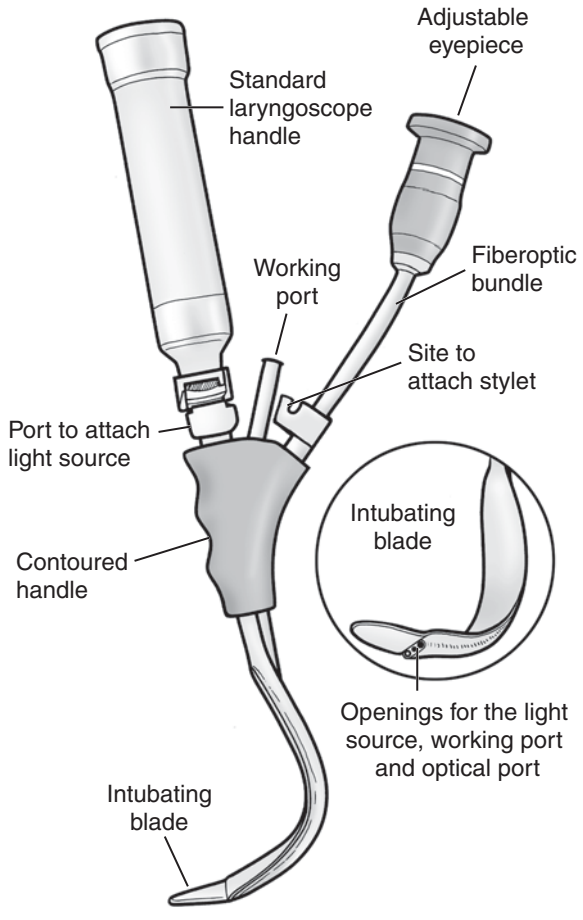


FIGURE 14-7. Anatomy of the Bullard laryngoscope.

PREPARATION

Assemble the Bullard laryngoscope when the possible need for airway intervention is recognized. The working port can be fitted with a three-way stopcock to provide intermittent suction and oxygen insufflation. Attach a traditional laryngoscope handle as the light source. If available, a fiberoptic light source, with the required adapter, may be used to provide illumination. Lubricate the lower half of the intubating stylet with a water-soluble lubricant. Attach



FIGURE 14-8. Three versions of the Bullard laryngoscope. From left to right: the pediatric model, the pediatric long model, and the standard model.

the stylet to the fiberoptic bundle, between the eyepiece and the handle, on the right side of the laryngoscope. Select and load the appropriate size endotracheal tube onto the intubating stylet. The tip of the stylet should extend 0.5 cm past the distal end of the endotracheal tube. Place the tip of the stylet beneath the flange of the blade. It is recommended, but not required, that a disposable plastic blade extender be placed on the tip of the metal blade for adult intubations.

TECHNIQUE

Stand at the head of the bed. Open the patient's mouth to a minimum opening of 0.6 cm between the upper and lower incisors. Grasp the handle of the Bullard laryngoscope parallel to the patient and toward the patient's feet (**Figure 14-9A**). Insert the blade into the midline of the mouth. Lift the laryngoscope handle upward (**Figure 14-9B**). Slightly elevate the Bullard laryngoscope to lift up

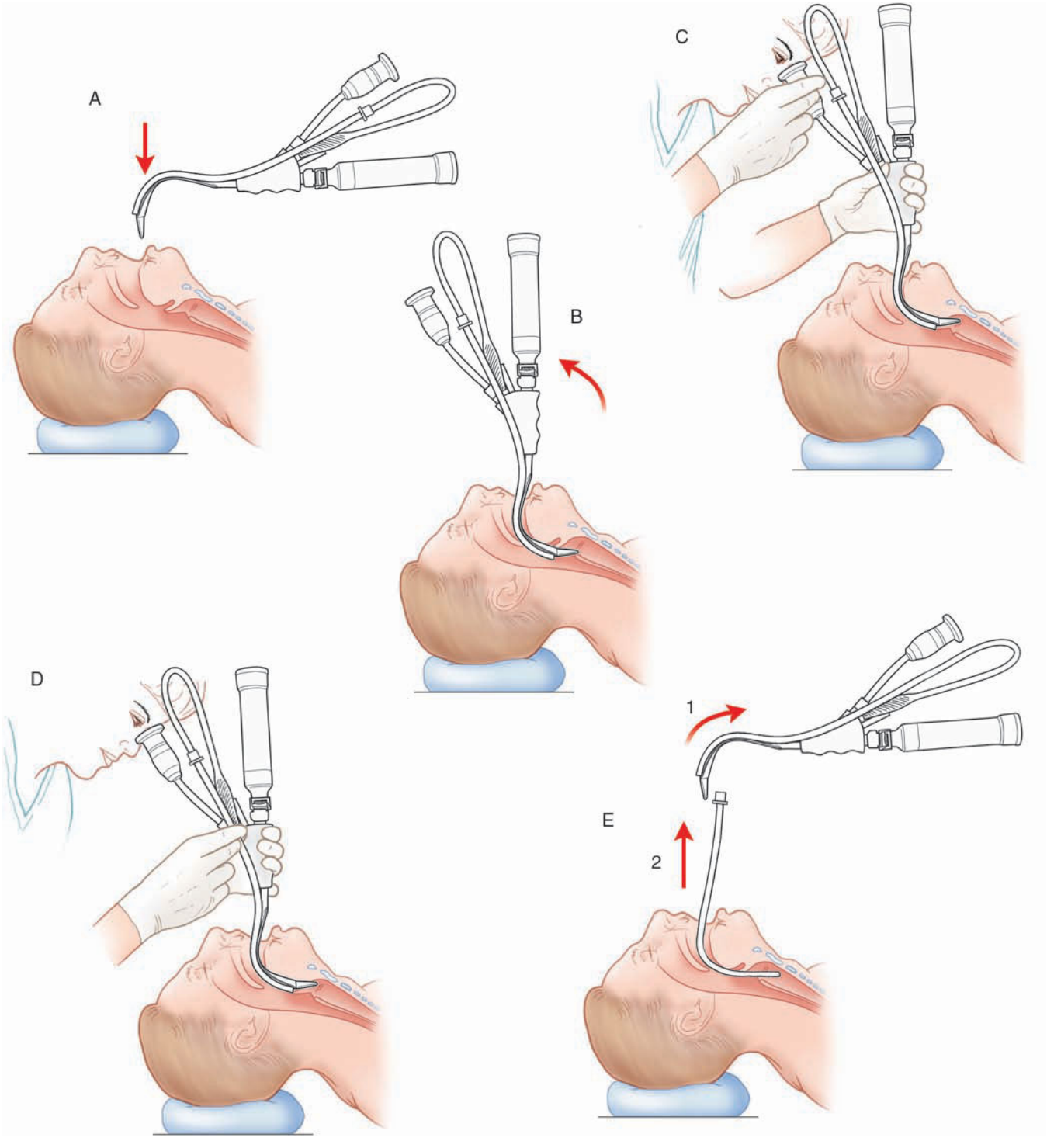


FIGURE 14-9. Intubating with the Bullard laryngoscope. **A.** Inserting the laryngoscope. **B.** Rotation of the handle 90° properly positions the laryngoscope. **C.** Slight elevation of the laryngoscope moves the tongue and epiglottis out of the visual axis. **D.** Advancement of the endotracheal tube under direct visualization. **E.** Removal of the Bullard laryngoscope. It is first rotated 90° toward the patient's feet (*curved arrow*), then lifted out of the mouth (*straight arrow*).

the tongue (**Figure 14-9C**). The blade will follow the contour of the tongue and pharynx with minimal effort.

The blade of the Bullard laryngoscope should elevate the epiglottis (**Figures 14-9C and D**). Visualize the airway through the fiberoptic port (**Figure 14-9D**). The view can be focused by turning the eyepiece. If the blade is not beneath the epiglottis, it can be repositioned by withdrawing the blade toward the posterior pharynx in an attempt to catch the epiglottis. If blood, debris or secretions limit the view, suction through the working port. When the vocal cords are visualized, advance the endotracheal tube under direct visualization (**Figure 14-9D**). Secure the endotracheal tube at the patient's teeth with your nondominant hand. Remove the Bullard laryngoscope with your dominant hand by reversing the technique of insertion (**Figure 14-9E**).

The Bullard laryngoscope allows for other strategies to aid in endotracheal intubation. The stylet has a central opening (4.5 mm in the adult, 3.6 mm in the pediatric long), which can be used to pass an intubating guidewire through the vocal cords.[15] An intubating guidewire may also be passed through the working port and through the vocal cords. In either case, after inserting the guidewire, remove the Bullard laryngoscope and pass the endotracheal tube over the guidewire and into the trachea. It is also possible to pass an endotracheal tube with a standard malleable stylet. The styletted endotracheal tube can be bent into a shape approximating that of the Bullard laryngoscope.

Problems specific to the Bullard laryngoscope include the inability to visualize the vocal cords. First, confirm that the laryngoscope is midline. If the blade is above the epiglottis and the view obscured, reposition it by moving the blade into the posterior pharynx and attempt to capture the epiglottis. To avoid this difficulty, use a disposable plastic blade extender. If the view is obscured by debris, suction through the working port. Once positioned, the stylet with the loaded endotracheal tube should be visualized through the scope. If not, it may have slipped underneath the blade. Reposition the stylet and endotracheal tube without removing the laryngoscope.[15] The stylet, if extended too far beyond the endotracheal tube, may cause abrasions, bleeding, and lacerations to the walls of the oral cavity, oropharynx, and laryngopharynx. These can be prevented with proper assembly of the Bullard laryngoscope.

COMPLICATIONS

The majority of complications associated with fiberoptic devices mirror those of endotracheal intubation. These include failure to intubate, esophageal intubation, right mainstem bronchus intubation, and all of the hemodynamic consequences of intubation. Refer to Chapter 11 for a complete discussion of the complications associated with endotracheal intubation The most common difficulty encountered in endotracheal tube passage is impaction of the endotracheal tube on the right arytenoid cartilage. This obstacle can be overcome by directing the device slightly toward the patient's left side. Alternatively, rotate the endotracheal tube until the bevel is facing the viewing channel.

SUMMARY

A variety of fiberoptic devices are available to help indirectly visualize the glottic opening and aid in intubating the trachea. The scopes have a variety of features including malleable stylets, articulating tips, and differing lengths. The devices can be shaped for differing applications such as being used with and without a laryngoscope or to be inserted through a supraglottic airway. The devices feature different visualization capabilities such as a fixed eyepiece or an optional video screen. Fiberoptic devices offer alternative techniques for managing the airway. Every Emergency Department should have at least one of these devices available to aid in intubation when direct laryngoscopy is difficult or fails.

15 Endotracheal Tube Intubating Introducers and Bougies

Olga Pawelek and Eric F. Reichman

INTRODUCTION

Airway management in the Emergency Department often occurs in an unpredictable and uncontrolled environment, sometimes with the patient arriving unannounced.[1] The American Society of Anesthesiology defines a difficult intubation as an inability to properly insert an endotracheal tube with traditional direct laryngoscopy within three attempts or if it takes longer than 10 minutes.[2] Difficult intubations usually reflect poor glottic visualization during direct laryngoscopy. A four-grade classification system by Cormack and Lehane describe the views of the laryngeal inlet during laryngoscopy.[3] The exact incidence of difficult to intubate patients in the Emergency Department is difficult to extrapolate but estimates range between 6% and 11%.[4,5]

Difficulties arise when the vocal cords cannot be fully visualized due to airway distortion (e.g., edema, expanding hematomas, radiation, surgery, or trauma), airway masses, anatomical variations, cervical collars, deformities of the head and neck, orofacial injuries, or oropharyngeal blood and secretions. One study reported that the vocal cords could not be visualized in 22% of patients wearing a cervical collar.[6] **This failure to visualize the glottis can make intubation difficult or impossible. The intubating introducer, tracheal tube introducer, or bougie can be a good rescue device in these situations.** The main advantage of many of these devices is their angled or coudé tip that can be aimed anteriorly, advanced under the epiglottis, and into the trachea. Intubation with one of these devices was first described by Macintosh in 1949.[7] The device he used was a 60 cm long, 15 French, elastic catheter with a J or coudé tip that was bent 40° at the distal end.

This chapter reviews the general principles for using tracheal tube introducers, intubating introducers, and bougies; as well as reviewing some of the more commonly available devices. The terms tracheal tube introducers, intubating introducers, and bougies are often used interchangeably. This chapter uses the term bougie unless some other term is specific to a manufacturer's device.

INDICATIONS

The bougie is intended to facilitate endotracheal intubation in patients where visualization of the glottis is difficult or inadequate despite external laryngeal manipulation and optimal patient positioning. The most frequent indication for the use of a bougie is the inability to intubate endotracheally using traditional direct laryngoscopy. It can also be used for "routine intubations." The narrower and more flexible bougie, compared to an endotracheal tube, can easily be inserted into the trachea when the glottis is visualized during direct laryngoscopy and the endotracheal tube inserted then advanced over the bougie. A bougie can be inserted directly into the trachea or through a supraglottic airway device to facilitate endotracheal intubation. A bougie may be inserted when the glottic opening is visible, but the endotracheal tube will not

pass through the vocal cords. The bougie serves as a placeholder in these cases and avoids the need to remove the laryngoscope and re-perform direct laryngoscopy when the bougie is available. The use of a bougie to intubate the trauma patient may result in less cervical spine motion than traditional direct laryngoscopy.[8] Long bougies, at least 70 cm, can also be used as an endotracheal tube exchanger.

CONTRAINDICATIONS

There are no absolute contraindications to the use of bougies. Use caution when inserting these in the patient with airway trauma as they can result in additional injury and hemorrhage to the airway structures, perforation (e.g., piriform fossa, trachea, bronchus, or esophagus), or barotrauma.[9–11]

EQUIPMENT

- Endotracheal tubes, various sizes
- 10 mL syringe
- Water-soluble lubricant or anesthetic jelly
- Wire stylet, malleable type
- Laryngoscope handle
- Fresh batteries for the laryngoscope
- Laryngoscope blades, various sizes and shapes
- Supplemental oxygen with appropriate tubing and connectors
- Nonrebreather oxygen masks, various sizes
- Wall suction with appropriate tubing
- Yankauer suction catheter
- Bag-valve device, various sizes
- Oral airways, various sizes
- Nasal airways, various sizes
- Benzoin adhesive
- Tape
- Pulse oximeter
- Cardiac monitor
- Automatic sphygmomanometer
- End-tidal carbon dioxide (CO_2) monitor/device
- Cricothyroidotomy backup tray
- Crash cart
- Resuscitation medicines
- Personnel (respiratory technician, medication nurse, in-line stabilization assistant, recorder)
- Medications (premedications, induction, anesthetics, and paralytics), see **Table 11-2**
- Endotracheal tube introducer or bougie

The bougie is used to facilitate difficult intubation. It is a thin, long cylindrical rod composed of rubber or plastic. Despite sometimes being called "gum elastic bougies," they are not composed of gum or elastic. They are inexpensive, most costing less than US $20.00 each. The bougie is available in numerous adult and pediatric sizes, various degrees of flexibility, and equipped with a variety of ports and/or devices. Bougies are flexible enough to allow an endotracheal tube to freely pass over it or to be inserted through a supraglottic airway device, yet stiff enough to be easily maneuvered and advanced into the airway.

The bougie should not be confused with the more rigid malleable stylet that is inserted into an endotracheal tube and used to alter its shape prior to intubation. Unlike the stylet, a bougie is usually inserted independently of the endotracheal tube and is used as a guide. The bougie is considerably softer, more malleable, and blunter than a stylet. The insertion of a bougie is considered to be a relatively atraumatic procedure.[12]



FIGURE 15-1. The Portex Tracheal Tube Introducer (Photo courtesy of Smiths Medical, Dublin, OH).

ESCHMANN TRACHEAL TUBE INTRODUCER

The Eschmann tracheal tube introducer was formerly known as the gum elastic bougie. Re-usable (or multiple-use) and single-use disposable versions are available. The Eschmann multiple-use introducer was introduced into clinical practice in 1973. The Portex single-use introducer (Smiths-Medical, Dublin, OH) became available in 1997 and replaced the Eschmann Introducer. It is a 60 cm long, 15 French, flexible device with a J-angle at its distal tip (**Figure 15-1**). During use, the multiple-use introducer forms a curve toward its distal end. The single-use introducer is more rigid and is thus more likely to cause trauma.[13] It does not maintain a curved shape when bent and it has a significantly lower tracheal placement rate in simulated grade 3 laryngoscopic views.[14] The multiple-use device retained the curved shape for longer compared with the single-use device.

FROVA INTUBATING INTRODUCER

The Frova Intubating Introducer (Cook Medical Inc., Bloomington, IN) was introduced into clinical practice in 1998. The Frova is a single-use device that is able to maintain the desired curvature—a feature shared with the Eschmann multiple-use introducer.[15] It is a flexible, hollow, radiopaque polyethylene plastic catheter with centimeter markings, and a blunt curved



FIGURE 15-2. The Frova Intubating Introducer with Rapi-Fit adapter. From left to right: the proximal end with the Rapi-Fit adapter, the body with centimeter markings, and the distal end (Photo courtesy of Cook Medical Inc., Bloomington, IN).

tip (**Figure 15-2**). It is available in two sizes, the 14 French version for 6.0 mm and larger endotracheal tubes and the 8 French version for 3.0 mm and larger endotracheal tubes. It is packaged with a removable metal cannula that stiffens the device except for the distal tip. The advantages of the metal cannula are that it can be bent to change the shape of the Frova and make it easier to advance. The disadvantages of the metal cannula are that it makes the Frova more rigid, harder to maneuver, and potentially increases airway soft tissue trauma. Products with the suffix "-FII" also include a stiffening cannula and two Rapi-Fit® adapters for connection to a ventilatory device. Products with the suffix "-FI" include two Rapi-Fit® adapters for connection to a ventilatory device, but no stiffening cannula. The adapter can be used to ventilate the patient and confirm proper tracheal placement before advancing the endotracheal tube. It takes only 15 seconds to attach an aspirating esophageal detector device to the adapter and confirm its position.[16]

SUNMED BOUGIE

The SunMed Bougie (SunMed, Largo, FL) is made of a blend of low and high density polyethylene for optimal stiffness and has depth calibration markings. It is 70 cm long and available as a 10 French pediatric size or a 15 French adult size (**Figure 15-3**). Three versions of these devices are available: the original, the malleable, and a ported version. The original adult version is available with a straight or curved tip and fits 4.0 to 11.0 mm endotracheal tubes. The original pediatric version is only available with a curved tip. The malleable version has a color-coded stopper and fits 6.0 to 11.0 mm endotracheal tubes. A new ported version allows insufflation of oxygen and gas sampling. It is available only in the 15 French size. It uses a blend of low and medium density polyethylene for optimum firmness, and it is depth calibrated in centimeters. A study comparing the SunMed, Portex, Greenfield, and Eschmann bougies demonstrated that Emergency Physicians had better success rates using the SunMed and Greenfield devices, but they had a low preference for the Greenfield bougie.[17]

GREENFIELD FLEX-GUIDE ET TUBE INTRODUCER

The Flex-Guide ET Tube Introducer (Greenfield Medical Sourcing Inc., Austin, TX) is a 60 cm long polyethylene tube that is available in a 15 French (5.0 mm) diameter for adults and a 10 French (3.3 mm) diameter for children (**Figure 15-4**). The ends of the Flex-Guide are smooth and rounded with a bend 2 cm from the distal end, resulting in a 30° coudé tip. The tubing is flexible and can be straightened or bent as required. The adult Flex-Guide has a black band marking 37 cm from its proximal end (**Figure 15-4**) to help determine correct placement depth. The pediatric Flex-Guide has markings every 10 cm (**Figure 15-4**). The Flex-Guide is similar to the Eschmann or Portex bougie, only more economical. This device has been used in the Emergency Department to intubate difficult airways.[18]

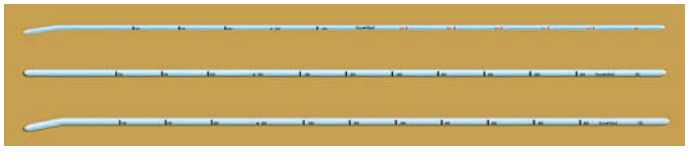


FIGURE 15-3. The SunMed Bougie. From top to bottom: 10 French Coudé tip pediatric version, 15 French straight tip adult version, and the 15 French Coudé tip adult version (Photo courtesy of SunMed, Largo, FL).



FIGURE 15-4. The Greenfield Flex-Guide Endotracheal Tube Introducer adult version (above) and pediatric version (below) (Photo courtesy of Greenfield Medical Sourcing Inc., Austin, TX).

AINTREE INTUBATION CATHETER

The Aintree Intubation Catheter (Cook Medical Inc., Bloomington, IN) was designed to be used with a fiberoptic bronchoscope (**Figure 15-5**). It is packaged with a Rapi-Fit Adapter, which allows ventilation through the device and air exchange through the multiple distal side ports. The Aintree is only available in one size and for use with endotracheal tubes greater than 7.0 mm in diameter. It may also be used as a bougie without the fiberoptic bronchoscope. It is generally not used as a bougie due to it being hollow, flexible, straight, and lacking the flexed tip of a typical bougie.

ENDOTRACHEAL TUBE EXCHANGERS

The use of an endotracheal tube exchanger to facilitate orotracheal intubation similar to a bougie is not recommended. These devices are straight, very flexible, thin-walled, and hollow tubes. Their flexibility makes it difficult to advance into the trachea and more often enters the esophagus. When inserted and warmed by the patient's body temperature, these thin-walled hollow tubes become even more flexible.



FIGURE 15-5. The Aintree Intubation Catheter. From left to right: the proximal end with the Rapi-Fit adapter, the body with centimeter markings, and the distal end (Photo courtesy of Cook Medical Inc., Bloomington, IN).

PATIENT PREPARATION

The patient preparation is exactly the same as that for orotracheal intubation (Chapter 11). Refer to Chapter 11 for a complete discussion regarding the patient preparation. The patient should be appropriately monitored with electrocardiography (ECG), end-tidal CO_2 monitoring, noninvasive blood pressure cuff, and pulse oximetry. As for any situation where airway manipulation is to occur and the patient's protective airway reflexes are blunted or ablated, a fully functioning suction apparatus with a variety of catheters must be immediately available. Place the patient supine with their head in a neutral position.

Place the patient, with a normal neck, in the "sniffing" position, with their head extended at the atlantooccipital joint while the neck is relatively flexed. A folded towel under the occiput helps to gently raise and tilt the head back into the proper position. **Correct positioning is probably the most important preparation of the patient.** Dentures should be left in place temporarily, as they help to stabilize the mouth and prevent occlusion during preoxygenation and bag-valve-mask ventilation.

TECHNIQUES

OROTRACHEAL INTUBATION

The bougie can be used in anticipation of a difficult airway or when a difficult airway is encountered and direct laryngoscopy is not successful. Instruct an assistant to ventilate the patient with a bag-valve-mask device. Liberally lubricate the bougie with a water-soluble lubricant. Insert the laryngoscope loaded with either a Macintosh or Miller blade. Elevate the laryngoscope and attempt to visualize the epiglottis and vocal cords. If the vocal cords are visualized, partially or completely, insert the bougie through the vocal cords and into the trachea.

If the vocal cords are not visualized, attempt to pass the bougie under the epiglottis with the curved distal tip facing anteriorly (**Figures 15-6A & 16-6B**). Slowly and carefully advance the bougie distally toward the trachea. The bougie will slightly jump or bounce as its tip is advanced over each tracheal ring (**Figure 15-6C**). This is sometimes referred to as the "palpation of a click" as the tip passes over each tracheal ring. Advance the bougie approximately 10 to 15 cm into the trachea (**Figure 15-6D**). Securely hold the bougie in place. **Do not remove the laryngoscope after the bougie is placed within the trachea. The laryngoscope will continue to elevate the tongue and allow easier passage of the endotracheal tube.**

There are several signs that signify proper bougie placement within the trachea. If the bougie is unable to be advanced more than 40 cm from the patient's lips in an adolescent or adult, or more than 24 cm in the child, it is likely caught at the carina or bronchus as the airway narrows. This is sometimes referred to as the "hold-up" sign. The "hold-up" sign in addition to the palpation of "clicks" as it is inserted confirms proper tracheal positioning of the bougie.[19] If the bougie freely advances more than 40 cm from the adolescent or adult patient's lips, or 24 cm in the child, it is most likely in the esophagus or stomach. One study noted the bougie getting caught and the palpation of "clicks" to be a less reliable indicator of tracheal placement than some other studies.[20] An assistant performing the Sellick maneuver should feel the tip of the bougie passing under their fingertips as it is advanced down the trachea. The bougie will rotate as the tip passes the carina and enters the mainstem bronchus. It will rotate clockwise if it enters the right mainstem bronchus and counterclockwise if it enters the left mainstem bronchus.

Instruct an assistant to load the endotracheal tube over the bougie and slide it to the level of the patient's lips. **The assistant should hold and advance the endotracheal tube until its tip is at the patient's lips while the Emergency Physician controls the bougie, controls the laryngoscope, and provides instruction to the assistant. The Emergency Physician must now grasp and control the endotracheal tube with their right hand while the assistant holds the bougie securely in place.** Advance the endotracheal tube over the bougie and into the trachea (**Figure 15-6E**). Under direct visualization, rotate the endotracheal tube 90° counterclockwise so that the bevel is facing posteriorly as the endotracheal tube passes through the vocal cords. This maneuver allows the endotracheal tube bevel to not get caught on the arytenoid cartilage and to gently spread the arytenoids with a minimum of force, thus avoiding any injury to the vocal cords.[21] **If resistance is felt, do not try to advance the endotracheal tube.** Instruct the assistant to slightly withdraw the endotracheal tube, rotate it in a slightly more counterclockwise direction, and re-advance it again.

Hold the endotracheal tube firmly in place. Remove the laryngoscope. Remove the bougie. Secure the endotracheal tube, confirm its proper position, and begin ventilation of the patient.

ALTERNATIVE OROTRACHEAL INTUBATION TECHNIQUE

An assistant is not always available to load the endotracheal tube and advance it over the bougie. An alternative is for the Emergency Physician to preload the endotracheal tube on the bougie (**Figure 15-7**) and insert them as a unit without the use of an assistant. Load the endotracheal tube over the bougie so that the bougie projects approximately 10 cm from the distal end of the endotracheal tube (**Figure 15-7A**). Form a loop with the endotracheal tube and proximal bougie and grasp it with the right hand (**Figure 15-7A**). A second technique is to load the endotracheal tube on the bougie so that the bougie projects approximately 6 to 10 cm from the distal end of the endotracheal tube and grasp it with the right hand (**Figure 15-7B**).

Insert the laryngoscope into the patient's mouth and attempt to visualize the glottis. Grasp the bougie loaded with the endotracheal tube in the right hand. Insert the distal end of the bougie through the vocal cords and into the trachea. Remove the laryngoscope. Advance the endotracheal tube over the bougie and into the trachea. Securely hold the endotracheal tube. Remove the bougie. Secure the endotracheal tube, confirm its proper position, and begin ventilation of the patient.

BOUGIE-GUIDED SUPRAGLOTTIC AIRWAY INSERTION

Bougies can be used to guide supraglottic airway devices.[22–24] A bougie was utilized as a guide through the Pro-Seal LMA.[22] The esophageal channel of the LMA was used to load the bougie and place it in the esophagus. This resulted in a better success rate than using the LMA introducer tool. The bougie-guided insertion caused less trauma than the LMA insertion tool after failed digital insertion of the ProSeal LMA. A similar technique has been used in the pediatric population.[23] Other studies have used bougies as guides through a supralaryngeal device for rescue intubation.[24]

BOUGIE-ASSISTED RETROGRADE INTUBATION

Retrograde intubation with a bougie may be considered as an emergent airway management option.[25] A patient was successfully intubated using a modified retrograde technique through a tracheal defect with a bougie. The bougie is often more conveniently

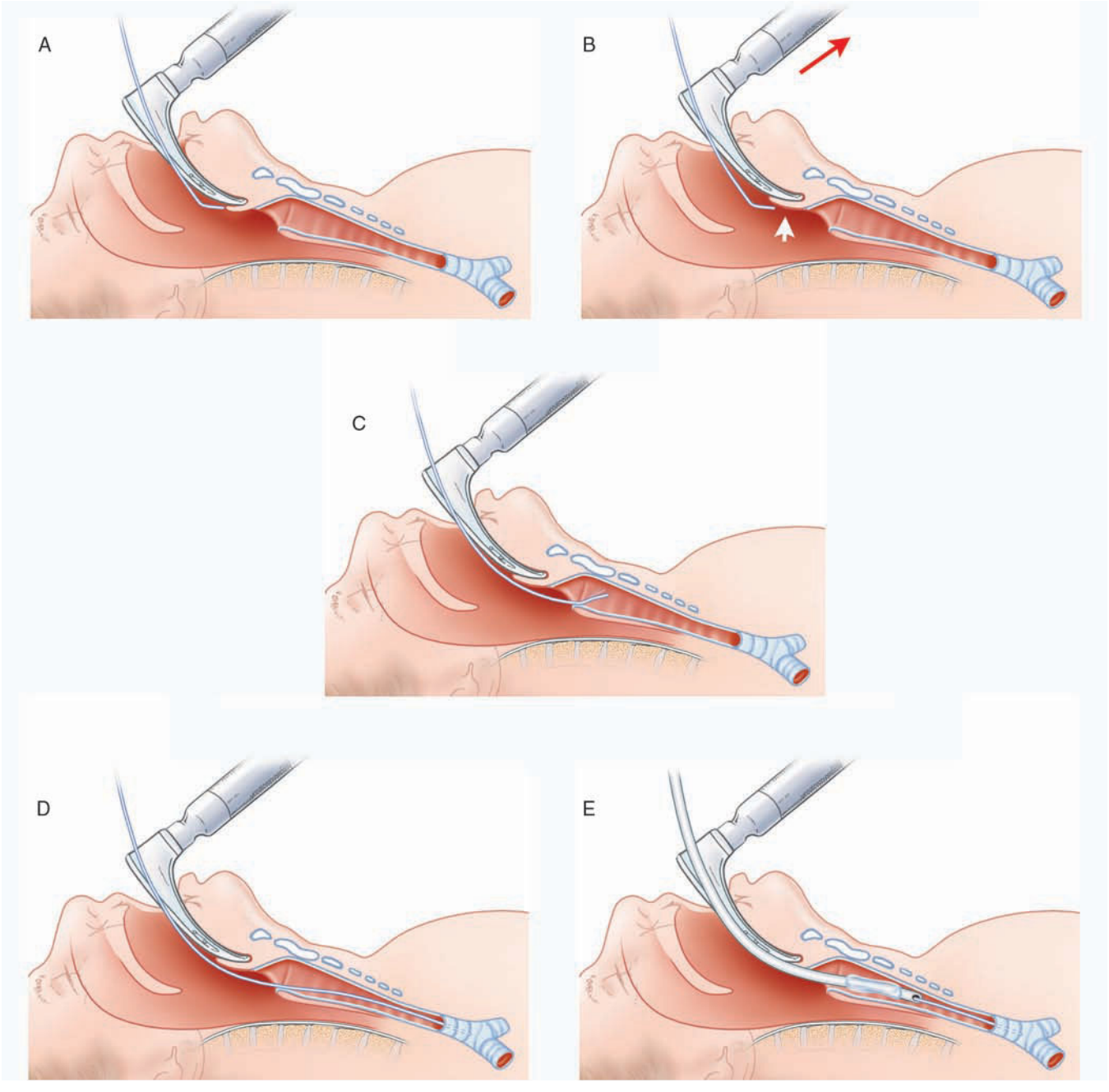


FIGURE 15-6. Intubation using a bougie. **A.** The laryngoscope has been inserted and the bougie advanced into the hypopharynx. **B.** The bougie is advanced under the epiglottis. **C.** The bougie is inserted into the trachea and advanced over the tracheal rings. **D.** The bougie is advanced until its tip is at the carina or mainstem bronchus. **E.** The endotracheal tube is advanced over the bougie and into the trachea.

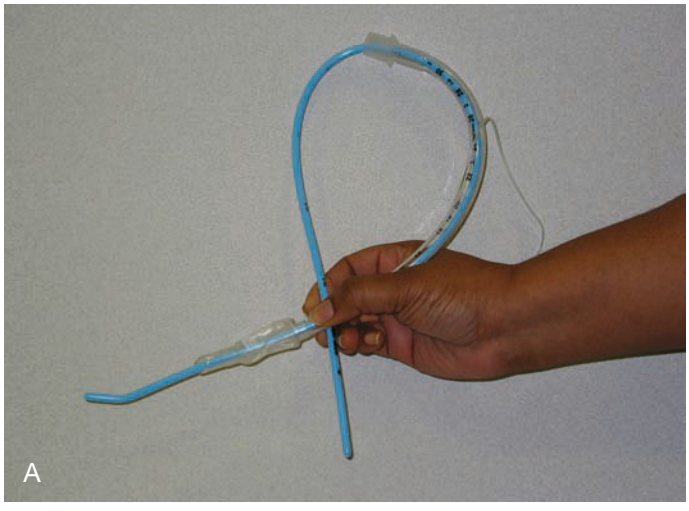
available than a retrograde guidewire kit. A bougie can be inserted through the skin and airway incision, laceration, or defect and advanced superiorly to exit the patient's mouth. The endotracheal tube can then be loaded over the bougie and advanced into the trachea. Refer to Chapter 23 for the complete details of retrograde guidewire intubation.

BOUGIE-ASSISTED CRICOTHYROIDOTOMY

Various medical and surgical specialities have used the bougie as an aid when performing a cricothyroidotomy.[26,27] It was found using a bougie as an aid to be easier and faster to teach how to perform a cricothyroidotomy in an animal lab than a traditional cricothyroidotomy.[28] The military describes this as the preferred technique of combat airway management.[29] The three-step technique using the bougie can be quickly taught to combat medics and performed in complete darkness using night vision goggles. A bougie placed through the incision maintains the open tract, provides tactile confirmation of tracheal placement, and serves as a guide for the endotracheal tube insertion.

ALTERNATIVE USES

Various other applications of the bougie have been described.[30–33] The bougie can be used as an adjunct in nasal intubation in the adult and pediatric populations.[30,31] The bougie has been successfully used



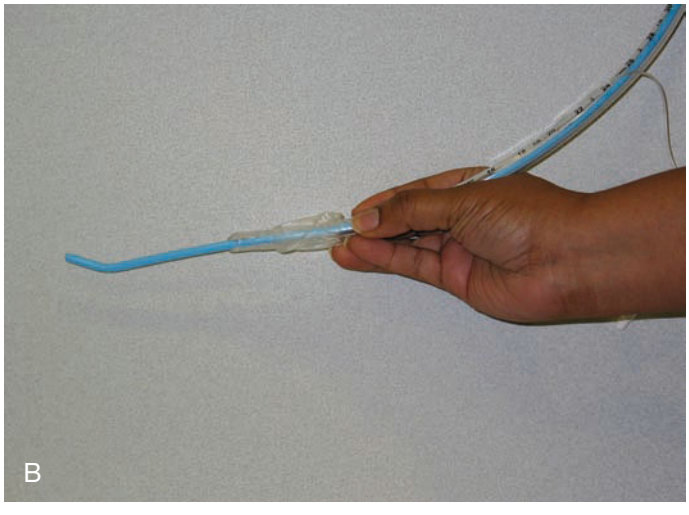


FIGURE 15-7. Two methods to preload an endotracheal tube onto a bougie. **A.** The curved hold. **B.** The straight hold.

to aid in correct placement of a double-lumen airway tube in a difficult airway.[32] It has also been described and tested as a back-up device during extubation to allow for a quick reintubation in case of the need to re-secure the airway.[33]

COMPLICATIONS

There are some complications specific to the use of a bougie. The bougie can cause trauma to the airway soft tissues.[9–11,34,35] The Frova causes significantly more complications than other bougies (5% incidence vs. rare).[34] This difference is most likely due to using the metal cannula, making the Frova quite stiff. The Frova with the metal cannula exerts more force on the airway tissues than other bougies.[15,35] Using the Frova without the metal cannula will reduce the incidence of tissue trauma. Single-use bougies may be more prone to cause soft tissue trauma when compared to multiple-use bougies, especially if they are held close to the distal end.[13,35] A false passage can be created by the tip of the bougie penetrating the soft tissues.[9] Insertion of an endotracheal tube over the bougie and into a false passage can increase the amount of soft tissue damage and hemorrhage. Insufflation of air into the surrounding soft tissues can compress the trachea and cause an external airway obstruction. A bougie can perforate the airway and result in a tension pneumothorax.[36] Advancement of the bougie into the trachea or mainstem bronchus can induce bronchospasm.[34] The remainder of the complications is similar to those of orotracheal intubation (Chapter 11).

SUMMARY

Bougies are widely used to aid in intubation with traditional direct laryngoscopy when the glottic opening cannot be adequately visualized. They have been successfully used both in the adult and pediatric population, with devices available for use with endotracheal tubes as small as 3.0 mm in size. They are also used to aid in placement of supralaryngeal devices, blind nasotracheal intubations, placement of double-lumen airway tubes, retrograde intubation, and cricothyroidotomies. A bougie should be a required device in any emergency or difficult airway cart.

16 Digital (Tactile) Orotracheal Intubation

O. John Ma and Amanda Munk

INTRODUCTION

For patients who require orotracheal intubation, digital (tactile) intubation is an alternative technique to traditional direct laryngoscopy.[1–12] This procedure involves using the index and middle fingers as a guide to blindly place the endotracheal tube into the patient's larynx. Digital tracheal intubation has been demonstrated to be a safe, simple, and rapid method.[1] It should be considered as a secondary method of intubation when other methods prove difficult or impossible.[1] It is particularly suited for prehospital and aeromedical use, where equipment and alternate intubation techniques are limited or unavailable. One study demonstrated an 88% success rate among paramedics who intubated with this technique.[2]

ANATOMY AND PATHOPHYSIOLOGY

For this procedure, the only two significant anatomic structures that the intubator will encounter are the patient's tongue and the epiglottis. The epiglottis is the cartilaginous structure that is located at the root of the tongue and serves as a valve over the superior aperture of the larynx during the act of swallowing.[3]

INDICATIONS

Digital orotracheal intubation is an ideal alternative technique for intubating the comatose or chemically paralyzed patient when other more conventional methods for intubation have failed. In particular, this procedure is useful when oral secretions or blood inhibit the direct visualization of the upper airway.[1] Since this technique involves minimal movement of the head and neck, it may be a suitable method for intubating patients with known or suspected cervical spine injuries. Digital intubation may be a useful procedure for paramedics and aeromedical personnel in the out-of-hospital setting, when trapped patients require intubation but are not in a position for more conventional methods.[2] It is an alternative technique for out-of-hospital intubation where other techniques and equipment are unavailable or limited.

This procedure has also been performed successfully in intubating neonates.[4,11,12] One study comparing neonatal digital intubation with direct laryngoscopy demonstrated digital intubation to be more rapid and more successful on the first attempt.[5]

CONTRAINDICATIONS

There are no absolute contraindications to digital intubation. The main danger of this procedure is to the healthcare worker performing the intubation, who is at risk for having his or her fingers bitten by the patient. **This technique should not be performed on any patient who is awake or semiconscious. It should be performed only on patients who are paralyzed or unconscious.** Relative contraindications would be performing this procedure on a patient with multiple fractured teeth that may abrade or cut the intubator's fingers, or a patient whose ingestion may present a biochemical hazard to the intubator.

EQUIPMENT

- Endotracheal tubes, various sizes
- Wire stylet, malleable (optional)
- 10 mL syringe
- Water-soluble lubricant or anesthetic jelly
- Bag-valve device
- Oxygen source and tubing
- Gauze, 4 × 4 squares

PATIENT PREPARATION

Endotracheal intubation in the Emergency Department is commonly performed on an emergent or urgent basis. If there is time, explain the risks, benefits, and complications of the procedure to the patient and/or the patient's representative.

The use of gloves, a bite block, and gauze over the teeth as guards are recommended when performing this procedure. The patient should be lying supine. If the patient has sustained a concerning mechanism of injury, the cervical spine should be immobilized. An assistant can help hold the patient's head to maintain in-line immobilization. Place the patient on continuous cardiac monitoring, pulse oximetry, and supplemental oxygen.

TECHNIQUE

Prepare the endotracheal tube. Attach a 10 mL syringe to the cuff's inflation port. Inflate the cuff and inspect it for any air leaks. Deflate the cuff and leave the syringe attached to the inflation port. The use of a stylet is optional, but commonly used by most practitioners in this procedure.[6] It may be used if the patient's larynx is anterior, the intubator has short fingers, or it is the physician's preference. Lubricate and insert the stylet until it is 1 cm proximal to the distal end of the endotracheal tube. Bend the malleable stylet just as it enters the endotracheal tube. This will prevent it from migrating distally and injuring the patient. Gently bend the distal end of the endotracheal tube into a "J."[1] Liberally lubricate the distal end of the endotracheal tube. Induce anesthesia (Chapters 8 and 10) if the patient is conscious.

The intubator should stand at the patient's right side and be facing the patient. Insert the index and middle fingers of the right hand into the right angle of the patient's mouth (**Figure 16-1**).[1,5] Slide the fingers along the surface of the tongue until the epiglottis is palpated. The metacarpophalangeal joints of the index and middle fingers will usually be at the level of the patient's incisors in an adult. The tip of the epiglottis is approximately 8 to 10 cm from the incisors. Elevate the epiglottis with the index finger (**Figure 16-2**). The thumb of the left hand may be used to provide cricoid pressure if needed.[7]

With the left hand, insert the endotracheal tube along the left side of the patient's mouth and between the two fingers (**Figures 16-1 & 16-2**).[1,5] Alternatively, the endotracheal tube can be advanced between the two fingers and the tongue. Gently advance the tip of the endotracheal tube into the patient's trachea (**Figure 16-2**). Do not advance the endotracheal tube if any resistance is encountered. Partially withdraw the endotracheal tube and reattempt to insert it into the patient's trachea. Alternatively, withdraw the endotracheal tube completely, bend it more sharply, and then attempt to insert it into the trachea. Have an assistant withdraw the stylet if one was used. Advance the endotracheal tube approximately 3 to 4 cm.[1,8] While securely holding the endotracheal tube with the left hand, gently withdraw the right hand from the patient's mouth. Inflate the cuff of the endotracheal tube. Begin ventilating the patient while securely holding the endotracheal tube and confirming proper placement.

The technique of digital orotracheal intubation is not as simple as some may think. A patient's mouth may appear too small to allow an



FIGURE 16-1. The index and middle fingers are placed in the right side of the patient's mouth and advanced until the epiglottis is palpated. The endotracheal tube is inserted into the patient's mouth between the two fingers.

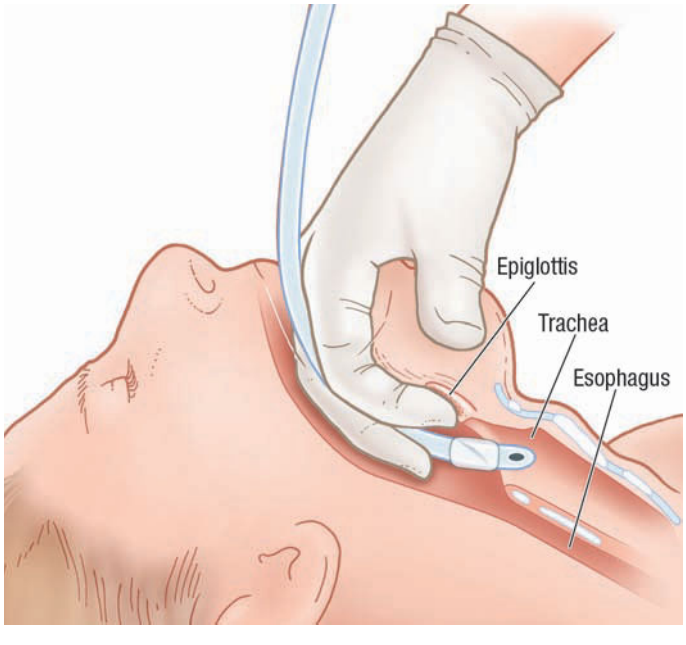


FIGURE 16-2. Advancing the endotracheal tube. The epiglottis is elevated with the index finger. The endotracheal tube is advanced between the fingers and into the larynx.

endotracheal tube and two fingers of the intubator. Use the fingers in the patient's mouth to push their jaw and tongue forward. If the patient's mouth still appears small, apply gauze squares over their mandibular incisors and push their mouth open further with the bases of the fingers in their mouth.

It may be difficult to blindly identify the patient's epiglottis. Insert your fingers in the midline of the patient's mouth and slowly push them posteriorly. The fingers will roll off the posterior portion of the tongue and allow you to palpate the epiglottis. Be careful to not push the epiglottis posteriorly. Once identified, move your fingers to the right side of the patient's mouth while the fingertips are in constant contact with the epiglottis. Continue the procedure as described above.

Some may be concerned their fingers are not long enough to palpate the epiglottis. Push the soft tissue in the right angle of the patient's mouth posteriorly while inserting your fingers posteriorly in their mouth. This will allow your fingers to reach more posteriorly.

This technique can be used in patients of all ages, including neonates.[11,12] Use only the index finger of little finger when performing this procedure in young children. Use the appropriate size suction catheter or endotracheal tube as would be used to orally intubate the child. Do not insert the catheter or endotracheal tube if the child is breathing using this technique or their vocal cords can be damaged.

ASSESSMENT

The placement of an endotracheal tube should be followed by an assessment to ensure its proper positioning (Chapter 12). This includes visual inspection of chest rise and lack of abdominal movement with ventilation, fogging in the endotracheal tube for at least six breaths, auscultation, and end-tidal CO_2 monitoring. This should be followed by a chest X-ray to confirm proper positioning of the endotracheal tube within the trachea.

AFTERCARE

The steps of ensuring proper placement of the endotracheal tube and securing the tube are the same as for any patient who has undergone orotracheal intubation (Chapter 11).

COMPLICATIONS

No significant complications to the patient have been identified with digital intubation. One study involving a small number of cadavers found that digital intubation predisposes to left mainstem intubation.[9] The investigators concluded that decreased right-sided breath sounds after tactile intubation may represent an easily corrected left mainstem intubation rather than other pathology. An awake or semiconscious patient may gag, with subsequent vomiting and aspiration and injury to the intubator's fingers. For added safety, insert a bite block between the patient's molars if its placement still allows enough space in the patient's mouth for two fingers and the endotracheal tube. The possibility of esophageal intubation is significant, especially if the intubator has small fingers or the airway is anterior. Hypoxemia can result from numerous attempts at intubation without any intervening ventilations. The endotracheal tube should be inserted gently to prevent traumatic injury to the patient's hypopharynx, vocal cords, or trachea.[6]

SUMMARY

Digital (tactile) intubation remains a viable alternative technique for management of the airway. Every Emergency Physician should become familiar with this technique. It is a rapid and safe method to intubate a patient. It is an ideal method for intubating a comatose or paralyzed patient if the upper airway cannot be visualized because of trauma, secretions, or blood. Digital intubation should also be considered when intubating the patient with a known or suspected cervical spine fracture, since this technique requires minimal head and neck movement. It is also a viable method for out-of-hospital intubation.

17 Lighted Stylet Intubation

Philip Bossart and Michael Wallace

INTRODUCTION

Direct laryngoscopy is the most common method of tracheal intubation in the Emergency Department. However, in about 1% to 3% of Emergency Department patients requiring intubation, direct laryngoscopy will be very difficult or impossible.[1,2] This may be due to many different causes including jaw immobility, limited cervical spine mobility, or excessive airway bleeding. In these situations, blind intubation using a lighted stylet is a proven valuable technique.[3–7] Lighted stylet intubation relies on the transillumination of the soft tissues of the anterior neck to indicate intratracheal endotracheal (ET) tube placement. A bright, well-defined glow is seen in the anterior neck when the light is in the trachea. However, a diffuse, less intense glow is seen with esophageal intubation. Lighted stylet intubation is a relatively easy technique to learn and rapid to perform.

The first published report of using a light source to guide intubation was in 1959.[8] They described the device and technique in order to perform blind nasal intubations in the operating room. However, this technique did not receive much attention until the late 1970s when the Flexi-lum light wand (Concept Corporation, Clearwater, FL) was introduced.[9] Over the years, more powerful and less heat emitting light sources have been developed along with more flexible stylets. Today there are at least four currently available devices, all of which are inserted into an ET tube instead of a standard stylet. These include the Trachlight (**Figure 17-1**), the Light Wand (**Figure 17-2**), the Flexible Lighted Stylet (**Figure 17-3**), and the Tube-Stat (**Figure 17-4**). Although there are slight differences in design, they all rely on using a lighted stylet to transilluminate the anterior neck and guide blind intubation of the trachea.

ANATOMY AND PATHOPHYSIOLOGY

The trachea lies anterior to most structures of the neck and is covered anteriorly only by skin, subcutaneous tissue, and pretracheal fascia. A light source positioned within the trachea will transilluminate a bright and discrete glow that can easily be seen on the surface of the neck. In contrast, the esophagus lies posteriorly and is surrounded by numerous soft tissue structures. A light source directed within the esophagus will be diffused by the surrounding tissue and appears dull. At the bedside, the Emergency Physician can easily discriminate between the dull, diffuse transillumination of an esophageal light source and the more discrete, intense signal transmitted from within the trachea. A submental, superior to the hyoid bone, glowing light indicates that the tip is positioned in the vallecula. A lateral glowing light indicates placement in the pyriform sinus.



FIGURE 17-1. The Trachlight (Laerdal Medical Inc., Wappinger Falls, NY).

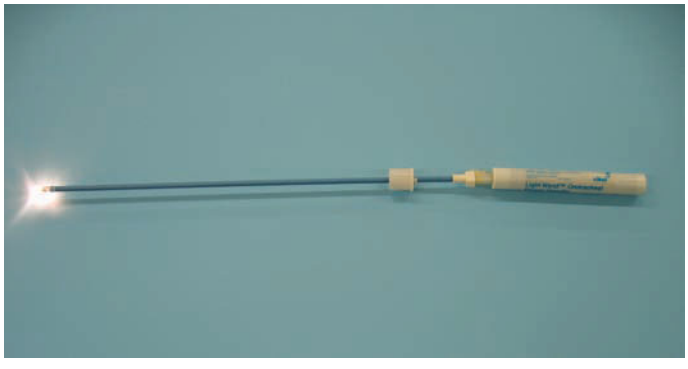


FIGURE 17-2. The Light Wand (Vital Signs Inc., Totowa, NJ).

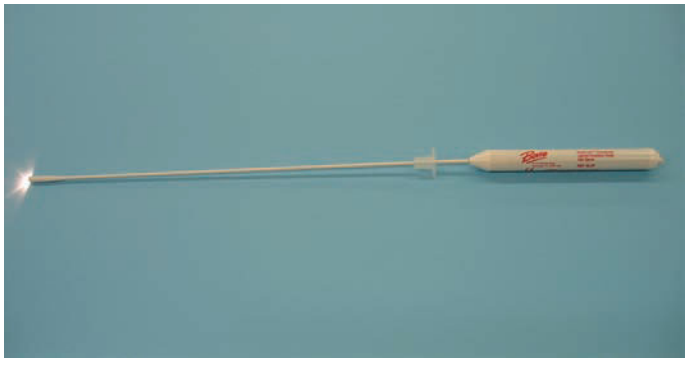


FIGURE 17-3. The Flexible Lighted Stylet (Aaron Medical, St. Petersburg, FL).



FIGURE 17-4. The Tube-Stat Lighted Intubation Stylet (Medtronic Xomed Inc., Minneapolis, MN).

TABLE 17-1 Indications for Intubating with a Lighted Stylet

Anatomic abnormalities	**Limited jaw mobility**
Congenital head and neck anomalies	Temporomandibular immobility
Pierre Robin syndrome	Trismus
Treacher Collins syndrome	
Midface hypoplasia	**Trauma**
	Dental trauma
Excessive secretions	Maxillofacial trauma
Blood	
Vomitus	**Miscellaneous**
	Unable to intubate by other methods
Limited cervical spine movement	
Known or suspected cervical spine injury	
Cervical arthritis	
Burn strictures of the neck	

INDICATIONS

There are numerous indications for lighted stylet intubation (**Table 17-1**). Lighted stylet intubation is a valuable rescue technique in patients who can be ventilated and oxygenated but are unable to be intubated with direct laryngoscopy. It is particularly useful in patients that have cervical spine immobilization or restricted neck movement, limited jaw opening, extensive oral trauma, loose teeth, or extensive blood or secretions in the hypopharynx that limit visibility. It can be used as a backup technique or primarily if direct laryngoscopy is predicted to be difficult. There are limited data comparing lighted stylet intubations to other rescue techniques.[10–12] However, there is literature to suggest that lighted stylet intubations are faster and have fewer complications than blind nasotracheal and fiberoptic bronchoscopy-assisted intubations.[6,11,12] In addition, lighted stylets are easier to use, less expensive, and more portable than fiberoptic bronchoscopes.[12]

Lighted stylet intubations can be performed as part of rapid sequence intubation as well as on sedated, spontaneously breathing patients with topical airway anesthesia. Lighted stylets can be used for oral or nasal intubations.[13] This technique can also be used for pediatric patients and infants.[14–16]

CONTRAINDICATIONS

Intubation with lighted stylets is relatively safe and simple. There are few contraindications to this technique. **Patients with laryngeal trauma should have direct laryngeal visualization for intubation rather than a blind technique that may cause additional trauma.** As a blind technique, it should not be used if there is any active infection or known tumor of the posterior pharynx or upper airway. The presence of epiglottitis, a retropharyngeal abscess, tracheal stenosis, a laryngeal polyp or tumor, or an airway foreign body precludes the use of this technology. It may be less successful in bright sunlight, in those with very dark skin, and particularly in the obese patient.[17,21,22]

It is relatively contraindicated in patients who cannot be oxygenated and ventilated. However, it could be used in this situation by very experienced physicians while simultaneous preparations are underway for a cricothyroidotomy. Lighted stylets should be used only by physicians who have sufficient experience and training with the equipment and the technique.

If the lighted stylet meets resistance, it should be withdrawn, redirected, and advanced only if it passes with ease. **Should unexpected difficulty occur during passage of the lighted stylet, the technique should be abandoned and an alternative method used to intubate the patient.**

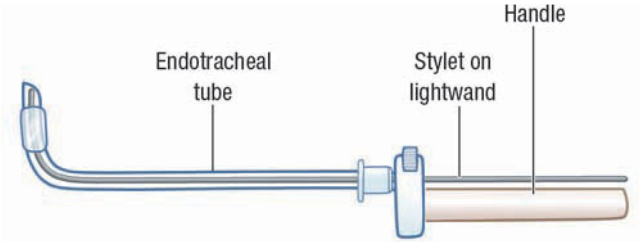


FIGURE 17-5. The Trachlight brand lighted stylet

EQUIPMENT

- Lighted stylet
- ET tubes, various sizes (ETT)
- 10 mL syringe
- Water-soluble lubricant
- Bag-valve device
- Equipment for orotracheal intubation (Chapter 11)

The basic unit of a lighted stylet is quite simple. It consists of a handle, a malleable stylet, and a light on the end of the stylet (**Figure 17-5**). Numerous variations exist on the basic unit. The handle contains the battery, an on–off switch, and sometimes an on–off indicator light. They may be reusable or single-use disposable devices. The stylet is malleable and available in numerous sizes. Longer stylets allow for nasal and oral intubation in adults. Stylets are also available in smaller lengths and widths to allow for use in the small ET tubes for infants and children. The stylet is inserted into the ET tube instead of a standard stylet.

PATIENT PREPARATION

Once the decision is made to intubate, the patient should be prepared as for any other intubation (Chapter 11). The patient should have intravenous access secured and routine hemodynamic monitoring, including an automatic blood pressure monitor, a cardiac monitor, and a continuous pulse oximetry monitor. Suction should be immediately available. Rapid sequence intubation with an induction agent and paralytic agent is the most common technique used in the Emergency Department. However, lighted stylet intubations can be performed with mild sedation and topical anesthesia in cooperative patients.

As with all intubations, the patient should be preoxygenated prior to airway manipulation. Unlike the case with other techniques, the position of the neck can be neutral. The "sniffing" position is not required for this technique. If the patient is in a cervical collar, the anterior half must be opened or removed to be able to visualize the glowing light. An assistant can maintain in-line stabilization of the cervical spine when the collar is opened.

TECHNIQUE

OROTRACHEAL INTUBATION

The exact technique will depend upon the type of lighted stylet or lightwand used. Since this technology varies by the manufacturer, anyone employing these airway adjuncts should be familiar with the equipment and manufacturer's instructions prior to adopting them for use clinically. This text describes the general guidelines for the lighted stylets available at the time of this writing. The reader is urged to take advantage of the teaching videos supplied by some manufacturers.

Check that the light source is working and apply a water-based lubricant to the stylet. Attach a 10 mL syringe to the ET tube cuff inflation port and ensure the integrity of the cuff. Insert the stylet through the ET tube. **The tip of the stylet should remain just inside the ET tube so that the stylet does not damage soft tissues.**

Bend the tip of the ET tube and stylet just proximal to the cuff or about 3 to 6 cm from the distal end (**Figure 17-5**). The bend may have to be a little more proximal or distal depending on the length of the patient's neck. Measure the mandibular–hyoid distance in the patient. Place the index finger in the submental space below the chin and determine the number of finger breadths between the mandible and the hyoid bone.[5] Typical measurements are one to three finger breadths. Bend the tip of the ET tube and stylet sharply at a site that approximates the mandibular–hyoid distance between the bend and the junction of the lighted tip of the stylet. This is usually 3 to 6 cm from the distal end of the ET tube and just above the cuff. Avoid making the bend at the cuff, if possible, to prevent damaging the cuff. **Be sure the bend is about 90° to allow the maximal light intensity to be directed anteriorly.**

Stand above or to the side of the patient's head. The lighted stylet, unlike the traditional laryngoscope, can be held in either hand. Lower the bed to facilitate insertion of the lighted stylet. Grasp the patient's jaw with your nondominant hand. Place your thumb on the mandibular molars and your fingers under the body of the mandible. Lift upward and inferiorly to open the jaw, elevate the tongue, and elevate the epiglottis. Grasp the lighted stylet with your dominant hand and turn it on. It is best held with a "pencil-grip" over the proximal ET tube.

Introduce the ET tube from the side of the patient's mouth and bring it to the midline. As the hockey stick-shaped tip is placed over the tongue, the handle will project toward the patient's feet (**Figure 17-6A**). Advance the tip by moving the handle in a vertical arc toward the patient's head (**Figure 17-6B**). This will bring the ET tube tip toward the vocal cords. A bright light will be seen in the midline of the neck just below the hyoid bone (**Figure 17-7A**). **If the light is in the submental space, the tip of the ET tube is in the vallecula (Figure 17-7B). If the light is lateral, the tip of the ET tube is lodged in the pyriform sinus (Figure 17-7C). A dull, faint light in the midline signifies that the tip of the ET tube is in the esophagus (Figure 17-7D).** If the glowing light is malpositioned, simply withdraw the ET tube, reposition it in the midline, and advance it again.

Once a bright and discrete light is detected in the midline at the level of the thyroid cartilage (Adam's apple), it is safe to advance the ET tube. If you are using the Trachlight, the manufacturer suggests withdrawing the stylet 10 cm before advancing the ET tube. This makes the distal tip of the ET tube more flexible and helps it make the acute turn before advancing down the trachea.

Advance the ET tube while observing the transilluminating light march down the neck to the suprasternal notch (**Figure 17-7A**). The light will disappear as the tube passes behind the suprasternal notch. If the glowing light is in the midline and the ET tube is resistant to advancement, the epiglottis is obstructing its advancement. Slightly rock the unit in the sagittal plane (from the patient's head to the feet) to slip the tip of the ET tube under the epiglottis. If resistance is still encountered, remove the lighted stylet. Ventilate the patient with a bag-valve-mask device. Load a smaller ET tube onto the lighted stylet and try again. At the point the light is lost, the tip of the ET tube is appropriately positioned midway between the vocal cords and carina.[25] Remove the stylet, inflate the ET tube cuff, confirm proper ET tube placement, secure the ET tube at the lips, and begin ventilating the patient.

Special caution should be used in very thin or very obese patients. In the thin patient, a bright light may be visible even when the stylet

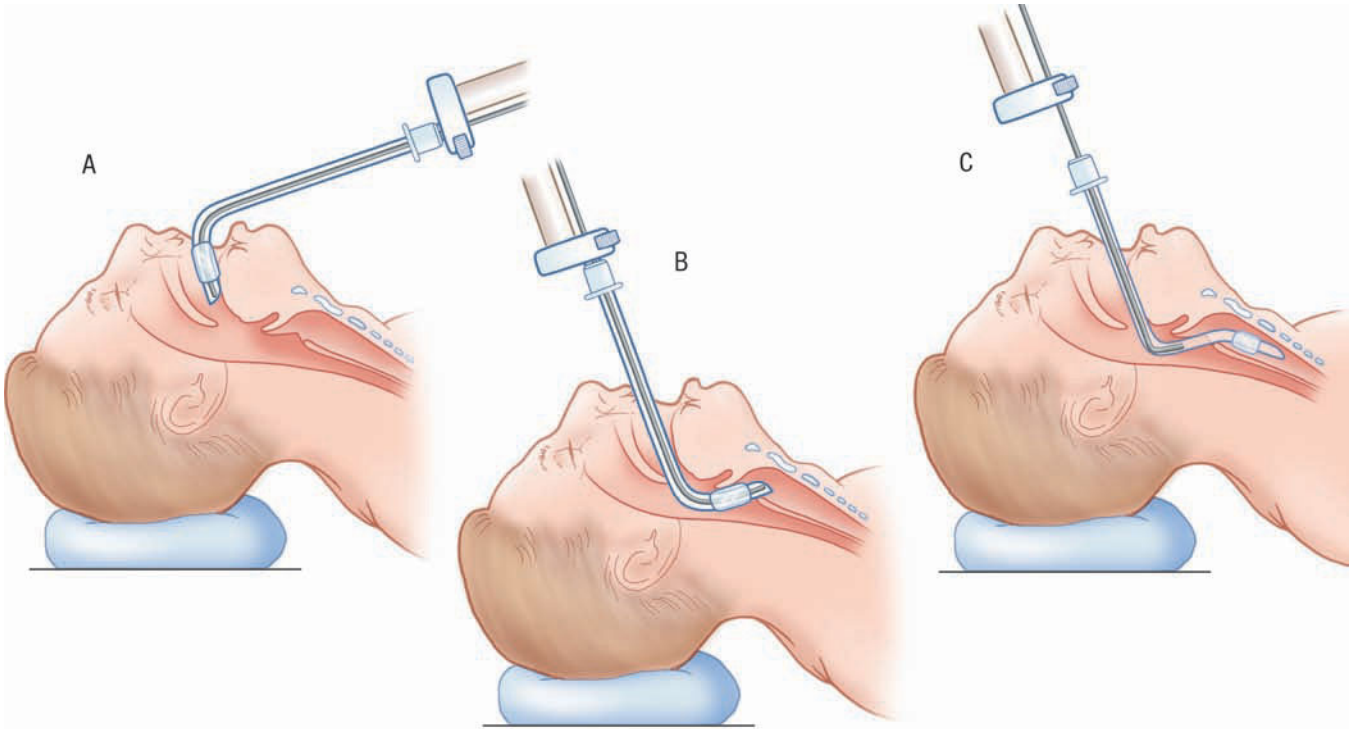


FIGURE 17-6. Insertion of the Trachlight lighted stylet. **A.** Insert the hockey stick-shaped ET tube and the stylet over the tongue. **B.** Move the tube in a vertical arc toward the patient's head. As the lighted stylet approaches the trachea, the bright light transilluminates the anterior neck. **C.** The ET tube is advanced into the trachea.

is in the esophagus. When the patient is thin, gently rock the light off midline to compare the diffuse dull light to that seen when the light is truly midline. In the obese patient, the extra soft tissue may dull the light. Dim the room lights to facilitate adequate visualization.

The glowing light must maintain a continual brightness to demonstrate tracheal intubation. If the glowing light is briefly lost or dulls and then returns, the ET tube has been misplaced in the esophagus. The brief loss or dulling of the glowing light corresponds to its passage behind the larynx. The return of the bright glowing light corresponds to the ET tube advancing past the larynx and into the esophagus. This is commonly seen in infants, small children, and very thin adults. Gently withdraw the lighted stylet while applying anteriorly directed traction to the tip of the stylet. Stop withdrawing the lighted stylet when the glowing light suddenly intensifies after it exits the esophagus. Readvance the lighted stylet, as previously described, while applying anterior traction on the unit to help it enter the larynx.

NASOTRACHEAL INTUBATION

The procedure for nasotracheal intubation is similar to orotracheal intubation with the lighted stylet with a few differences. The nasal passages should be treated with a topical anesthetic and a topical decongestant to vasoconstrict the mucosal tissue. The nasal passage may need to be dilated to accommodate the ET tube. Please refer to Chapter 22 for a complete discussion on the preparation of the nasal cavity for intubation. The lighted stylet should have a more gentle curve of about 100° to 120°. The bend to tip length should correspond to the distance from the posterior nasopharynx to the cricothyroid membrane.

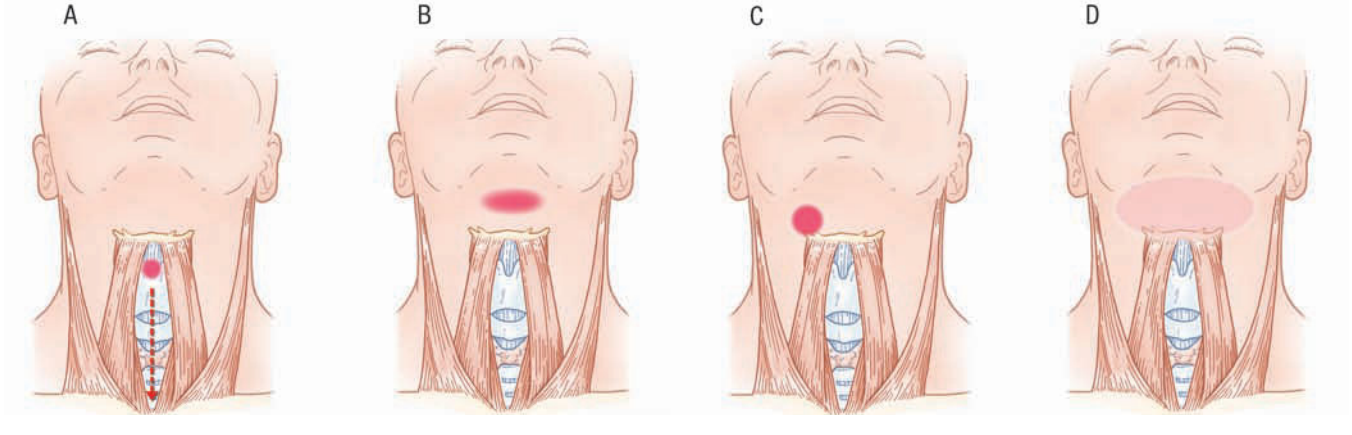


FIGURE 17-7. Appearance of the transilluminated light of the lighted stylet based on the location of the tip. **A.** Proper placement in the larynx with a bright distinct light in the midline at the level of the thyroid cartilage. With advancement of the ET tube, the light moves down the anterior neck and disappears behind the sternal notch (*dashed arrow*). **B.** Incorrect placement in the vallecula causes a submental glow, superior to the hyoid. **C.** Incorrect placement in the pyriform sinus causes a glow off the midline. **D.** Incorrect esophageal placement causes a diffuse, dull, or absent light.

ASSESSMENT

The patient should be assessed continuously at every step of the procedure to assure adequate oxygenation and ventilation. The position of the ET tube should be confirmed by end-tidal CO_2 monitoring, esophageal detector device, fogging in the ET tube for at least six ventilations, auscultation, and chest X-ray. Please refer to Chapter 12 for a more complete discussion regarding the confirmation of ET intubation.

AFTERCARE

The ongoing care of the patient should proceed as with any other intubation technique. Routine care of the ET tube is no different. The manufacturer's guidelines should be followed for maintenance of the equipment.

COMPLICATIONS

Intubation with a lighted stylet is a very safe procedure with a very low complication rate.[6,17] In over 30 years of use, there are only a small number of reported complications. These include two reports of accidental bulb dislodgment, two arytenoid dislocations, one case of stylet fracture, a lacerated frenulum, and varied reports of mild soft tissue trauma.[18–20] However, sore throat, hoarseness, and dysphagia seem to occur less frequently with lighted stylets than with direct laryngoscopy.[7] The cases of equipment failure noted above have been in older models of lighted stylets. There are data to suggest that lighted stylet intubations are less traumatic than direct laryngoscopy.[7] No complications were noted in 253 patients intubated with light stylets.[17] In addition, intubation with lighted stylets may cause less cervical spine motion compared with direct laryngoscopy.[25]

Success rates with lighted stylet intubation are comparable to those with other techniques. First attempt success rates are reported to be from 70% to 92%.[4,6,7] When multiple attempts were allowed, success rates approached 100%. In the prehospital setting with suboptimal intubating conditions, success rates of 88% have been reported.[21] Hung *et al.* reported successful intubation with lighted stylets in 95 out of 96 patients who had known difficult airways.[22] This series included patients with difficult or failed intubations by direct laryngoscopy, patients with unstable cervical spines, severe jaw immobility, and morbid obesity. Holzman *et al.* reported successful intubation of 30 out of 31 children with anatomic airway abnormalities.[14]

Intubation times with lighted stylets are comparable to those with other techniques and range from 16 to 45 seconds.[3,4,22] There does not appear to be any significant difference in degree of sympathetic stimulation and hemodynamic alterations between intubations with direct laryngoscopy and those with lighted stylets.[23,24] The skill level of the intubator is an important factor in the success rate, time to intubation, and possible complication rate.[14] Experience leads to faster intubation times and skills most likely will improve with practice in a cadaver lab or with a patient simulator.[5,10]

SUMMARY

Lighted stylet intubation is an easily learned technique that is a valuable adjunct for securing difficult airways. It is particularly useful in patients with limited jaw opening, limited neck movement, and marked airway bleeding. The American Society of Anesthesiologists includes use of lighted stylets in its recommendations for the management of difficult airways. The American Heart Association encourages instruction in alternative airway approaches, including lighted stylets, for difficult airways. The use of lighted stylets has proven to be rapid, safe, and effective in emergent and difficult settings.

The success of lighted stylet techniques is determined by the experience of the Emergency Physician. Since this technique is likely to be of greatest benefit in the occasional unexpected airway emergency, maintaining sufficient skills to use it in the emergent setting is a challenge. In order to be of use in the acute situation, Emergency Physicians will need to devote time and effort to developing and maintaining the skills they will need to cope with an airway emergency when it presents.

18 Supraglottic Airway Devices

Fred A. Severyn

INTRODUCTION

Airway management remains one of the cornerstones of the clinical practice of Emergency Medicine in both the Emergency Department and the prehospital environment. The majority of advanced airway placements in the prehospital environment occur in the cardiac arrest or trauma patient. Advances in the science of performing better cardiopulmonary resuscitation (CPR) aim to limit the "no-flow-time" associated with resuscitation. Most supraglottic airway devices aim for an insertion time under 30 seconds. Some Emergency Medical Service (EMS) systems have emphasized the use of an alternative airway device over endotracheal intubation.[1,2]

In the overall performance of airway management, the provider often begins with the basic life support (BLS) skill subset such as airway positioning, suctioning, and assisting spontaneous respirations with the use of a bag-valve-mask (BVM) device. They then jump to the advanced life support (ALS) skill subset such as placement of cuffed endotracheal tubes and surgical airway management. Traditional ALS management has revolved around the concept of placing an endotracheal tube. Over time, this has rolled out to the prehospital environment of care and is now firmly established into the current scope of practice for EMS professionals. The literature remains controversial and divided, with multiple recent studies suggesting limited benefit of prehospital endotracheal intubation in a variety of clinical settings. Even more disheartening are numerous studies demonstrating a significant percentage of unrecognized esophageal airway placement or endotracheal tube migration out of the airway upon Emergency Department arrival. Such therapeutic misadventures guarantee bad outcomes.[3] Most of these studies describe relatively busy EMS systems with clearly defined medical oversight. With inexperienced hands, the success rate is lower and the complications rates are high, and aggressive airway management has been linked to a decreased odds ratio for patient survival. In between BLS and ALS lies a very large grey area, with many airway adjuncts available to help with airway management.

The creation of a wide variety of airway adjuncts termed "supraglottic airway devices" (SADs) has occurred in order to facilitate airway management. Simplistically, SADs function as a bridge between the mouth and the vocal cords, allowing for air movements while bypassing tongue-induced airway obstruction.[4] Some recommended the term "extraglottic" to replace supraglottic in order to better define the relationship between function and not define anatomic position. For the purposes of this chapter, the two terms will be considered synonymous.

The classic laryngeal mask airway (LMA) is a common example of a SAD. It is utilized daily in operating room cases with a cumulative record of over 200 million episodes of use in patient care.[4,5] Most Emergency Physicians in training will get some exposure to the use of SADs as a result.[5] Not surprisingly, the logical migration

of airway devices from the operating room to the prehospital and Emergency Department environments has also begun. Each SAD comes with manufacturing claims as to their device superiority over the competition in a very competitive marketplace. It is difficult for Emergency Physicians to keep up with the industry explosion of these airway adjuncts. The disadvantages of SADs are that they are only temporary airway devices and must be removed or replaced with another airway device within a few hours.

The Emergency Physician will be on the receiving end of patients in which a wide variety of SADs have been used by EMS agencies. **There is also a need for SADs in the event of airway rescue after a failed intubation in the Emergency Department.** The American Society of Anesthesiologists has incorporated SADs into their "Can't ventilate, Can't intubate" difficult airway algorithm. The American Heart Association has also included their use in the algorithms for airway management in association with CPR. It is a reasonable expectation for the Emergency Physician to develop expertise and experience with SADs. This chapter discusses some of the many commonly available SADs. The LMAs and supraglottic dual lumen airway tubes (i.e., Combitube and EasyTube) are discussed in Chapters 19 and 20, respectively.

ANATOMY AND PATHOPHYSIOLOGY

Endotracheal intubation relies upon the placement of a ventilation tube between the vocal cords and into the trachea in order to provide a low resistance bridge between the trachea and the ventilation circuit. This bypasses the most common airway obstruction, the posteriorly directed lax tongue. SADs do not pass between the vocal cords. **SADs offer low resistance to air flow, protect the respiratory tract from gastric and oropharyngeal secretions to a variable degree, and are suitable for positive pressure ventilation in the nonspontaneously breathing patient while limiting potential adverse events.**[5] They rely on the close anatomic relationship between the laryngeal inlet and the upper esophagus. Many SADs allow the insertion of an introducer or an endotracheal tube to be passed through the airway tube and into the trachea.

INDICATIONS

The use of SADs is reserved for the unconscious patient without an intact gag reflex. They can be used in the unconscious patient who is difficult to ventilate with a face mask while preparations are being made for endotracheal intubation. The patient's mouth must be able to open at least 1.5 to 2.0 cm to allow for the insertion of the SAD. They can be used as either a primary or secondary airway. They are used more commonly as a primary airway, replacing the endotracheal tube, in the prehospital environment. They are used in the prehospital environment, and more often in the Emergency Department, as a secondary airway or rescue airway management device in cases of difficult or failed intubations. They should be considered in the "can't ventilate, can't intubate" patient when time is of the essence. Their use as a rescue airway device can "buy time" until additional airway assistance, equipment, and/or expertise can be brought to the patient. Consider using SADs during the initial resuscitation of the cardiac arrest patient as they are quick to insert and do not require stopping chest compressions during CPR.

CONTRAINDICATIONS

The presence of an intact gag reflex is an absolute contraindication to the use of SADs, regardless of which device is used. The inability to open the patient's mouth at least 1.5 to 2.0 cm will prevent the insertion of most SADs. Oral, pharyngeal, and laryngeal trauma are relative contraindications to using a SAD. These devices are contraindicated in the patient with known esophageal disease, a caustic ingestion, or airway burns. Many SADs require the patient to be over a certain height and/or weight to be used. Refer to the specific manufacturer recommendations when choosing a SAD and the appropriate size.

EQUIPMENT

- SADs, various types and sizes
- Endotracheal tubes
- Water-soluble lubricant
- Syringes, various sizes
- Oxygen source, tubing, and regulator
- Face masks
- Bag-valve device
- Pulse oximeter
- Cardiac monitor
- Noninvasive blood pressure monitor
- ALS medications
- Advanced airway equipment
- Surgical airway equipment

There are at least 17 variations of SADs on the market today. They are conceptually divided into three broad categories based on the primary separation between the respiratory and gastrointestinal tracts. These include cuffless anatomic preshaped sealers, cuffed perilaryngeal sealers, and cuffed pharyngeal sealers.[6,7]

The cuffless anatomic preshaped sealers are flexible devices whose shape is based on spiral computed tomography (CT) scan investigations of normal subjects of varying heights and weights.[8] These studies created a design template for a device that when inserted will accommodate the "normal" airway in the majority of cases.[8] Without an inflatable separation between the respiratory and gastrointestinal tracts, there is less flexibility to their design and use. **These devices offer less protection from aspiration of gastric contents than other SADs.** SADs in this category include the single use liner of pharyngeal airway or SLIPA (Hudson RCI, Research Triangle Park, NC) and the I-gel (Intersurgical Ltd., Berkshire, England). The SLIPA (**Figure 18-1**) is more commonly used in the operating room



FIGURE 18-1. The SLIPA.



FIGURE 18-2. The I-gel.

than the Emergency Department. The I-gel (**Figure 18-2**) can often be found in the Emergency Department difficult airway cart. The I-gel performs as well as the LMA-Supreme in both ventilation and protecting the airway from aspiration.[9]

Cuffed perilaryngeal sealers include the LMA (LMA North America, San Diego, CA), its many variations, and other manufacturers' laryngeal mask devices. These balloon sealers impact above the laryngeal inlet. The narrowest part of the inflatable lumen wedges into the upper esophagus, theoretically limiting gastric inflation during positive pressure ventilation. Design advances have allowed for inclusions of a potential gastric channel in the tip of the laryngeal mask that allows for placement of a narrow (typically 14 French or smaller) gastric tube for gastric suction and decompression. Refer to Chapter 19 for the complete details regarding LMAs.

Cuffed pharyngeal sealers utilize a design in which a balloon seals the hypopharynx at the base of the tongue, preventing passive air escape through the mouth. Downstream from the hypopharyngeal occluding balloon are a number and variety of ventilation apertures that allow air to pass into both the trachea and esophageal lumens. This category of SADs can be subdivided into those devices with and without a second balloon for the esophagus. Those devices without distal downstream esophageal balloons have a less specific anatomic placement. This may require more device manipulation to allow for easy ventilation, with a theoretically lower aspiration protection. Devices in this category include the cuffed oropharyngeal airway or COPA (Covidien, Mansfield, MA), PAexpress or PAX (Vital Signs Inc., Totowa, NJ), and the CobraPLA and CobraPlus (Pulmodyne Inc., Indianapolis, IN). Of these, the CobraPLA (**Figure 18-3**) may be found in the Emergency Department difficult airway cart.

Cuffed pharyngeal sealers with esophageal balloons not only occlude the airway at the base of the tongue, but the esophageal balloon theoretically isolates the esophageal lumen from the respiratory tract. Devices in this category include the Combitube (Kendall Sheridan, Mansfield, MA), the EasyTube (Teleflex Medical, Kernen, Germany), and the King Laryngeal Tubes (King Systems, Noblesville, IN). All of these SADs may be found in the Emergency Department difficult airway cart. Refer to Chapter 20 regarding the complete details of the Combitube and EasyTube. These two SADs are more commonly used in the prehospital environment for a primary or secondary airway. The King Laryngeal Tubes (**Figure 18-4**) are available in several models.

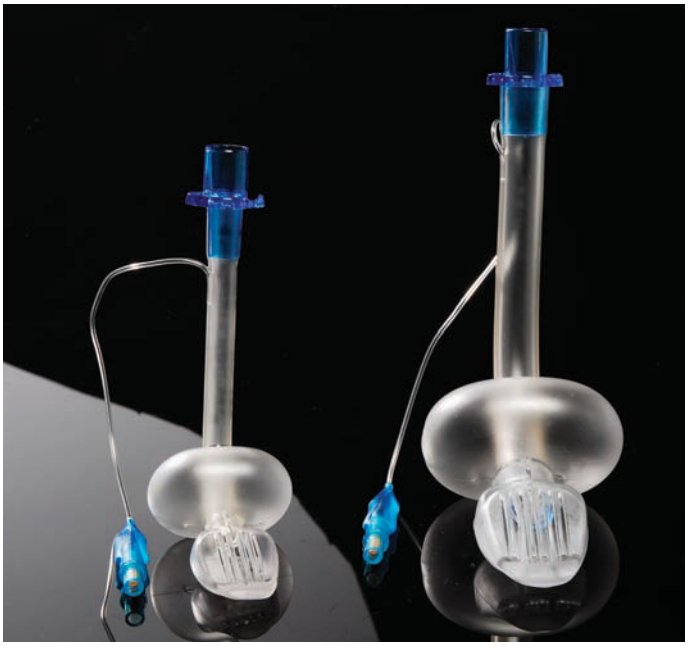


FIGURE 18-3. The CobraPLA (Photo courtesy of Pulmodyne Inc., Indianapolis, IN).

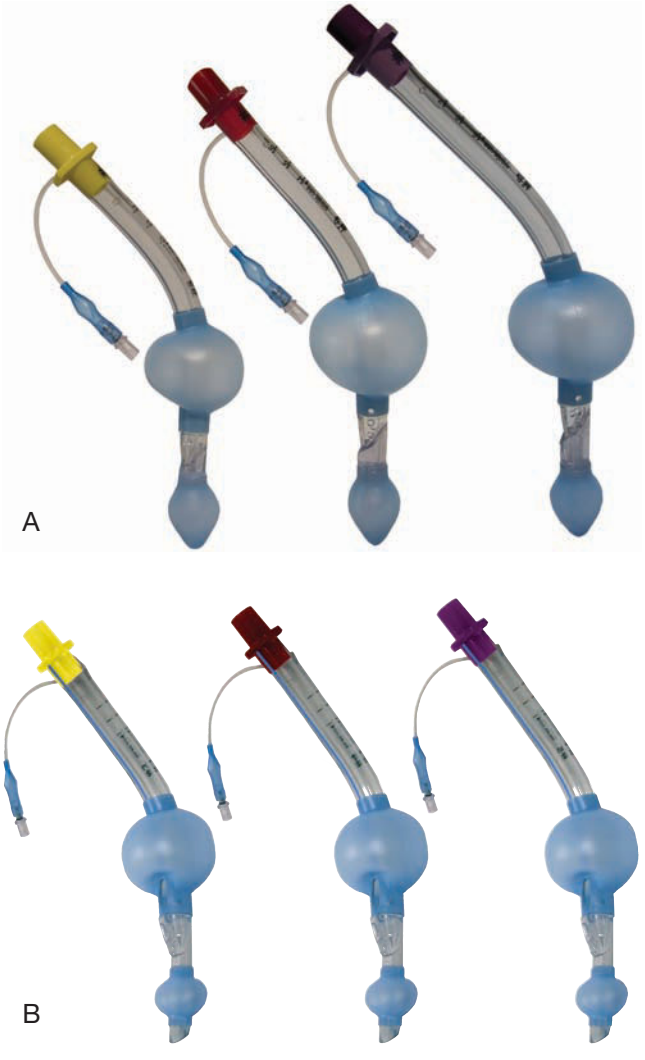


FIGURE 18-4. The King Laryngeal Tubes. **A.** King LTD models. **B.** King LTS-D models (Photos courtesy of King Systems Inc., Noblesville, IN).

The specific equipment needed for the various SADs will vary slightly according to the device used, but is relatively similar. The majority of the airway adjuncts are silicone based, and require the use of a water-soluble sterile lubricant to help ease airway placement without mucosal trauma from abrasion. Size appropriate airway adjuncts must be chosen for the individual patient's anatomy.

PATIENT PREPARATION

The patient should be appropriately monitored with electrocardiography (ECG), end-tidal CO_2 monitoring, noninvasive blood pressure cuff, and pulse oximetry. The patient preparation is exactly the same as that for orotracheal intubation. As for any situation where airway manipulation is to occur and the patient's protective airway reflexes are blunted or ablated, a fully functioning suction apparatus with a variety of catheters must be immediately available. Insertion of the SAD requires an anesthetic depth similar to that which allows placement and acceptance of an oropharyngeal airway. Successful placement of the SAD is much more likely if the patient is premedicated. The optimal induction agent should produce jaw relaxation and attenuation of airway reflexes, permitting insertion of the SAD within 30 to 60 seconds of loss of consciousness. A variety of induction agents may be used.

Select the appropriately sized SAD. Inflate the cuff(s), if present, to ensure that there are no air leaks. Deflate the cuff(s) and leave the air-filled syringe(s) attached to the SAD. Liberally lubricate the SAD with a water-soluble lubricant to aid in its insertion.

TECHNIQUE

The basic insertion technique begins with choosing the appropriate SAD and size. Gently access the airway. Use the nondominant thumb and forefinger in a scissors-like manner to open the patient's mouth, allowing for device insertion. Insert the liberally lubricated SAD. Insert the SAD until either resistance is noted, markers on the airway tube are at the incisor level, or the airway sealing balloon is situated in the hypopharynx and cannot be advanced any further depending on the device.[10]

Most SADs utilize a balloon cuff surrounding the air lumen that limits leakage of instilled air back into the oropharyngeal cavity and into the environment. The cuffless preshaped pharyngeal sealers do not have a cuff that requires inflation. Each cuffed SAD has a range of air required for cuff inflation. **Inflate the cuff with the recommended volume of air. Injection of higher volumes of air above the recommended volume risks SAD migration, airway or esophageal trauma, balloon herniation over the airway passage ports, or device rupture.**

The success rate for first pass insertion of SADs varies depending on the device, the indication for placement, the setting, and the person performing the procedure. Success rates between 72% and 95% are documented throughout the literature.

Begin ventilating the patient. Attach a bag-valve device to the SAD airway tube and begin ventilations. Minor manipulations of the SAD may be required to maximize the ease of ventilation in each particular patient. Slightly rotate or withdraw the SAD with the nondominant hand while ventilating through the device until ventilations are smooth and without resistance. Repositioning of the airway device during its use over time may be required in up to 18% of patients.[10]

ASSESSMENT

The SAD allows for air movement into the trachea, with varying degrees of potential air leakage into the digestive system during positive pressure ventilation. Successful placement will allow for relatively effortless air movement between the patient and the bag-valve device. Successful placement of the SAD is most accurately demonstrated by auscultation of bilateral breath sounds, chest wall movement, and end-tidal CO_2 monitoring. One may also gain a sense of accuracy of placement during insertion.

There exists the possibility of failure to insert, migration of placement after insertion, or the failure to maintain an adequate internal seal that prevents effective patient positive pressure ventilation.[3] If the patient cannot effectively be ventilated or oxygenated, remove the SAD and fall back to BLS skills until either additional expertise arrives or another airway option is available and successful.

AFTERCARE

Secure the SAD similar to that of an endotracheal tube. Place the patient on a ventilator. **Periodically reevaluate the SAD to ensure its position has not changed and it is still providing appropriate ventilations. The SAD may need an occasional position adjustment during ventilation.**

The SAD does not protect against aspiration as well as an endotracheal tube. It should be replaced with an endotracheal tube or a surgical airway. The method of securing the airway with a device other than a SAD will be determined by the patient's condition, if they have a "difficult airway," available equipment, and experience of the Emergency Physician. Some SADs allow the passage of an endotracheal tube through the airway tube similar to the LMAs.

COMPLICATIONS

There are numerous documented complications associated with the use of SADs. One of the most obvious of these and potentially the most devastating is the failure to place the device successfully or to obtain a satisfactory seal. Fortunately, even in inexperienced hands, the incidence of failure to achieve satisfactory ventilation is quite low. Failure to place a SAD appropriately with inadequate ventilation has been estimated to occur in up to 5% of all insertions. The SAD can be displaced if the patient moves their head or their head and neck is moved during transportation and transfers.

The insertion can result in mucosal damage and abrasions, especially if not properly lubricated or forcefully inserted. Unilateral vocal cord paralysis can occur secondary to traumatic insertion. Bilateral vocal cord paralysis has not been reported. Dental trauma may occur during the insertion or during maintenance of the airway. The cuffs are large and thin, thus they may be torn during use.[11,12]

Overinflation of balloons and cuffs can result in tissue ischemia, erosion, and rupture. Herniation of pharyngeal and airway structures into the SAD has been documented utilizing fiberoptic airway evaluation.[13] Trapping of the epiglottis in the distal aperture of the SAD may result in edema of the epiglottis. The oropharyngeal balloons have been linked to the development of tongue swelling secondary to venous congestion as a potential complication with prolonged use.[11,14,15] Lingual nerve injury, tongue numbness, parotid gland swelling, and hypoglossal nerve palsy are sometimes noted.

SAD placement in the patient with an intact gag reflex can induce emesis and aspiration. Emesis and aspiration are associated with a decreased survival.[1,16,17] Always be vigilant to suspect, prevent, and identify aspiration. When the SAD permits, provide gastric decompression via a suction tube prior to device removal or additional airway manipulation.[18]

SUMMARY

Supraglottic airway devices can be effectively utilized for both primary and secondary airway management in both the Emergency Department and the prehospital environment. A highly competitive

marketplace has allowed for a wide variety of constructions. These devices are relatively simple and quick to insert. They provide an effective bridge between the tracheobronchial tree and the ventilating device. Many EMS agencies utilize SADs as either a primary or secondary airway. The Emergency Physician must be familiar with their use and limitations.

19 Laryngeal Mask Airways

Katrin Takenaka and Theltonia Howard

INTRODUCTION

The laryngeal mask airway (LMA) is a device that fills the gap in airway management between that of endotracheal (ET) intubation and the use of a face mask. It was introduced in the United Kingdom in 1983 by British anesthesiologist A. I. J. Brain. His goal was to develop an airway apparatus that could rapidly overcome an obstructed airway, is simple to use, and is atraumatic to insert. In 1991, the LMA was approved for use in the United States by the Food and Drug Administration.

The LMA was designed primarily as a means of providing ventilatory support while avoiding the fundamental disadvantage of the need to visualize and penetrate the vocal cords with an ET tube.[1] The LMA is introduced into the hypopharynx without direct visualization. It forms a low-pressure seal around the laryngeal inlet and permits positive-pressure ventilation. With the introduction of the LMA ProSeal, pressures of up to 30 cmH_2O may be administered safely (A.I.J. Brain, M.D., personal communication). Once inserted, the LMA may be used as a conduit for fiberoptically guided ET intubation or to place an ET tube blindly.[2] The LMA has come to be viewed as a viable method of airway management, with over 800 articles and case reports describing the advantages and disadvantages of the device.[3] A more recent Medline search for articles involving the use of LMAs yielded over 3500 results.

Many disadvantages of the standard LMA became apparent with widespread use of the device. More than 10 years after its introduction, Dr. Brain and colleagues began to work on a new airway system with better intubation characteristics than the standard LMA. The intubating laryngeal mask airway (ILMA) was developed through the aid of analysis of magnetic resonance images of the human pharynx and laboratory testing of ET tubes.[4] The new and more "anatomically correct" ILMA effects more precise placement. The design of the ILMA also avoids head and neck manipulation and insertion of the intubator's fingers into the patient's mouth, both of which occur during the placement of the standard LMA.[4,5]

There are approximately nine different models of the LMA. The term "laryngeal mask airway" is specific to one brand of laryngeal mask devices produced by LMA North America, San Diego, CA. Several other manufactures also make laryngeal mask devices. Some of these will also be described in this chapter. The LMA Classic (LMA-C) is the original and most commonly used version. The LMA Classic Excel (LMA-CE) is more durable than the original LMA-C and can be reused up to 60 times. The LMA Unique (LMA-U) is a single-use disposable version of the LMA-C. The LMA Flexible is a wire-reinforced version of the LMA that is more flexible than the original version and resists kinking. It is used by Anesthesiologists for patients undergoing head and neck procedures. It is not used in the Emergency Department. The LMA Fastrach is a modified version of the LMA that allows ET intubation through the unit. It is also referred to as the ILMA. It allows ventilation during intubation attempts. Its advantages include the following: no manipulation of the head and neck is required, it can accommodate up to a size 8 ET tube, it facilitates one-handed insertion, it can be inserted from the patient's side or from above the head, and it can be used in conjunction with fiberoptic intubation. The LMA ProSeal (LMA-PS) features a cuff deflator, modified cuff design, dual tubes, and a bite block. Similar to the LMA-PS, the LMA Supreme (LMA-S) has a built-in drain tube and a bite block. However, the LMA-S is intended for a single-use and has a more curved airway tube than the LMA-PS. The LMA CTrach (LMA-CT) includes an insertion site for an ET tube and allows for direct visualization of the larynx using built-in fiberoptics. The Ambu laryngeal mask (Ambu LM) has an airway tube that is curved more acutely than the LMA-Cs. This curve follows the anatomy of the upper airway and allows for easier insertion without having to manipulate the head or neck.

The standard LMA, ILMA, LMA-PS, LMA-CT, or Ambu LM may be available in the Emergency Department. The techniques for inserting these devices are discussed in this chapter. The anatomic differences between these devices produce subtle differences in their insertion methods. The indications, contraindications, assessment, and complications associated with these devices are largely identical.

ANATOMY AND PATHOPHYSIOLOGY

The anatomy of the airway is briefly reviewed (**Figure 19-1**). Refer to Chapter 6 for the complete details of the airway anatomy. The oral cavity is bounded by the hard and soft palate above and the anterior portion of the tongue and the reflection of its mucosa onto the floor of the mouth below. Posteriorly, the mouth opens into the oropharynx through the oropharyngeal isthmus. The pharynx is a U-shaped tube extending from the base of the skull to the level of the cricoid cartilage, at which point it becomes continuous with the esophagus.[6]

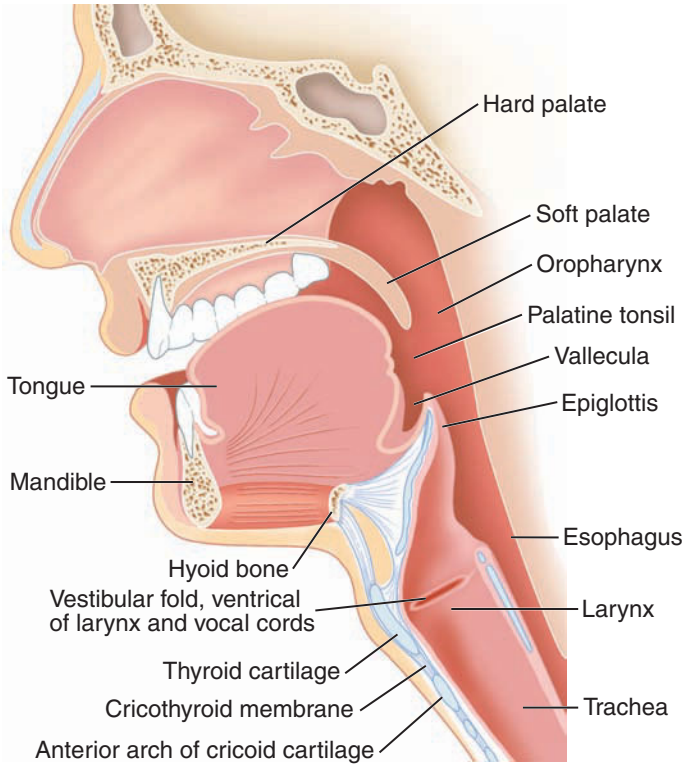


FIGURE 19-1. Midsagittal section of the head and neck demonstrating the airway anatomy.

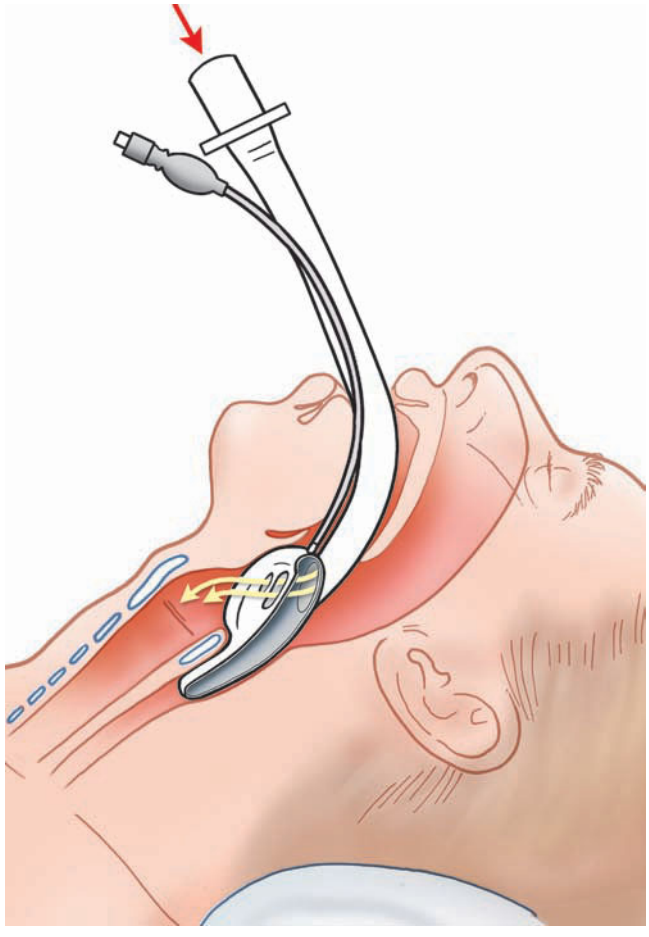


FIGURE 19-2. Sagittal view of the airway demonstrating correct placement of the LMA.

The larynx extends from its oblique opening bordered by the aryepiglottic folds, the tip of the epiglottis, and the posterior commissure to the base of the cricoid cartilage.[6] The esophagus lies posterior to the airway. When inflated and properly positioned, the tip of the device will lie in the esophagus at the level of the upper esophageal sphincter and directly posterior to the cricoid cartilage (**Figure 19-2**).

INDICATIONS

The indications for the use of an LMA device parallel the general indications for active airway management. These include the correction of hypoxemia or hypercarbia, the provision of controlled hyperventilation, the provision of a secure airway in the presence of obstruction, and the provision of airway access for pulmonary hygiene and bronchoscopy. An LMA may aid in supporting airways that are difficult to manage as well as being an invaluable aid to blind and fiberoptic intubation. The success rate of correct placement in inexperienced hands approaches 90%.[7] This makes the LMA superbly suited for use by medical personnel who have had only a minimal amount of training in airway management.

Airway control also facilitates emergent radiographic investigations, for example, computed tomography (CT) or magnetic resonance imaging (MRI) scans without motion artifact.[6] The standard LMA contains no ferromagnetic components and is a suitable alternative to an ET tube in many situations. It is ideal for use in patients emergently requiring diagnostic MRI scans. Use of the LMA does not require a metal laryngoscope, which is contraindicated if a patient requires airway management in the MRI suite.

LMA devices may be used in the event of a failed ET intubation. They have a role in securing the airway presumptively in patients with an "anteriorly" situated larynx, a situation whereby direct laryngoscopy and ET intubation are historically difficult. In emergent situations, the LMA is a safe alternative to the esophageal obturator airway, King tube, Combitube, and EasyTube. The LMA has also proved to be useful in burn patients requiring repeated dressing changes, especially of the face. Finally, the LMA may well be the airway technique of choice for professional singers who require short-term airway management since there is less likelihood of causing vocal cord or laryngeal nerve injury with this approach.[7]

However, in all its uses, there is a conspicuous absence of airway protection from aspiration. The LMA-PS and LMA-S are being marketed as superior to the LMA-C for use in nonfasting patients. These versions feature an improved laryngeal seal for permitting positive-pressure ventilation at pressures up to 30 cmH_2O and a drain tube in tandem with the airway tube. The drain tube facilitates blind insertion of a gastric tube for decompressing the stomach. An introducer aids insertion of the LMA-PS while obviating the need to introduce fingers into the patient's mouth.

CONTRAINDICATIONS

There are no absolute contraindications to the use of LMAs. However, there are several relative contraindications. These devices should not be used in individuals who are at an increased risk of regurgitation or aspiration unless the benefit of securing an airway outweighs the risk of aspiration (e.g., when other techniques for securing the airway have failed).[8] This is supported by uncontrolled studies using fiberoptic bronchoscopy, which have shown that the esophagus is visible within the LMA mask in 6% to 9% of patients.[7] Patients at high risk for aspiration include those with previous upper gastrointestinal surgery, known or symptomatic hiatal hernia, gastroesophageal reflux disease, women more than 10 weeks pregnant, patients with intestinal ileus or peptic ulcer disease, obese patients, or those individuals who are not fasted.[5,9,10]

In emergent situations where cricoid pressure is needed to prevent active or passive regurgitation of stomach contents prior to airway placement, the LMA is not an appropriate airway device. It will not prevent subsequent aspiration of stomach contents as efficiently as will a cuffed ET tube. The act of placing an LMA after the application of cricoid pressure (i.e., the Sellick maneuver) has been shown to have a significantly high failure rate.[7] The LMA-PS and LMA-S feature dual tubes (i.e., airway and drain) as well as a modified cuff designed to provide separation of the respiratory and alimentary tracts. As a result, they may prove invaluable in negating this "Achilles' heel" of the standard LMA.

These devices should not be used in individuals with severe respiratory diseases.[2,9,10] Specifically, individuals with airway obstruction at or below the larynx and those with low pulmonary compliance or high airway resistance (e.g., morbid obesity, bronchospasm, pulmonary edema, pulmonary fibrosis, or thoracic trauma) are not appropriate candidates for LMAs. **The only possible exception is that it can be inserted as a temporary airway rescue device in preparation of another method of ET intubation or a surgical airway.**

Patients must be able to assume the "sniffing" position, analogous to that of individuals positioned for direct laryngoscopy prior to ET intubation. Patients who cannot passively or actively extend their head and flex their neck are not candidates for the LMA-C, LMA-CE, LMA-U, or LMA-S. The ILMA, LMA-CT, LMA-PS with an introducer, or the Ambu LM are more appropriate for these patients. Patients should not receive these devices if they cannot open their mouth at least 1.5 cm due to anatomic limitations (e.g., ankylosing spondylitis, severe rheumatoid arthritis, cervical spine

instability, etc.).[7] This is one situation where blind nasotracheal intubation or fiberoptically guided nasotracheal tube placement has an advantage over the LMAs.

Finally, the LMA is relatively contraindicated in cases of pharyngeal pathology. This includes but is not limited to abscesses, caustic ingestions, hematomas, and tissue disruptions. These processes make the use of the LMA difficult. The device may rupture abscesses and hematomas, causing the patient to aspirate. The use of an LMA after a caustic ingestion can result in perforation of the eroded upper esophageal or hypopharyngeal walls from the pressure of the inflated cuff.

EQUIPMENT

- LMAs, various types and sizes
- ET tubes
- Water-soluble lubricant
- Syringes, 10 and 20 mL
- Oxygen source, tubing, and regulator
- Face masks
- Bag-valve device
- Pulse oximeter
- Cardiac monitor
- Noninvasive blood pressure monitor
- Advanced Cardiac Life Support (ACLS) medications
- Advanced airway equipment
- Surgical airway equipment

LMA CLASSIC (LMA-C) AND UNIQUE (LMA-U)

The standard LMA preceded the ILMA by more than a decade. The prototype of the LMA was constructed by forming a shallow mask with an inflatable rubber cuff joined to a tube communicating with the lumen of the mask at an angle.[1,2] The modern LMA is made of flexible silicone, is completely latex-free, and has a more tapered appearance. It has a variably sized, internally ridged tube fused at a 30° angle to a spoon-shaped mask with a flexible rim.

The LMA-C is a disposable unit that can be used multiple times. It must be sterilized between uses following specific manufacturer recommendations. The LMA-U is similar in construct to the LMA-C. However, the LMA-U is a single-use device. These LMAs are designed to conform to the contours of the hypopharynx, with the lumen facing the glottic opening (**Figure 19-2**).

They consist of an airway tube, an inflation line, and a mask (**Figure 19-3**). Overall, they resemble a giant spoon. The airway tube has a large bore and is clear, like an ET tube.[2] The proximal end contains a standard 15 mm airway adapter that can connect to a bag-valve device or a ventilator. A black line along the posterior border is used as a marker for proper positioning. The distal end of the airway tube connects to the mask.

The mask is elliptical in shape (**Figure 19-4**). The outer rim of the mask contains an inflatable cuff. When inflated and properly



FIGURE 19-3. The LMA-C (Photo courtesy of LMA North America, San Diego, CA).





FIGURE 19-4. The distal end or mask of the LMA-C. **A.** The deflated cuff. **B.** The inflated cuff.

TABLE 19-1 LMA-C and LMA-U Size Selection

Patient's weight (kg)	LMA size	Maximum cuff inflation volume (mL)	Largest ET tube size*	Fiberoptic bronchoscope size (mm)
<5	1.0	4	3.5	2.7
5–10	1.5	7	4.0	3.0
10–20	2.0	10	4.5	3.5
20–30	2.5	14	5.0	4.0
30–50	3.0	20	6.0 (cuffed)	5.0
50–70	4.0	30	6.0 (cuffed)	5.0
70–100	5.0	40	7.0 (cuffed)	5.0
>100	6.0	50	7.0 (cuffed)	5.0

*The inner diameter in millimeters.

positioned, the tip of the LMA will lie in the esophagus at the level of the upper esophageal sphincter and directly posterior to the cricoid cartilage (**Figure 19-2**). The lateral edges of the mask rest in the pyriform fossae. The upper edge rests against the base of the tongue. The LMA provides a seal against the upper esophageal sphincter, aryepiglottic folds, and distal epiglottis so as to direct air into the trachea and avoid insufflation of the stomach (**Figure 19-2**).[2,3]

The distal end of the airway tube opens into the mask. This opening is covered by two vertical aperture-bars that prevent the epiglottis from obstructing the lumen of the airway tube (**Figure 19-4**). The aperture bars should be cut off prior to inserting the LMA if an ET tube is to be inserted through the LMA.

The inflation line is used to inflate and deflate the cuff (**Figure 19-4**). The distal end of the inflation line attaches to the upper border of the cuff. The proximal end contains an inflation port and balloon, similar to an ET tube. An air-filled syringe attaches to the inflation port to inflate the cuff.

The correct size of the LMA is based on the patient's weight and is crucial to ensure a proper seal and reduce complications (**Table 19-1**).[8] The distal end assumes a different shape when the cuff is inflated and deflated. The distal end is pentagon-shaped when deflated (**Figure 19-4A**). It is oval-shaped when inflated (**Figure 19-4B**).

LMA CLASSIC EXCEL (LMA-CE)

Although similar in construct to the standard LMA, the LMA-CE has been designed as an "enhanced" version of the LMA-C (**Figure 19-5**). The airway tube has been reinforced, allowing the LMA-CE to be used up to 60 times. It must be sterilized between uses following specific manufacturer recommendations. The inflatable cuff is made of soft silicone to minimize throat stimulation and irritation. The LMA-CE is available in three sizes (**Table 19-2**).



FIGURE 19-5. The LMA-CE. (Photo courtesy of LMA North America, San Diego, CA).

TABLE 19-2 LMA-CE Size Selection

Patient's weight (kg)	LMA size	Maximum cuff inflation volume (mL)	Largest ET tube size*
30–50	3.0	20	7.0 (cuffed)
50–70	4.0	30	7.5 (cuffed)
70–100	5.0	40	7.5 (cuffed)

*The inner diameter in millimeters.

Several modifications have been made in order to facilitate ET intubation with the aid of a fiberoptic bronchoscope. Proximally, the airway tube has a 15 mm connector that can be easily removed to allow for access. The airway tube has been designed to accommodate up to a 7.0 cuffed ET tube. It is short enough that the cuff of the ET tube can pass through the LMA-CE and beyond the vocal cords. The mask aperture includes a vertically oriented epiglottic elevating bar, also known as the EEB (**Figure 19-5**). The EEB is free at the caudal end and fixed at the cephalad end, effectively creating a hinge mechanism. An ET tube passed through the mask aperture swings the EEB backward and elevates the epiglottis away from the path of the advancing ET tube.

LMA FASTRACH (ILMA)

The LMA Fastrach is also known as the intubating LMA or ILMA (**Figures 19-6 & 19-7**). The form of the ILMA was derived from head and neck sagittal MRI studies in 50 normal subjects whose

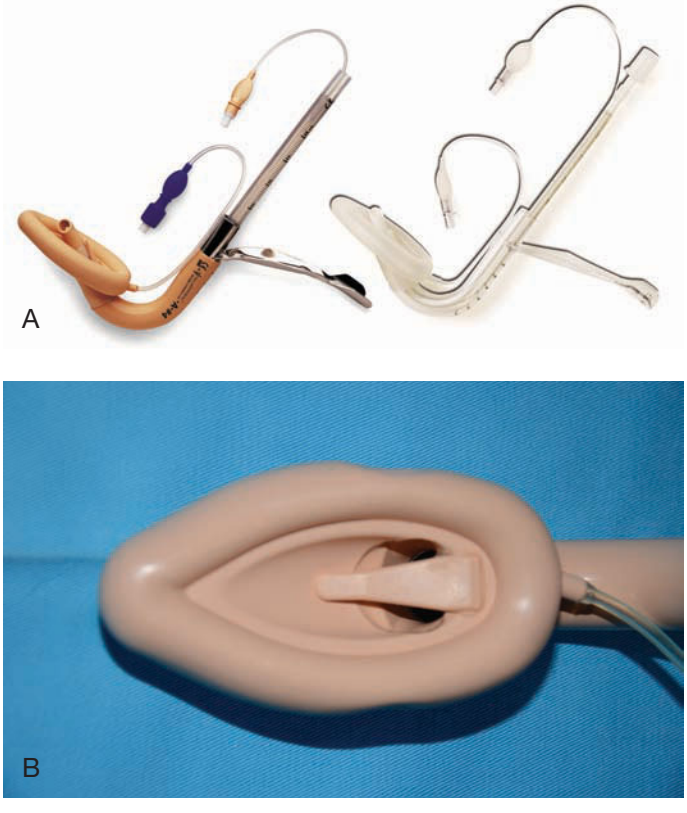


FIGURE 19-6. The ILMA. **A.** The reusable device (left) and the single-use device (right) (Photo courtesy of LMA North America, San Diego, CA). **B.** The mask.



FIGURE 19-7. An ET tube is inserted through the ILMA. The tip of the ET tube is guided by the V-shaped EEB.

heads were held in a neutral position. The convex radius of the curve of the silicone-covered steel tube represents a value close to the best-fit curve derived from the MRI studies.[4] The new prototype consists of an anatomically curved steel tube connected to standard LMA cuff sizes 3, 4, and 5.[5,9]

The ILMA has several significant modifications that make it different from the LMA-C (**Figures 19-6 & 19-7**). It is available in a reusable stainless steel version and a plastic single-use disposable version (**Figure 19-6A**). Both versions are available in three sizes (**Table 19-3**). The airway tube is stainless steel covered with silicone rubber. The proximal end has a handle fused to the airway tube to facilitate insertion, manipulation, and removal of the ILMA. It is curved to follow the curve of the hypopharynx and position the mask aperture over the glottic aperture. It has a larger diameter (13 mm vs. 9 mm) than the LMA.[9] This allows the ILMA to accommodate a cuffed ET tube with an inner diameter up to 9.0 mm.[5,11] It is significantly shorter (14.5 vs. 20 cm) than the LMA-C.[9]

The mask of the ILMA is similar to that of the LMA with two major modifications. The ILMA contains a ramp inside the distal airway tube as it meets the mask and continues into the mask aperture. It is designed to direct the ET tube into the center of the aperture and into the patient's airway. It also has a large, single, and stiff EEB designed to lift the epiglottis out of the way of the advancing ET tube (**Figures 19-6B & 19-7**).

The ILMA was designed to be used with a wire-reinforced cuffed silicone ET tube with an 8.0 mm inner diameter (**Figure 19-8**).[5] The ILMA ET tube is available in 6.0, 6.5, 7.0, 7.5, and 8.0 mm sizes. The molded tip allows atraumatic insertion through the vocal cords. It has a transverse block line along its posterior surface. This line serves as a marker to let the intubator know when the tip of the ET tube is positioned at the EEB. This occurs when the ET tube is inserted through the ILMA, and the transverse bar is located at the proximal end of the airway tube. While it is ideal to use the wire-reinforced silicone ILMA ET tube, a standard ET tube may also be used.

TABLE 19-3 LMA Fastrach or ILMA Size Selection

Patient's weight (kg)	LMA size	Maximum cuff inflation volume (mL)	Largest ET tube size*
30–50	3.0	20	7.0 (cuffed)
50–70	4.0	30	7.5 (cuffed)
70–100	5.0	40	8.0 (cuffed)

*The inner diameter in millimeters.



FIGURE 19-8. The silicone ET tube and pusher used with the ILMA (Photo courtesy of LMA North America, San Diego, CA).

LMA CTRACH (LMA-CT)

The LMA-CT is basically an ILMA with built-in fiberoptics that allow direct visualization of airway anatomy (**Figure 19-9**). Two fiberoptic channels lie along the lateral edges of the airway tube. These channels merge and exit under the EEB. The properly positioned LMA-CT fiberoptics project an image of the laryngeal inlet directly in front of the mask aperture. A portable color display, the LMA CTrach Viewer, attaches magnetically to the top of the LMA-CT airway tube. This allows the intubator to monitor the passage of the ET tube through the vocal cords. The LMA-CT Viewer lies just above the patient's chin and in line with the actual airway anatomy, making intubation easier from a hand-eye coordination standpoint. Images may be recorded and downloaded onto a computer for later documentation and teaching purposes.



FIGURE 19-9. The LMA-CT (Photo courtesy of LMA North America, San Diego, CA).



FIGURE 19-10. The LMA-PS (Photo courtesy of LMA North America, San Diego, CA).

LMA PROSEAL (LMA-PS)

The LMA-PS has been designed to be inserted manually or with the aid of a metal introducer (**Figure 19-10**). The use of the introducer obviates the need for the intubator to place their fingers in the patient's mouth. The LMA-PS has been modified to allow for ventilation at higher airway pressures. A combination of a softer silicone cuff, an additional rear cuff in larger sizes, and a deeper bowl mask permit higher seal pressures up to 30 cmH_2O. This is approximately 50% higher than with the LMA-C. The LMA-PS provides a tighter seal without increasing mucosal pressure or the risk of complications. It is a reusable device that is available in numerous sizes (**Table 19-4**).

The LMA-PS features a dual tube (i.e., drain tube and airway tube) system that decreases the risk of rotational dislodgement of the device. The drain tube communicates with the upper esophageal sphincter, allowing for blind insertion of an orogastric tube and for venting of gastric gases and liquids. The drain tube is positioned in the cuff to prevent the epiglottis from blocking the airway tube. The LMA-PS has been designed to decrease the risk of aspiration. Despite this, the manufacturer cautions that the LMA-PS does not provide complete protection against aspiration.

LMA SUPREME (LMA-S)

The LMA-S, like the LMA-PS, is a dual tube system that provides some separation of the respiratory and digestive tracts. The LMA-S is a single-use device and has an airway tube that is more curved and anatomically shaped (**Figure 19-11**). It has a more rigid airway tube than the LMA-PS, thus it requires no digital or metal introducer for placement. It can be used for the blind passage of an orogastric tube. The drain tube can help monitor correct positioning of the LMS-S. Gases will audibly leak from the drain tube if the LMA-S does not have a tight airway seal. The LMA-S incorporates a bite block. It is available in numerous sizes (**Table 19-5**).

TABLE 19-4 LMA-PS Size Selection

Patient's weight (kg)	LMA size	Maximum cuff inflation volume (mL)	Largest ET tube size*	Largest size OG tube/Salem Sump
5–10	1.5	7	4.0	10 French/8 French
10–20	2.0	10	4.5	10 French/8 French
20–30	2.5	14	5.0	14 French/12 French
30–50	3.0	20	5.0	16 French/14 French
50–70	4.0	30	5.0	16 French/14 French
70–100	5.0	40	6.0 (cuffed)	18 French/16 French

*The inner diameter in millimeters.

AMBU LARYNGEAL MASK (AMBU LM)

The Ambu LM (Ambu Inc., Glen Burnie, MD) consists of an airway tube, spoon-shaped mask, and inflatable cuff similar to the LMA-C (**Figure 19-12**). However, the airway tube of the Ambu LM is bent into a smooth curve of approximately 90° to conform to the anatomy of the upper airway and to facilitate easier insertion. Because of this anatomically correct curve, the device can be placed without manipulating the patient's head or neck. The airway tube is D-shaped and easier to grip than other tubes. The distal tip of the Ambu LM is reinforced so that the cuff does not fold over during insertion.

KING LARYNGEAL AIRWAY DEVICE (KING LAD)

The King LAD (King Systems, Noblesville, IN) is a disposable, single-use, silicone device similar to the LMA-C. It is available in two



FIGURE 19-11. The LMA-S (Photo courtesy of LMA North America, San Diego, CA).

TABLE 19-5 LMA-S Size Selection

Patient's weight (kg)	LMA size	Maximum cuff inflation volume (mL)	Largest ET tube size*	Largest size OG tube
<5	1	5	4.0	6 French
10–20	2	12	4.5	10 French
30–50	3	30	5.0	14 French
50–70	4	45	5.0	14 French
70–100	5	45	6.0 (cuffed)	14 French

*The inner diameter in millimeters.

styles (**Figure 19-13**), and a wide range of sizes in each style. The standard model has a curved airway tube while the flexible model has a straight and easily bendable airway tube.

AIR-Q MASKED LARYNGEAL AIRWAY (AIR-Q)

The Air-Q Masked Laryngeal Airway or Air-Q (Mercury Medical, Clearwater, FL) is another commonly used device (**Figure 19-14A**). It is available in a full range of sizes (**Table 19-6**). The airway tube shape and mask inlet have a different shape than the LMAs. An ET tube can be inserted through the Air-Q similar to the ILMA.

The Air-Q Blocker Masked Laryngeal Airway or Air-Q Blocker (Mercury Medical, Clearwater, FL) has been modified from the Air-Q to include a soft guide tube along side of the airway tube (**Figure 19-14B**). A lubricated suction catheter or nasogastric tube (up to size 18 French) can be inserted and directed into the posterior pharynx and esophagus to suction secretions. A proprietary suction catheter with an inflatable balloon near the distal end can be inserted through the guide tube (**Figure 19-14B**). The inflated balloon blocks the upper esophagus to prevent aspiration. The tip of this catheter has multiple holes to allow esophageal venting while the balloon prevents aspiration. The Air-Q Blocker is available in three sizes (**Table 19-6**).

The Air-Q Self-Pressurizing Masked Laryngeal Airway or Air-Q SP (Mercury Medical, Clearwater, FL) is similar to the Air-Q except for one major structural change. The Air-Q SP has a self-pressurizing cuff that does not require a pilot balloon, a inflation line, or a syringe to inflate the cuff (**Figure 19-14C**). Positive-pressure ventilation provided by a bag-valve device or ventilator inflates and self-pressurizes the cuff. The Air-Q SP is available in a full range of sizes (**Table 19-6**).



FIGURE 19-12. The Ambu LM.



FIGURE 19-13. The King LAD standard model (left) and flexible model (right).

PATIENT PREPARATION

The patient should be appropriately monitored with electrocardiography (ECG), end-tidal CO_2 monitoring, noninvasive blood pressure cuff, and pulse oximetry. The patient preparation is exactly the same as that for orotracheal intubation. As for any situation where airway manipulation is to occur and the patient's protective airway reflexes are blunted or ablated, a fully functioning suction apparatus with a variety of catheters must be immediately available. Insertion of the LMA requires an anesthetic depth similar to that which allows placement and acceptance of an oropharyngeal airway.[7] Successful placement of the standard LMA is much more likely if the patient is premedicated. In the case of the ILMA, the successful placement of the ET tube is highly dependent on adequate sedation and/or muscle relaxation. The optimal induction agent should produce jaw relaxation and attenuation of airway reflexes, permitting insertion of the LMA device within 30 to 60 seconds of loss of consciousness. A variety of induction agents may be used.

There is some controversy as to what physical examination findings represent the endpoint for judging when to insert the LMA. The consensus is that the first attempt at insertion should occur following the loss of the eyelash reflex (seventh cranial nerve) as when the jaw is relaxed.[10,12] This typically occurs 30 to 60 seconds after administration of the ultra-short-acting induction agents. Some practitioners also rely on the onset of apnea and/or loss of response to verbal stimuli as signs of adequate depth of anesthesia.[12]

TECHNIQUES

LMA CLASSIC, UNIQUE, AND CLASSIC EXCEL

Prior to insertion, carefully inspect the cuff for leaks with the cuff slightly overinflated. Completely deflate the cuff so that it forms a smooth wedge shape. The technique for inserting the LMA-C, LMA-U, and LMA-CE is rather simple (**Figure 19-15**). Lubricate the

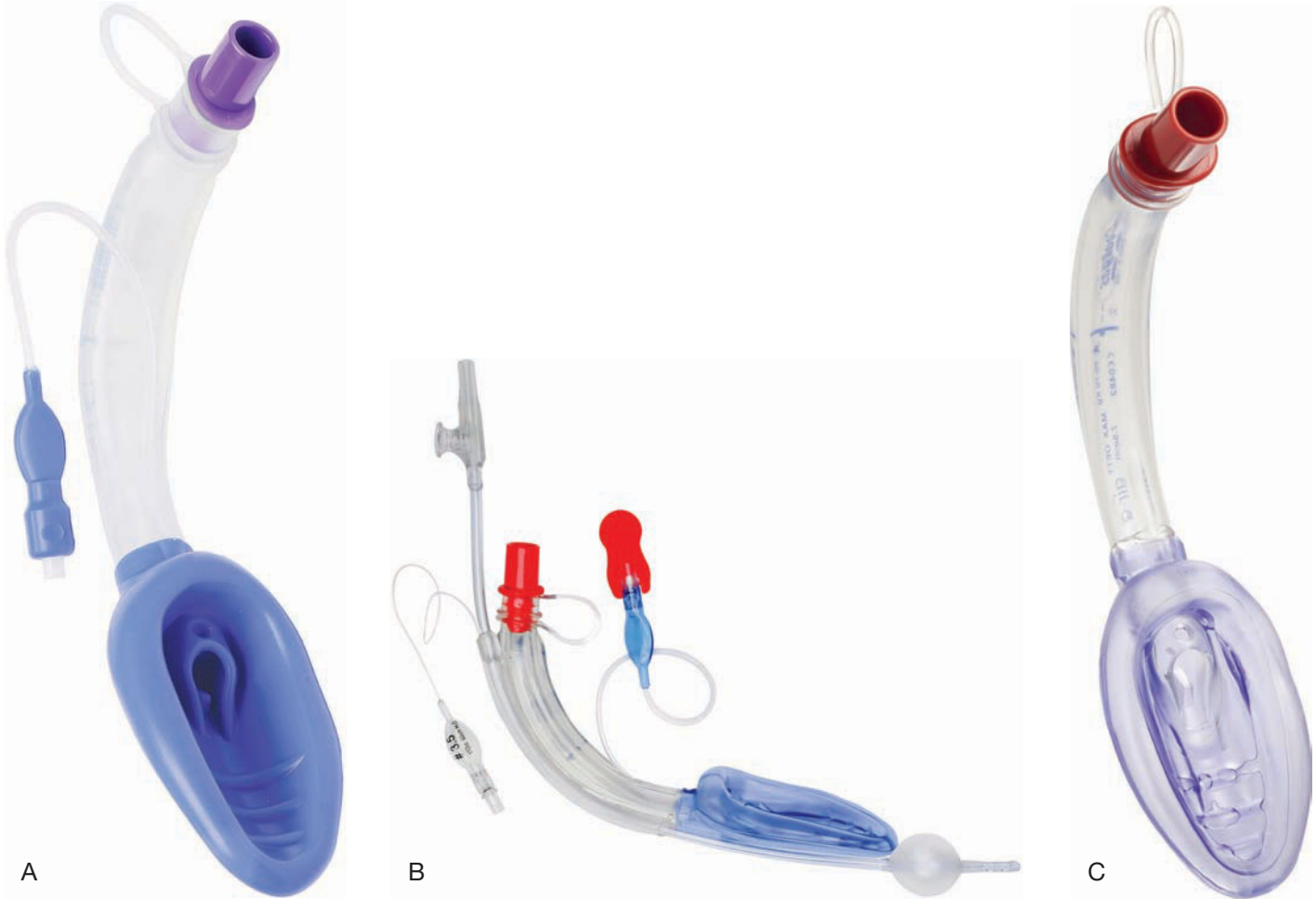


FIGURE 19-14. The Air-Q Masked Laryngeal Airway. **A.** The Air-Q. **B.** The Air-Q Blocker with the proprietary suction catheter inserted. **C.** The Air-Q SP. (Photos courtesy of Mercury Medical Inc., Clearwater, FL).

posterior surface of the LMA with a water-soluble lubricant. Care must be taken to avoid lubricating the anterior surface of the device, as the gel might obstruct the distal aperture or trickle into the larynx and provoke laryngospasm.[7] Avoid using silicone-based lubricants that may degrade the cuff.[8] Avoid lubricants containing lidocaine as they may provoke an allergic reaction or decrease laryngeal protective reflexes.[8]

Position the patient's head as for ET intubation in the sniffing position. Place the nondominant hand behind the patient's head to stabilize the occiput and slightly flex the neck (**Figure 19-15A**). Allow the patient's jaw to fall open. An assistant may be required to help open it.

TABLE 19-6 Air-Q, Air-Q Blocker, and Air-Q SP Size Selection

Patient's weight (kg)	Size	Maximum cuff inflation volume (mL)	Largest ET tube size*	Air-Q sizes	Air-Q Blocker sizes	Air-Q SP sizes
<7	1.0	3	4.5	X		X
7–17	1.5	5	5.0	X		X
17–30	2.0	8	5.5	X		X
30–50	2.5	12	6.5	X	X	X
50–70	3.5	18	7.5	X	X	X
70–100	4.5	25	8.5	X	X	X

*The inner diameter in millimeters.

Insert the LMA into the oral cavity with the aperture facing but not touching the tongue (**Figure 19-15A**). **It is essential that the leading edge of the cuff be smooth, wrinkle-free, and shaped like a wedge.** This facilitates passage of the cuff around the posterior pharyngeal curvature and into the hypopharynx while avoiding the epiglottis. Place the index and middle fingers of the dominant hand against the junction between the LMA and the cuff (**Figure 19-15B**). Advance the LMA in one smooth movement following the curvature of the pharynx until it enters the hypopharynx (**Figure 19-15B**). The fingers should lie almost horizontally when the LMA is properly positioned.[13,14] Grasp and stabilize the airway tube with the nondominant hand, then remove the index and middle fingers of the intubating hand (**Figure 19-15C**). **Slightly advance the LMA further downward until resistance is felt. At this point, it is important to not push further.** If difficulty is encountered, a rotational movement of the tube, slight inflation of the cuff, a jaw-thrust maneuver, or, in rare cases, the use of a laryngoscope may be helpful.[7]

Inflate the cuff with the recommended volume of air (**Figure 19-15D**). **Do not overinflate the cuff. Inflation usually causes a characteristic outward movement of the airway tube of up to 1.5 cm as the cuff centers itself around the laryngeal inlet.** A slight forward movement of both the thyroid and cricoid cartilages will be noted. **The longitudinal black line on the shaft of the tube should lie in the midline against the upper lip. Any deviation may indicate the wrong size device was used or misplacement of the cuff**

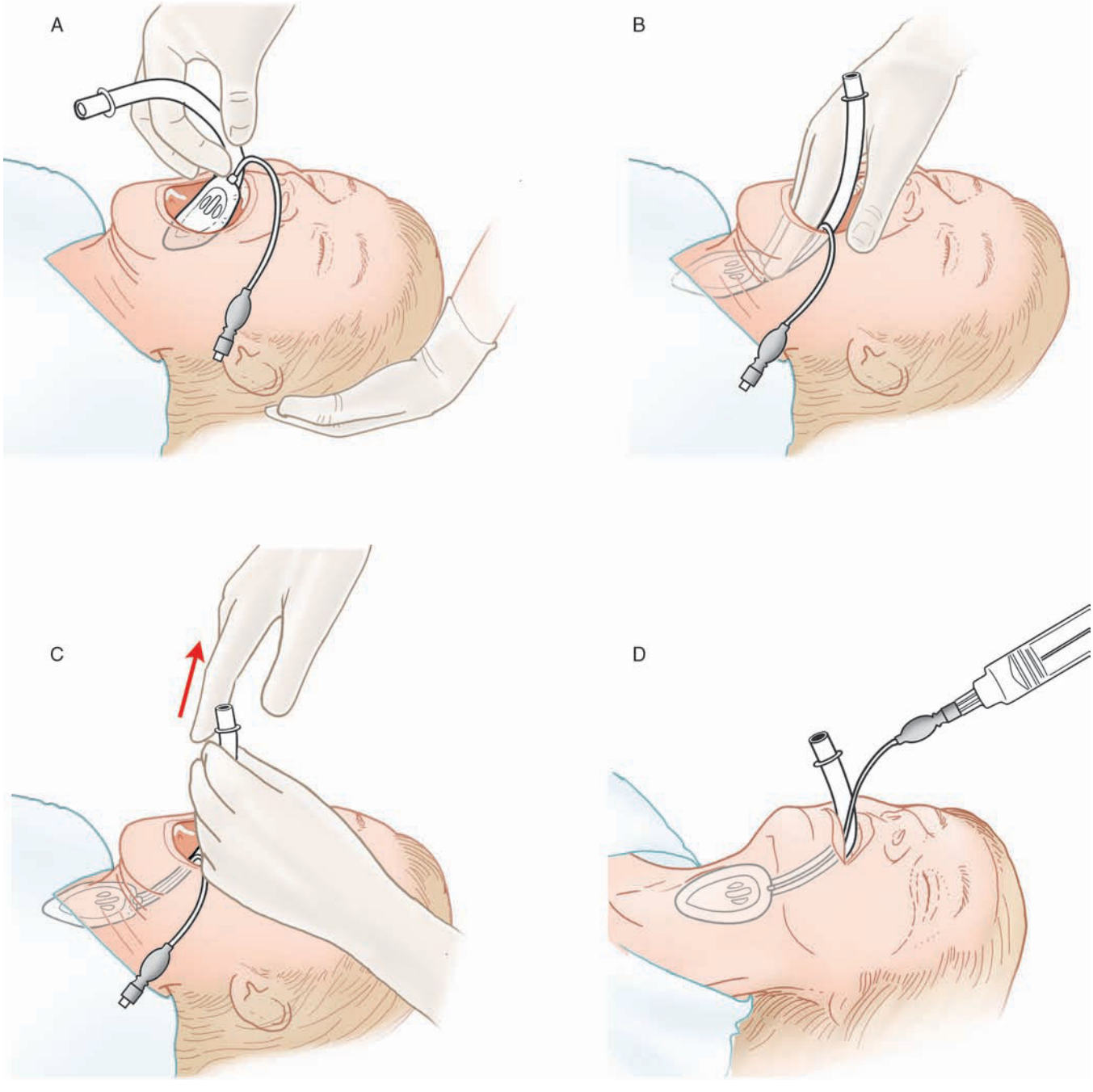


FIGURE 19-15. Insertion of the LMA. **A.** The patient's head is properly positioned and the LMA is inserted into the patient's mouth. **B.** The LMA is advanced with two fingers. **C.** The LMA is stabilized while the insertion hand is removed. **D.** The cuff is inflated.

and a partial airway obstruction.[7] When correctly positioned, the tip of the LMA cuff lies at the base of the hypopharynx against the upper esophageal sphincter, the sides lie in the pyriform fossae, and the upper border of the mask lies at the base of the tongue, pushing it forward.[7] Even when grossly malpositioned, the mask may still create a useful airway.[8] Secure the LMA like an ET tube.

LMA PROSEAL

Prior to insertion, carefully inspect the cuff for leaks with the cuff slightly overinflated. Completely deflate the cuff so that it forms a smooth wedge shape. The LMA-PS features a cuff deflator, which is a compact, portable instrument for assuring complete removal of air without causing the silicone to wrinkle. Lubricate the posterior surface of the LMA with a water-soluble lubricant. Insert the LMA-PS like that described above for the LMA-C. The only difference is that the fingertip should be pushed into the introducer strap at the rear of the cuff.

An alternative method of insertion involves a metal introducer. When using the introducer, head and/or neck manipulation may not be required. Place a properly sized introducer into the strap. Fold the tubes around the convex surface of the introducer and fit the proximal end of the airway tube into the matching slot. Insert the LMA-PS into the oral cavity with the aperture facing, but not touching, the tongue. The back of the mask must remain in constant contact with the hard palate. Rotate the LMA-PS inward in one smooth movement following the curvature of the introducer until it enters the hypopharynx and resistance is felt. Grasp and stabilize the

airway tube with the nondominant hand. Remove the introducer. Inflate the cuff and secure the LMA-PS. The LMA-PS includes a built-in bite block.

LMA SUPREME

Prior to insertion, carefully inspect the cuff for leaks with the cuff slightly overinflated. Completely deflate the cuff so that it forms a smooth wedge shape. Lubricate the posterior surface of the LMA-S with a water-soluble lubricant. Position the patient's head in a semi-sniffing position. The neutral position or a full "sniffing" position may preclude proper placement of the LMA-S.

Insert the LMA-S. Grasp the LMA-S by the connector end. Insert the LMA-S into the oral cavity with the aperture facing, but not touching, the tongue. Briefly rub the mask tip across the palate in order to lubricate the area. Rotate the LMA-S inward in one smooth movement following the curvature of the pharynx until it enters the hypopharynx and resistance is felt. Directing the distal tip toward the right or left side of the throat may facilitate placement. Grasp and stabilize the airway tube with the nondominant hand. Inflate the cuff and secure the LMA.

LMA FASTRACH (ILMA)

The technique for inserting the ILMA is not very different from that for the standard LMA. It involves a one-handed rotational movement in the sagittal plane with the patients head supported to achieve a neutral position.[5] The ILMA may be inserted from above the patient's head (like the LMA) or standing to the side of the patient's head. It may be inserted with the right or left hand.

Prior to insertion, slightly overinflate the cuff and check it for leaks. Completely deflate the cuff. Lubricate the posterior surface of the airway tube and the mask liberally. Grasp the ILMA by its handle. Place the patient in the sniffing position if no contraindications exist. Open the patient's mouth with the nondominant hand. Position the ILMA over the patient with the tip of the mask in the patient's mouth (**Figure 19-16A**). Slowly insert the mask while the posterior aspect of the mask remains in constant contact with the hard palate. When the entire mask is inside the patient's mouth and against the hard palate, rotate the ILMA inward along the natural curve of the hard palate and pharynx (**Figure 19-16B**). The airway tube should maintain constant contact with the upper central incisors as the unit is advanced. Stop advancing the unit when resistance is felt. This signifies that the tip of the mask is in the upper esophagus (**Figure 19-16B**).

Inflate the cuff with the recommended volume of air (**Figure 19-16C**). **Inflation usually causes a characteristic outward movement of the airway tube, up to 1.5 cm, as the cuff centers itself around the laryngeal inlet.** A slight forward movement of the thyroid and cricoid cartilages will be noted. The airway tube should lie in the midline against the upper central incisors. Any deviation may indicate the misplacement of the cuff and a partial airway obstruction. When correctly positioned, the tip of the ILMA cuff lies at the base of the hypopharynx against the upper esophageal sphincter, the sides lie in the pyriform fossae, and the upper border of the mask lies at the base of the tongue, pushing it forward.

Confirm proper placement of the ILMA. Have an assistant attach a bag-valve device to the proximal end of the airway tube and ventilate the patient. Observe the upper chest rise, auscultate bilateral breath sounds, and observe end-tidal CO_2 monitoring to confirm proper placement. An anterior movement, or bulging, of the cricoid and thyroid cartilages during or after cuff inflation also indicates correct positioning of the ILMA.[1]

Insert an ET tube. Lubricate the wire-reinforced silicone ET tube (or a standard ET tube) liberally. Insert the silicone ET tube into the ILMA until the transverse black line on its posterior surface is at the proximal end of the airway tube (**Figure 19-16D**). At this point, the tip of the silicone tube will be just inside the distal end of the airway tube. If necessary, an assistant can connect a bag-valve device to the silicone ET tube and ventilate the patient. Make sure that the longitudinal black line on the posterior surface of the silicone ET tube is facing upward.

Slowly and gently advance the silicone ET tube 1.5 cm beyond the transverse black line. If no resistance is felt, the tip of the silicone tube is just past the vocal cords. Continue to advance the silicone ET tube an additional 4 cm (**Figure 19-16E**). The patient can be ventilated by an assistant during this procedure if necessary. Inflate the cuff of the silicone ET tube and ventilate the patient through the silicone ET tube (**Figure 19-16F**). Confirm proper tube placement by the auscultation of breath sounds, observation of chest rise, and end-tidal CO_2 monitoring.

The ILMA should now be withdrawn. Deflate the cuff of the ILMA. Have an assistant remove the bag-valve device and the 15 mm adapter on the proximal end of the silicone ET tube. Withdraw the ILMA by gently reversing the ILMA over the silicone ET tube (**Figure 19-16G**). **Simultaneously apply slight pressure to the proximal end of the silicone ET tube so that it does not become dislodged (Figure 19-16G).** When the mask begins to exit the patient's mouth, stop withdrawing the ILMA. **Grasp the silicone ET tube firmly at the patient's mouth and hold it securely.** Withdraw the ILMA in a smooth curved motion (**Figure 19-16H**). Reattach the standard respiratory connector, ventilate the patient, and reconfirm proper placement of the silicone ET tube.

Some physicians prefer to use a "pusher" to prevent accidental extubation while the ILMA is being withdrawn. Cut a 25 cm length from a second silicone ET tube. Insert this into the ILMA as it is being removed. Apply slight pressure so it pushes against the first ET tube and prevents it from moving proximally. When the ILMA exits the patient's mouth, remove the ILMA and pusher as a unit. Secure and assess the proper positioning of the ET tube, as mentioned previously.

LMA CTRACH (LMA-CT)

The technique for inserting the LMA-CT is similar to that for the ILMA. The LMA-CT may be inserted from above the patient's head like the LMA-C or standing to the side of their head. Place the patient in the neutral position to avoid head extension. The manufacturer recommends only using the LMA-CT with straight, wire-reinforced cuffed silicone ET tubes with a 6.0 to 8.0 mm inner diameter. Standard curved plastic ET tubes may lead to an increased incidence of laryngeal trauma.

Insert the LMA-CT using the technique described for the ILMA. Inflate the cuff with the recommended volume of air and confirm proper placement of the ILMA. Have an assistant attach a bag-valve device to the proximal end of the airway tube and ventilate the patient. Observe the upper chest rise, auscultate bilateral breath sounds, and observe end-tidal CO_2 monitoring to confirm proper placement.

Attach the Viewer by placing the Viewer's socket onto the magnetic latch connector on the LMA-CT. Turn on the Viewer to visualize the glottis. Lubricate the wire-reinforced silicone ET tube. Grasp the LMA-CT by its handle and pass the ET tube back-and-forth through the airway tube several times in order to lubricate the entire airway tube. **Do not pass the lubricated silicone ET tube beyond the transverse black line on its posterior surface in order to avoid obscuring the fiberoptics with lubricant.** Make sure that the longitudinal black line on the posterior surface of the silicone ET tube is facing upward.

Slowly and gently advance the silicone ET tube 1.5 cm beyond the transverse black line. Gripping the handle and lifting a few

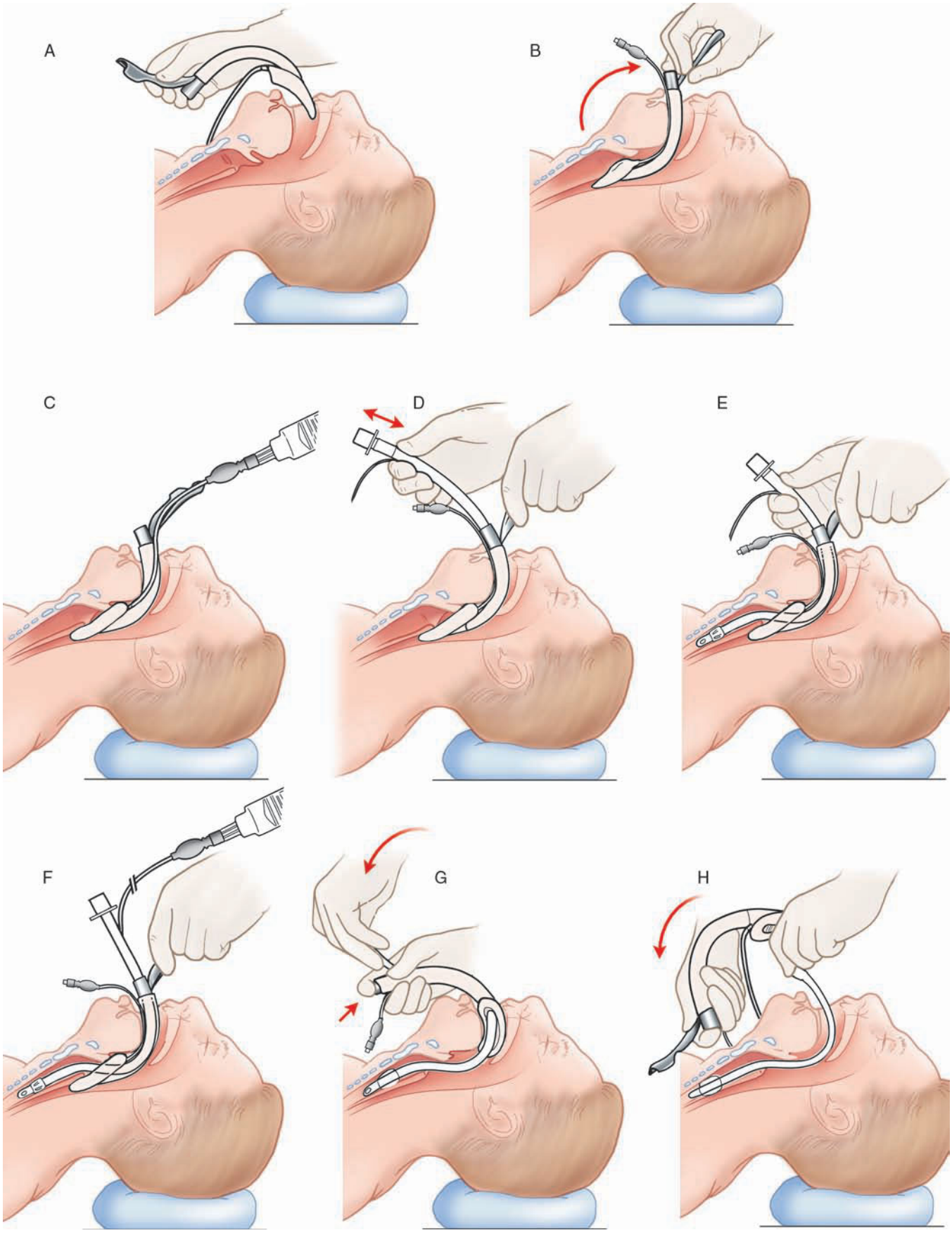


FIGURE 19-16. Insertion of the LMA Fastrach or ILMA. **A.** The ILMA is inserted. **B.** The ILMA is advanced until resistance is encountered. **C.** The cuff is inflated. **D.** The ILMA is stabilized and the ET tube is inserted. **E.** The ET tube is advanced into the trachea. **F.** The ET tube cuff is inflated. **G.** The ILMA is carefully removed. **H.** When the ILMA has exited the patient's mouth, grasp and stabilize the ET tube. Completely remove the ILMA.

millimeters optimize the alignment of the silicone ET tube and the trachea. As the silicone ET tube passes the mask aperture, the EEB will be seen to rise on the Viewer display. Continue to advance the silicone ET tube through the vocal cords. The patient can be ventilated by an assistant during this procedure if necessary. Detach the Viewer. Then, inflate the cuff of the silicone ET tube and ventilate the patient through the silicone ET tube. Confirm proper tube placement by the auscultation of breath sounds, observation of chest rise, and end-tidal CO_2 monitoring. Withdraw the LMA-CT similar to the technique described for the ILMA.

OTHER LARYNGEAL MASK DEVICES

The Ambu Laryngeal Mask (Ambu LM), King Laryngeal Airway Device (King LAD), and the Air-Q Masked Laryngeal Airway (Air-Q) can be inserted and secured similar to the LMA. An ET tube can be inserted through all the Air-Q models similar to the ILMA.

ALTERNATIVE TECHNIQUES

It is generally held that difficulty in insertion of the standard LMA occurs most frequently at the point where the tip of the mask passes just behind the tongue as it changes direction toward the hypopharynx.[15] Most of the suggested alternative methods for inserting the LMA involve the negotiation of direction change from the pharynx to the hypopharynx. Some authors suggest that a partially inflated mask is easier to place in the correct position.[15] Others employ a jaw-thrust maneuver. After adequate jaw relaxation has been established, the mask is positioned firmly and flatly against the hard palate, as recommended. Perform the jaw-thrust maneuver with the nondominant hand while firmly thrusting the mask into place with the dominant hand, in one motion.[16] The jaw-thrust creates a space in the hypopharynx for the mask. In rare cases, the use of a laryngoscope may help facilitate LMA placement, though this reduces the inherent simplicity of the technique of LMA insertion.

One study of the LMA-PS showed that a 90° rotation would improve rates of successful placement.[17] This technique was also associated with a lower incidence of mucosal bleeding and sore throat. After preparing the LMA-PS and the patient as usual, insert the device until the entire cuff is inside the mouth. Rotate the LMA-PS 90° counterclockwise and advance until resistance is felt. Once the LMA-PS is in the hypopharynx, straighten it out.

Given that there is less experience with the ILMA, few alternative methods of insertion exist. However, one must remember that the metal handle on the tip of the ILMA tube may be used to modify the position of the cuff within the hypopharynx.[9] Pulling back on the metal handle toward the intubator rotates the tube caudally in the sagittal plane. Pushing on the metal handle away from the intubator rotates the tube cephalad in the sagittal plane.

ASSESSMENT

Successful placement of an LMA device is most accurately demonstrated by auscultation of bilateral breath sounds, chest wall movement, and end-tidal CO_2 monitoring.[5,9] One may also gain a sense of accuracy of placement during insertion. During observation of the front of the neck while inserting an LMA, one may see a bulging of the tissues overlying the larynx. Visualization of this bulge, in addition to increased resistance to forward motion of the mask, indicates that the device is in the correct position.[1] A chest radiograph should be obtained if an ET tube has been placed through an LMA.

AFTERCARE

The LMA does not protect against aspiration as well as an ET tube. It should be replaced with an ET tube or a surgical airway. The method of securing the airway with a device other than an LMA will be determined by the patient's condition, if they have a "difficult airway," available equipment, and experience of the Emergency Physician.

COMPLICATIONS

There are numerous documented complications associated with the use of LMAs. One of the most obvious of these, and potentially the most devastating, is the failure to place the device successfully or to obtain a satisfactory laryngeal seal. Fortunately, even in inexperienced hands, the incidence of failure to achieve satisfactory ventilation is quite low. One large study, a retrospective review of 11,910 surgical cases where the standard LMA was used, noted an overall success rate of 99.81%.[18] Success rates have been classified as success on one single attempt and overall success. The overall success rate allows up to three attempts to be considered for successful placement. One investigator claimed a 99.5% single-attempt success rate in a retrospective analysis of 1500 cases.[10] Most studies imply correct LMA placement in 88% to 90% of first attempts.[7] Several studies have found success rates of 90% to 99% for ILMAs. Success rates appear to be higher if a wire-reinforced silicone ET tube is used rather than a standard ET tube.[19,20] Besides failure, there are other complications, which may be divided into minor complications and major complications.

MINOR COMPLICATIONS

Minor complications are those that may result in significant patient morbidity but usually are not associated with mortality or extremely deleterious outcomes. Stomach inflation can occur during positive-pressure ventilation at pressures greater than 20 cmH_2O for the standard LMA. Cuff herniation secondary to overinflation may result in failure of the cuff to seal effectively. Partial airway obstruction may occur in up to 10% of adults and 25% to 50% of pediatric patients when standard LMA cuffs are examined by fiberoptic bronchoscopy.[7] Trapping of the epiglottis in the distal aperture of the LMA may result in edema of the epiglottis. Air leaks around the cuff can occur during positive-pressure ventilation at pressures greater than 20 cmH_2O for the standard LMA and 30 cmH_2O for the LMA-PS. Forceful attempts to pass the LMA around the posterior pharyngeal curvature can result in uvular bruising.[7] Lingual nerve injury, tongue numbness, parotid gland swelling, and hypoglossal nerve palsy are sometimes noted. Unilateral vocal cord paralysis can occur secondary to traumatic insertion. Bilateral vocal cord paralysis has not been reported. Dental trauma may occur during the insertion or during maintenance of the airway.

MAJOR COMPLICATIONS

Major complications are those from which significant patient morbidity may be expected, including patient mortality. Fortunately, as regards the LMA, major complications are exceedingly rare. In a report of 11,910 surgical cases where the standard LMA was used, there were a total of 18 critical events related to the LMA, for an overall incidence of 0.15%.[18] These events included regurgitation of stomach contents (0.03%), vomiting of stomach contents (0.017%), pulmonary aspiration (0.009%), laryngospasm (0.07%), bronchospasm (0.025%), cardiac dysrhythmias (0.09%), and cardiac arrest (0.06%). While there appears to be a higher incidence of critical events when the device is used for controlled ventilation and positive-pressure ventilation, the incidence has not proved to be statistically significant.

In general, the complication rate (defined as events not attributable to the patient's underlying condition or to surgical or other interventions) should be equivalent to that seen during placement

of either a Guedel or Berman type oropharyngeal airway. Referring to standard anesthesiology textbooks, one realizes that the complication rate in each of the aforementioned categories when using the LMA is significantly lower than that occurring during direct laryngoscopy and ET intubation, potentially due to the intense autonomic nervous system stimulation occurring with the latter procedures.

SUMMARY

A major advancement in airway management was made with the introduction of the LMA. It is superior to a face mask in that it prevents supraglottic obstruction and reduces the likelihood of gastric insufflations.[2] However, it does not provide protection from aspiration. The LMA-PS and LMA-S, with their dual tube system, may help decrease the risk of aspiration.

The standard LMA has clearly earned a valuable place in the armamentarium of clinicians who provide airway management. The technique is easy to learn, easy to teach, and requires no specialized equipment. The LMA causes minimal autonomic nervous system activation and less of a response from the cardiovascular system than with direct laryngoscopy. The LMA is not associated with a risk of esophageal or endobronchial intubation. Both, however, are possible complications following use of the ILMA. The LMA has minimal effects on the intraocular pressure response to airway manipulation. The LMA may be of use in cases of suspected cervical spine injury.

The use of an LMA in place of a face mask avoids many risks, such as injury to the eyes, supraorbital and facial nerves, nose, and lips. There is less risk of hand fatigue than with the bag-valve-mask device. The LMA provides a safer and more secure airway in children and adults than does a face mask, with fewer episodes of hypoxemia as detected by pulse oximetry.[7]

The introduction of the ILMA more than a decade after the standard LMA further defined and expanded the role of this apparatus in airway management. It allows for precise ET tube placement, therefore ensuring airway protection. It is anatomically designed to ensure more accurate placement of the cuff. Given the ease of placement of the ILMA without the need for the rescuer to be positioned behind the head, there may be a significant place for the ILMA in future airway management algorithms.[4] The advent of the LMA-CT allows for direct fiberoptic visualization of the vocal cords prior to intubation.

20 Double Lumen Airway Tube Intubation

Joseph Weber

INTRODUCTION

The Esophageal-Tracheal Combitube (ETC; Kendall Sheridan, Mansfield, MA) and the EasyTube (EzT; Teflex Medical [Ruesch], Kernen, Germany) are double lumen airway devices that can be blindly inserted into the unconscious and unresponsive patient. The ETC and EzT function to adequately ventilate and oxygenate a patient while simultaneously protecting the airway from aspiration.[1,2] They are most often used in the prehospital setting by emergency medical technicians not trained in standard orotracheal intubation and by paramedic-level rescuers as an alternative airway device when standard orotracheal intubation fails.[3–5] These are the only two double lumen devices used in the prehospital setting and the Emergency Department. The Emergency Physician should be familiar with these devices so that it can be removed and exchanged with an endotracheal tube if placed in the prehospital environment or if required in the Emergency Department to manage a difficult airway.

ANATOMY AND PATHOPHYSIOLOGY

The ETC is a double-tube, double lumen, and double-cuffed device (**Figure 20-1**). The ETC starts as two distinct tubes that fuse into one, but remain functionally separated by a partition. The shorter clear tube is continuous with the distal open port, also known as the tracheoesophageal lumen. At its distal end is the distal tracheoesophageal cuff, similar to that of an endotracheal tube. It is a high-volume, low-pressure balloon that is inflated through the white inflation port. The longer blue tube is continuous with the eight perforations known as the proximal ports. A large pharyngeal cuff is just proximal to the perforations. This cuff is positioned between the base of the tongue and the palate, separating the oral and nasal cavities from the remainder of the airway. It is inflated through the blue inflation port.

The EzT is also a double-tube, double lumen, and double-cuffed device with a structure similar to the ETC (**Figure 20-2**). However, it has several differences in comparison to the ETC. First, the shorter clear tube ends as a conventional single lumen 7.5 mm endotracheal tube. Second, the longer blue tube ends in an open aperture, rather than multiple perforations. Third, the EzT is latex free.[6]

Both the ETC and EzT may be inserted blindly into a patient's airway. If the distal tip enters the trachea, the patient is ventilated through the shorter clear tube and the distal cuff prevents aspiration of gastric contents into the trachea. If the distal tip enters the esophagus, the patient is ventilated through the longer blue tube, whose proximal ports lie in the hypopharynx, while the distal cuff will occlude the esophagus.

The EzT may also be used as a primary airway device under direct laryngoscopy. When placed successfully into the trachea, it functions as a 7.5 mm endotracheal tube. If unable to pass it into the trachea, it can be advanced into the esophagus and the patient ventilated through the blue tube.[6,7]

Both devices are available in two sizes. The 37 French SA model of the ETC is meant for small adults. The manufacturer recommends its use in patients with a height of 122 to 168 cm (4.0 to 5.5 ft). The 41 French model of the ETC is meant for larger adults with a height of 152 cm (5 ft) and greater. Patients in the intermediate range of 152 to 168 cm (5.0 to 5.5 ft) can use either model. A recent study demonstrated that the 37 French SA model can be used in patients up to 183 cm (6 ft, 1 in) in height. The EzT is available in a 28 French model for patients with a height from 90 to 130 cm (3.0 to 4.3 ft) and a 41 French model for patients over 130 cm (4.3 ft).

Several attributes specific to these devices contribute to their usefulness in the acute setting. Both are effective as either a primary or backup airway management device. A patient can be ventilated with the tip positioned in either the esophagus or the trachea. Minimal training is necessary. There is no need for a laryngoscope. They are easily inserted with patient's head and neck in a neutral position. The dual lumens and balloons also offer certain advantages. When placed in the esophagus, the distal lumen of both allow for gastric suctioning. The proximal lumen of the EzT is an open lumen rather than perforations as in the ECT. This allows for the passage of a suction catheter, fiberoptic scope, or endotracheal tube changer (maximum diameter 3.99 mm) into the trachea.[6] The balloons firmly secure the device, making dislodgment unlikely. The proximal balloon can functionally tamponade oropharyngeal bleeding and serve to minimize the risk of

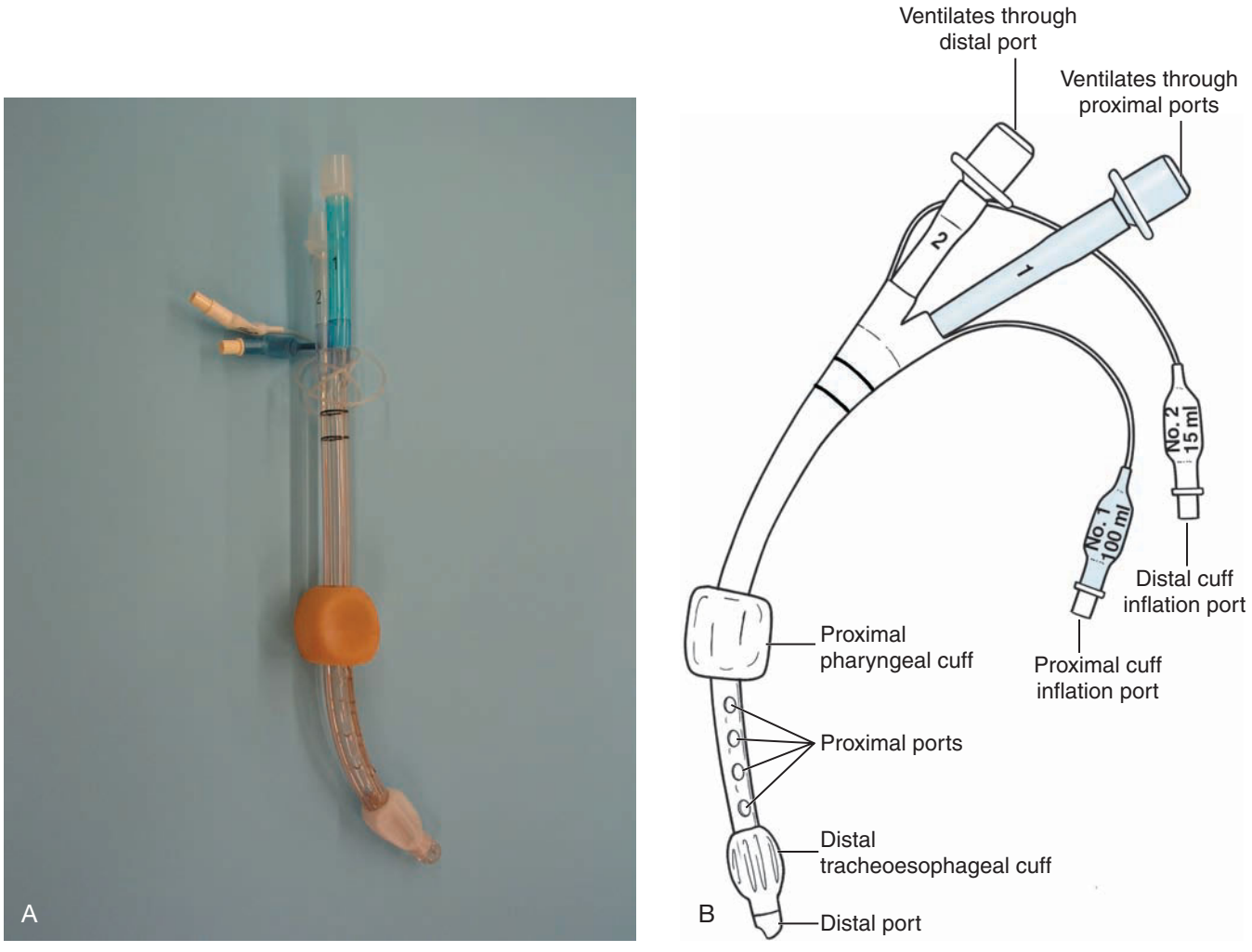


FIGURE 20-1. The Combitube. **A.** Photograph. **B.** Illustration.

aspirating oral debris.[8] These attributes make these devices suitable for rescuers of all skill levels.

INDICATIONS

The primary indication for an ETC or an EzT is as a backup device for airway management in and out of the hospital. It can be used for difficult or failed orotracheal intubations. It should be placed on crash carts for use by individuals not skilled with orotracheal intubation. In situations with limited access to the patient's head (e.g., extrication situations), they can be used where standard orotracheal intubation cannot be performed. They should be considered in situations of potential cervical spine injury as the device can be inserted with the patient's head and neck in a neutral position. The ETC is an appropriate device for management of the airway when visualization is limited due to bleeding or secretions. All Emergency Physicians should become familiar with these devices if they are used by emergency medical technicians in their region as well as considering it as an alternative airway device for difficult airways in the Emergency Department.[8,9]

CONTRAINDICATIONS

Certain contraindications exist and should be addressed. **These devices should not be used on patients with an intact gag reflex.** If intubation is anticipated, there should be enough time to premedicate the patient and induce anesthesia before inserting them. Size limits apply to both the ETC and the EzT. The standard ETC cannot be used in patients under 5 feet tall. The smaller ETC SA model cannot be used in patients under 4 feet tall. The EzT cannot be used in patients under 3 feet tall. The ETC cannot be used in patients with a latex allergy. The EzT is latex free and can be used in all patients.

Their use is contraindicated if the patient has known esophageal disease or an airway obstruction. Patients with known esophageal disease (e.g., strictures, cancer, or victims of caustic ingestions) are at an increased risk of complications such as perforation and failed performance of the device. Patients with known upper airway obstruction (e.g., secondary to congenital disorders, cancer, or other anatomic abnormalities) are also at increased risk for complications and performance failure.

EQUIPMENT

- Gloves, gown, and mask
- Eye protection, goggles or a face mask with an eye shield
- Pulse oximeter
- Noninvasive blood pressure cuff
- Cardiac monitor
- IV access equipment



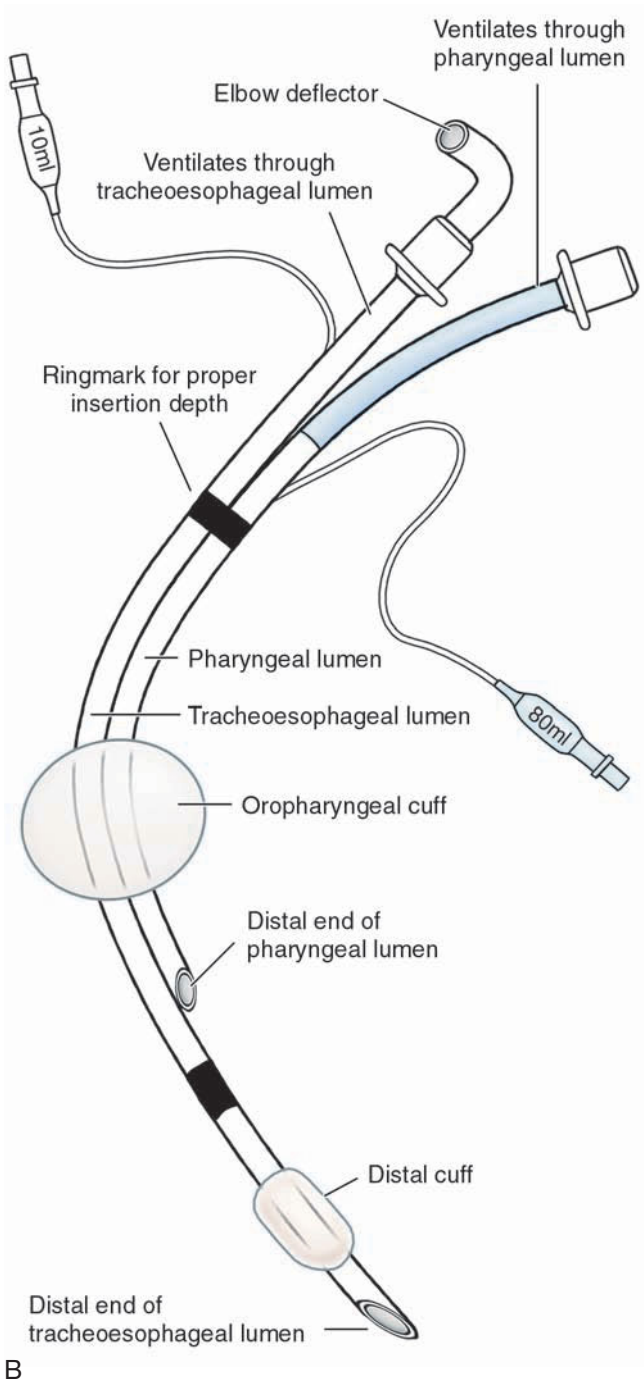


FIGURE 20-2. The EasyTube. **A.** Photograph. **B.** Illustration.

- ETC or EzT kit
- Oxygen source and tubing
- Suction source and tubing
- Water-soluble lubricant
- Bag-valve-mask device
- Advanced Cardiac Life Support equipment and medications
- Surgical airway equipment

The ETC and the EzT are prepackaged in a kit form with the dual lumen airway tube, two syringes for balloon inflation, a 90° elbow, and a flexible suction catheter (**Figures 20-3A & B**). The ETC kit also contains a vomit deflector that is not routinely used, as it may be associated with significant complications and gastric contents directed at the healthcare professional. The suction catheter included is designed to be inserted through the smaller tube and to exit the tracheoesophageal port.

PATIENT PREPARATION

Preoxygenate the patient with a bag-valve-mask device using 100% oxygen. Establish IV access. Apply the pulse oximeter, noninvasive blood pressure cuff, and the cardiac monitor. Place the patient in the supine position, or in any position that may be required. The neutral position is not required. Prepare the equipment while an assistant is ventilating the patient. Remove the ETC or EzT and equipment from the package. Attach the syringes to their respective ports and inflate the cuffs (**Figure 20-4**). If a leak of air is present or if the cuff does

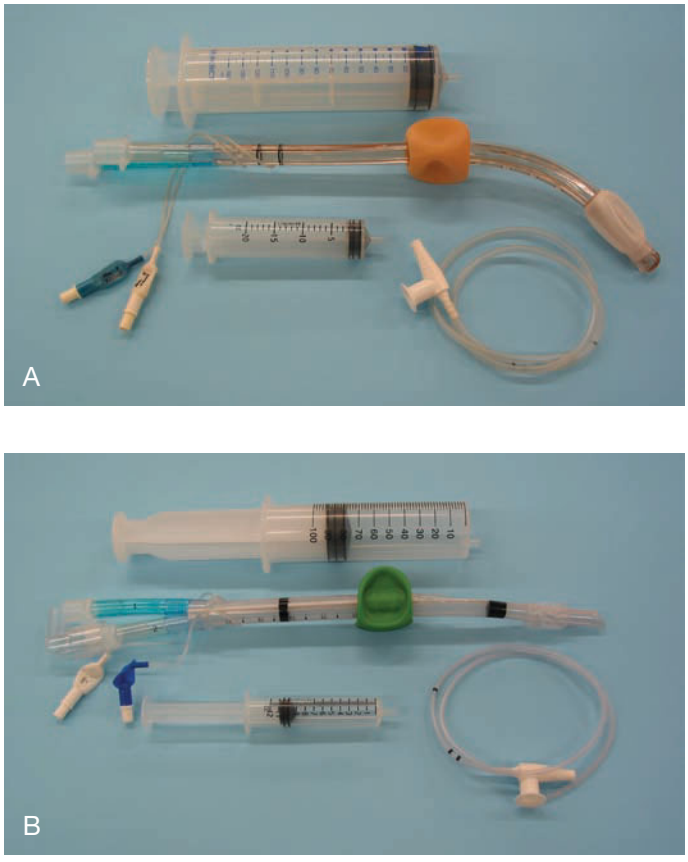


FIGURE 20-3. The contents of the double lumen kits. **A.** The Combitube kit. **B.** The EasyTube kit.

not inflate properly, discard the device and open another kit. Deflate the cuffs and leave the syringes attached to the ports. Liberally lubricate the tip of the device with a water-soluble lubricant.

TECHNIQUE

Insert the thumb of the nondominant hand into the patient's mouth and over their tongue (**Figure 20-5A**). Place the nondominant fingers under the chin. Depress the tongue and open the jaw simultaneously. Remove any dental devices and foreign bodies. Grasp the device with the dominant hand. The curve of the device should be in the same direction as the natural curve of the pharynx. Insert the device into the midline of the patient's mouth. Advance it in a downward curved motion until the patient's teeth or alveolar ridge lies between the two printed bands of the ETC (**Figure 20-5B**) or the black stripe of the EzT (**Figure 20-6**). **Do not insert the device forcefully as significant injury can occur.** If it does not advance easily, redirect it and then reinsert the device. Inflate the pharyngeal cuff with the volume of air marked on the blue port (100 mL for the ECT, 85 mL for the ECT SA, or 80 mL for the EzT). The device will withdraw slightly from the patient's mouth as the pharyngeal cuff is inflated. Inflate the distal cuff with the volume of air marked on the white port (15 mL for the ECT, 12 mL for the ECT SA, or 10 mL for the EzT).

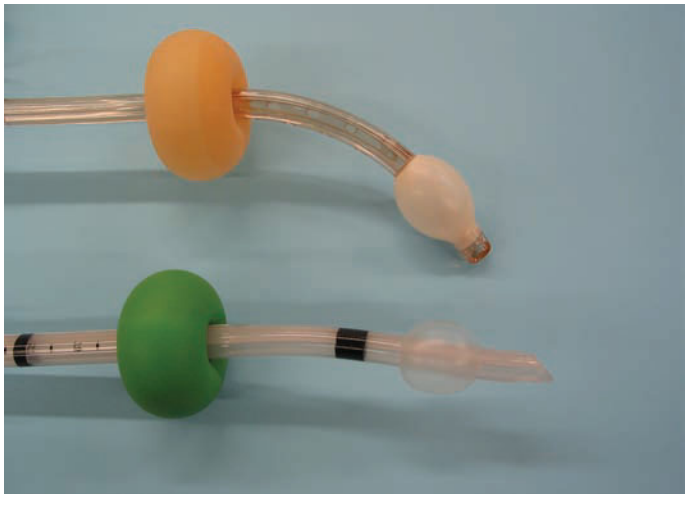


FIGURE 20-4. The Combitube (above) and the EasyTube (below) with their cuffs inflated.

Because most blind intubations are esophageal, begin ventilation through the longer blue tube (**Figures 20-5C & 20-6**). Auscultation of breath sounds, symmetric rise of the chest, fogging in the tube for more than six breaths, and lack of gastric insufflation confirm placement within the esophagus and ventilation through the proximal ports/aperture (**Figures 20-5C & 20-6**). If no breath sounds are auscultated and gastric insufflation occurs, the trachea is intubated (**Figure 20-5D**). Begin ventilation through the shorter clear tube and verify by auscultation the presence of breath sounds.

If breath sounds cannot be auscultated when ventilating through either tube, the device may be too far into the pharynx. Deflate the pharyngeal cuff and withdraw the device 2 to 3 cm. Reinflate the pharyngeal cuff. Ventilate through the longer tube and confirm tube placement as noted above.

AFTERCARE

Secure the device. This is accomplished using the standard method of taping or a commercially available endotracheal tube holder. Although there are reports of short-term (e.g., 4 to 6 hours) ventilator use with these devices, it should be replaced with a standard endotracheal tube for long-term ventilation.[10]

Several methods for replacing the device are available. The first is to remove the device entirely and intubate the patient orotracheally. Deflate the pharyngeal cuff. Suction the patient's mouth and oropharynx. Tilt the device to the left side of the patient's mouth. Deflate the distal cuff. Remove the device. Intubate the patient orotracheally.[11]

Alternative methods of intubation are also possible. Deflate the pharyngeal cuff. Suction the mouth and oropharynx. Tilt the device to the left side of the patient's mouth. Insert the laryngoscope and visualize the tip of the device. If it is in the esophagus, orotracheally intubate the patient, deflate the distal cuff of the device, and remove the device. This method will prevent aspiration, especially if endotracheal intubation is unsuccessful. If it is in the trachea, instruct an assistant to deflate the distal cuff of the device and remove it slowly. After the device clears the patient's vocal cords, immediately insert the endotracheal tube.

The EzT has a significant advantage over the ECT when attempting to replace it with a conventional endotracheal tube. If the distal end is in the trachea and the patient is being ventilated through the short clear tube, it can be left in place as it is functioning as a 7.5 mm endotracheal tube. If the distal end is in the esophagus and the patient is being ventilated through the long blue tube, a fiberoptic scope or an endotracheal tube changer can be passed through the blue tube and into the trachea. The EzT can then be removed and an endotracheal tube passed over the endotracheal tube changer. This cannot be done with the ECT because it has perforations rather than an open aperture.[6,7]

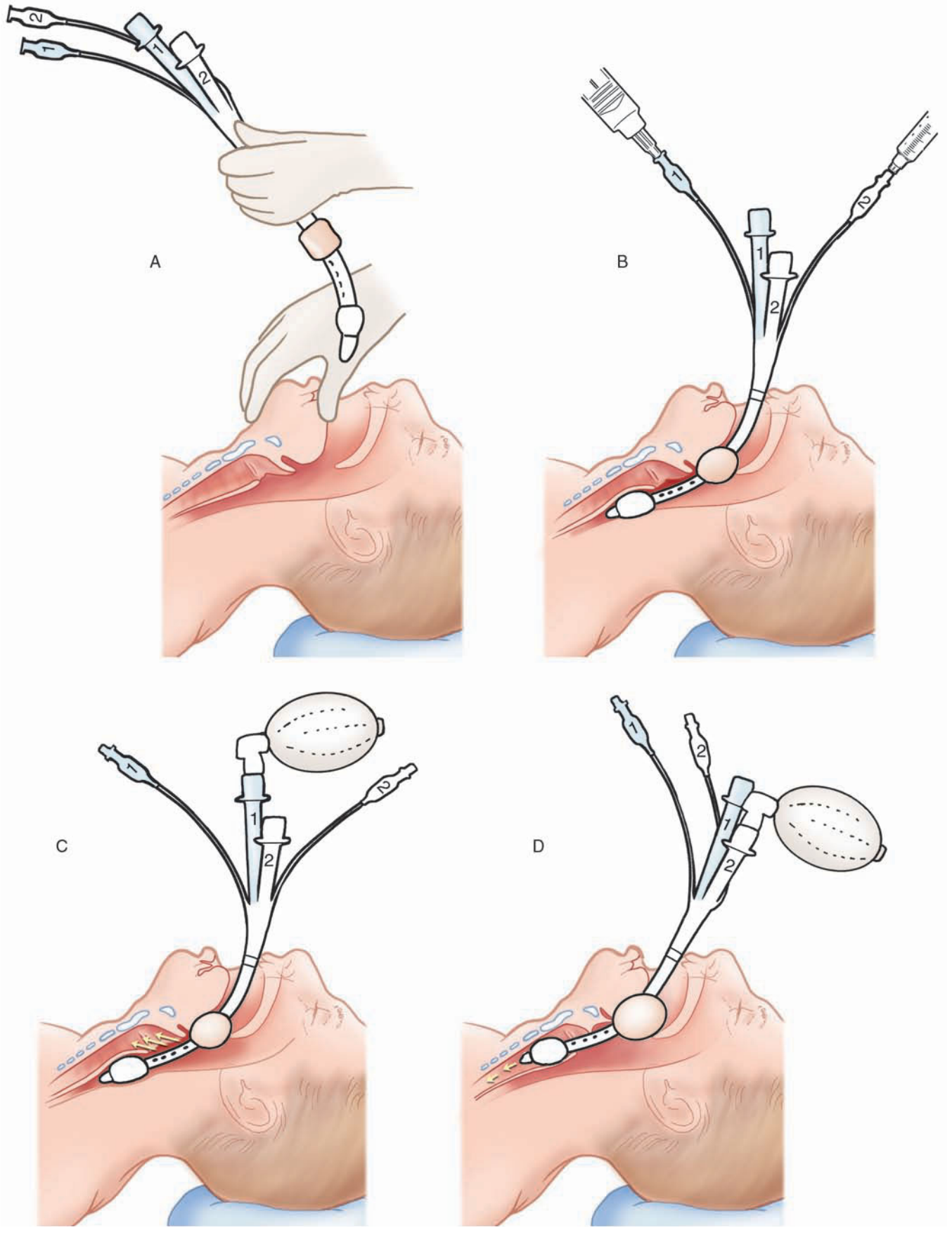


FIGURE 20-5. Insertion of the ETC. **A.** Positioning of the patient and the physician. **B.** The tube is inserted until the patient's teeth are between the black lines and the cuffs are inflated. **C.** The tube is inserted into the esophagus. The patient is ventilated through the longer tube (1) and air is directed from the proximal ports (*arrows*). **D.** The tube is inserted into the trachea. The patient is ventilated through the shorter tube (2) and air is directed through the distal port (*arrows*).

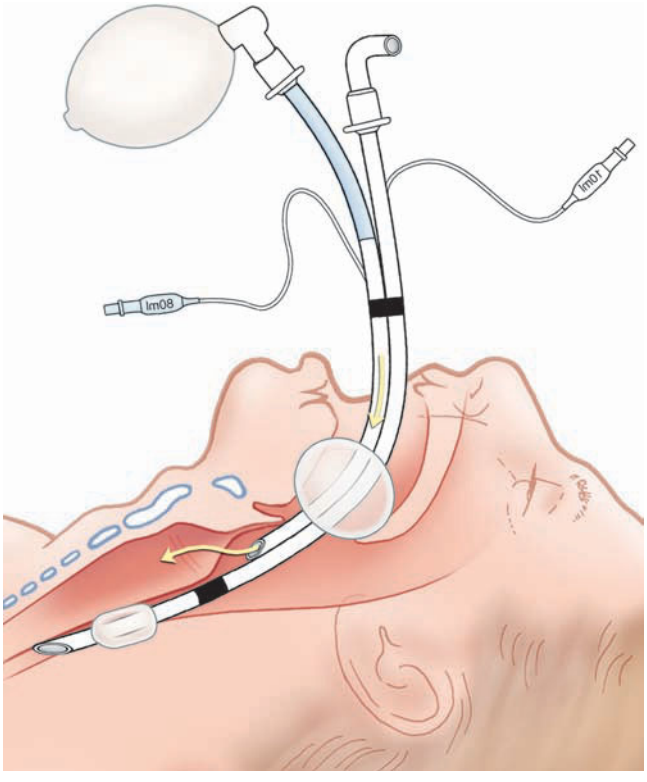


FIGURE 20-6. Insertion of the EzT with the distal end in the esophagus.

COMPLICATIONS

Despite the potential utility of the ETC or EzT in the acute setting, several disadvantages must be kept in mind. These include the high cost, bulky packaging, and the fact that the ETC detachable "vomit deflector" can expose providers to gastric contents if improperly managed. It is best not to use the vomit deflector, as it can be associated with aspiration. Several risks are also inherent to the insertion and mechanics of the devices. It should be recognized that the presence of a rigid cervical collar can cause great difficulties in the proper placement of this device.[12] The device is most frequently inserted into the esophagus. Therefore, there is a risk of esophageal injury.[13] **There is no way to suction the trachea with the open distal port in the esophagus. It is important to note that resuscitation drugs that can be routinely given through an endotracheal tube cannot be given through the device positioned with the tip in the esophagus.** Drugs will accumulate in the blind end of the tube or the hypopharynx. Significant soft tissue injury can occur due to the tip of the device or if the balloons contain too much air.[12,14] If forced, the tip can perforate the esophagus, piriform sinus, or vallecula. The increased cuff pressure of the ETC versus the EzT can result in mucosal injury.[15] An overinflated distal balloon located in the esophagus can compress the trachea and cause an airway obstruction.[16] **Always inflate the balloons with the recommended volume of air and not more.** Prolonged use of up to 4 hours can result in the proximal cuff obstructing the lingual veins and resultant tongue engorgement.[17] This can result in a difficult intubation when exchanging the device for an endotracheal tube.

SUMMARY

The Esophageal-Tracheal Combitube and the EasyTube can adequately ventilate a patient whether it is placed in the esophagus or trachea. It is relatively simple to use and requires minimal training. It offers an additional technique for emergency care providers to secure the airway in both the prehospital and hospital environment. It should be included in every armamentarium dedicated to the difficult airway.

21 Fiberoptic Endoscopic Intubation

Erika D. Schroeder, M. Scott Linscott, and Joseph Bledsoe

INTRODUCTION

The flexible fiberoptic bronchoscope is a useful instrument for placing endotracheal (ET) tubes in awake and nonparalyzed patients who may have contraindications to paralysis, as well as in patients undergoing rapid sequence intubation when other means of orotracheal intubation have failed. **The device is unique in that its flexible cord allows it to conform to the patient's anatomy, making intubation possible in a variety of clinical situations when intubation by direct laryngoscopy is likely to be difficult or impossible.** It is most useful in performing awake intubations as it is accepted by more patients and is associated with fewer complications than awake laryngoscopy.[1] Proficiency in the skills required for fiberoptic intubation requires both instruction and practice.[2] **Technical problems and failure to successfully intubate patients using this technique are usually due to a lack of familiarity and expertise with the fiberoptic bronchoscope, using it in the wrong clinical setting, and inadequate patient preparation.**

ANATOMY AND PATHOPHYSIOLOGY

A more detailed description of the airway anatomy is provided in Chapters 6 (Essential Anatomy of the Airway), 7 (Basic Airway Management), and 11 (Orotracheal Intubation). A brief description of the flexible fiberoptic bronchoscope is presented in this section. There are other sources for a more in depth description of the fiberoptic bronchoscope's anatomy.[3]

The basic anatomy of the flexible fiberoptic bronchoscope is shown in **Figure 21-1**. The major components are the handle, the insertion cord, and a light source. The handle contains the eyepiece for image viewing and a dial to bring the image into focus. A lever controls an angulation wire, which allows for movement of the bronchoscope's insertion cord tip in one plane.

The bronchoscope's insertion cord is composed of thousands of glass fibers, each approximately 10 μm in diameter. The fibers in the cord transmit an image to the proximal viewing lens. There is a side port that can be used for the insufflation of oxygen, instillation of local anesthetic or saline solution, limited suction (due to the small size of the port), passage of a guidewire, and end-tidal CO_2 monitoring. Any fiberoptic bronchoscope used for intubation should have a length of at least 55 to 60 cm.[4] Fiberoptic laryngoscopes or nasopharyngoscopes are usually unsuitable for intubation because of their short length.

INDICATIONS

Fiberoptic intubation of the airway is indicated in situations where an awake intubation technique is preferable to one that renders the patient unconscious. The awake technique is indicated when it is anticipated that direct laryngoscopy might be difficult to perform or if paralysis is contraindicated.[2] This would include morbidly obese

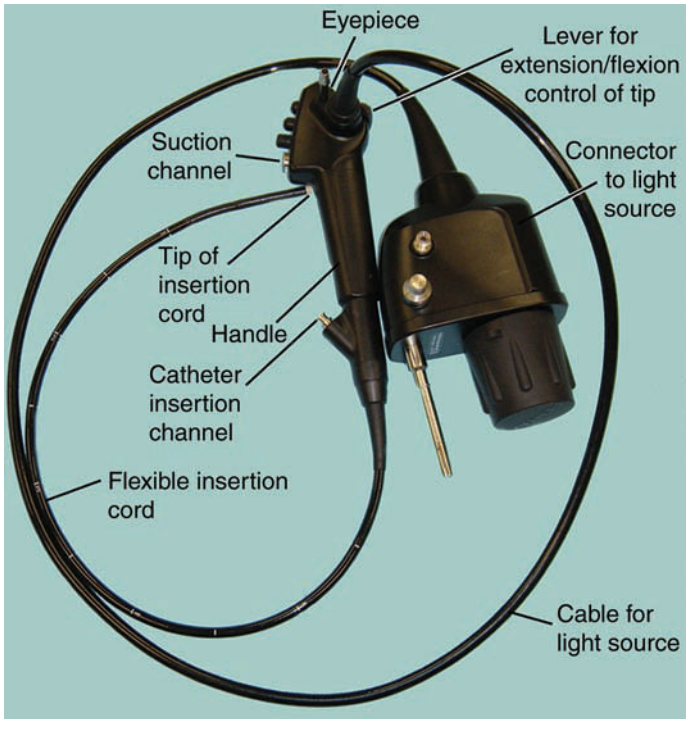


FIGURE 21-1. Anatomy of the flexible fiberoptic bronchoscope.

patients, those having limited mandibular opening, an unstable or immobile cervical spine, macroglossia, CHF, micrognathia, patients who appear to have pathologic airway anatomy (e.g., tracheal deviation, tracheal stenosis, tumors, and trauma), and those who appear to be at increased risk for dental damage.[5] Fiberoptic bronchoscopy has been used successfully in the case of a rapidly enlarging neck mass.[6] It should be considered in patients in whom neck extension should be avoided or who are at increased risk of aspiration of their gastric contents (e.g., those not fasted, pregnancy, alcohol intoxication, and bowel obstruction).[4]

CONTRAINDICATIONS

Fiberoptic intubation is not recommended for patients who are actively vomiting or have significant oropharyngeal bleeding. Opaque fluids cover the fiberoptic port and prevent adequate visualization through the bronchoscope. Patients who are hypoxic or require assisted ventilation by mask are poor candidates for fiberoptic intubation as the technique may require several minutes to perform. An exception may be made if the patient can be ventilated by a laryngeal mask airway (LMA) through which fiberoptic ET intubation may be performed.[7,8] Contraindications specific to nasal fiberoptic intubation would include coagulopathy, significant midface trauma, severe intranasal pathology, fracture of the cribriform plate, and leakage of cerebrospinal fluid.[9]

Relative contraindications to fiberoptic intubation of the airway are situations when instrumentation of the airway may further compromise airway patency, such as stridor resulting from airway edema, infection, or epiglottitis. **Some authors advocate fiberoptic intubation as an option to consider in these circumstances, but only by individuals extremely proficient at fiberoptic endoscopic intubation and only with a qualified physician standing by to perform an emergent tracheostomy or cricothyroidotomy if the need arises.**[10] In these circumstances, it would probably be prudent to establish a surgical airway in the operating room, under a more controlled setting, rather than attempt a fiberoptic bronchoscopic intubation. Occasionally, an emergent tracheostomy or cricothyroidotomy cannot be successfully performed in these patients before complete airway obstruction occurs. **Therefore, one should always be prepared to provide oxygen emergently by another route (e.g., transtracheal jet ventilation) to prevent hypoxic brain damage.**

EQUIPMENT

Nasal Anesthesia

- Cotton-tipped applicators
- 4% lidocaine
- 0.05% oxymetazoline (Afrin®)
- 4% cocaine

Oropharyngeal Anesthesia

- 1%, 2%, or 4% lidocaine or benzocaine spray
- Nebulizer device with tubing or a Mucosal Atomizer Device (MAD®, Wolfe Tory Medical, Salt Lake City, UT)
- Cotton 4 × 4 swabs soaked in 4% lidocaine
- Emesis basin
- Yankauer suction
- Tongue blade

Laryngeal Anesthesia

- Alcohol swabs
- 10 mL syringes
- 21 gauge needle, 1½ inches
- 2% lidocaine for atomization
- 1% and 4% lidocaine solution
- Nebulizer device with tubing

Fiberoptic Bronchoscopy and Intubation

- An assistant
- Fiberoptic bronchoscope with working channel
- Bite block
- Oral/nasopharyngeal airways
- Light source
- ET tubes, various sizes
- Suction source and catheters
- Cuffed tracheal tubes of various sizes, especially 5 and 7 mm
- Oxygen source
- Oxygen tubing
- Bag-valve device
- Face masks
- Water-soluble lubricant or anesthetic jelly
- Gauze 4 × 4 squares
- Antisialagogue (glycopyrrolate 0.3-0.4 mg IV or IM, atropine 0.5 mg IV)

Miscellaneous Supplies

- Povidone iodine solution or chlorhexidine
- Alternative intubation kit/devices (difficult airway cart)
- Cricothyroidotomy tray or kit
- Rapid sequence induction medications
- Crash cart
- Cardiac monitor
- Pulse oximetry

PATIENT PREPARATION

Fiberoptic intubation is best performed on awake and spontaneously breathing patients. Rendering the patient unconscious might relax and distort the airway anatomy, placing the patient at risk for more serious complications including apnea, airway obstruction, and aspiration of gastric contents.[11] **Proper patient preparation is essential to the successful completion of a fiberoptic intubation.** Proper patient preparation includes counseling the patient, clearing the airway of secretions and blood, judicious sedation, and airway anesthesia (nasopharynx, larynx, and trachea).[9] **Counseling is an important and often underestimated part of patient preparation.** Thoroughly explain the necessity for the procedure and the technique. The bronchoscopist can gain the patient's confidence and cooperation, which are invaluable aids for the performance of a successful fiberoptic intubation.

Before proceeding with fiberoptic bronchoscopy, monitors for electrocardiogram, blood pressure, and pulse oximetry should be placed along with an intravenous line for the administration of drugs. Supplemental oxygen should be administered and can be delivered either by nasal cannula, "blow-by," or through the side port of the fiberoptic bronchoscope. Delivering oxygen through the side port offers the additional advantage of blowing airway secretions away from the fiberoptic bronchoscope's tip and can be used to help visualize the vocal cords when redundant tissue is obscuring the view. Unfortunately, it has the potential disadvantage of causing gastric distention and rupture.[12,13]

The patient may be in a sitting, semirecumbent, supine, or left semilateral position during fiberoptic bronchoscopy.[14] In morbidly obese patients, the sitting position will, by virtue of gravity, displace redundant pharyngeal tissue anteriorly and open the pharyngeal space.[15] However, use of the sitting position also requires the bronchoscopist to stand at the patient's side, thus inverting the image seen through the fiberoptic bronchoscope. Alternatively, the bronchoscopist can stand on a platform in order to be of sufficient height to correctly perform the procedure. When performing the procedure with the patient in the supine position, the patient's head should lie flat against the table surface with the neck extended (if it is safe to do so). This head position brings the tracheal axis more in line with the nasal and oral passageways and elevates the epiglottis from the posterior pharyngeal wall. The "sniffing position," while optimal for direct laryngoscopy, increases obstruction of the glottis by the epiglottis during fiberoptic bronchoscopy and makes the passage of the fiberoptic bronchoscope more difficult.[15] Maneuvers performed by an assistant, such as the jaw thrust or pulling the tongue forward with a cotton swab, can help to move the pharyngeal soft issues anteriorly and allow increased maneuverability of the fiberoptic bronchoscope's tip.[9]

Instrumentation of the airway may cause the patient to produce copious secretions, making an otherwise straightforward fiberoptic bronchoscopy extremely difficult. Bronchoscopy via a "dry" airway devoid of secretions can be accomplished in most instances by administering 0.3 to 0.4 mg of glycopyrrolate. This is a potent antisialagogue and should be administered intravenously at least 10 minutes before or intramuscularly 30 minutes before fiberoptic bronchoscopy. Atropine is often more readily available in the Emergency Department than glycopyrrolate. It can be administered in a dose of 0.5 mg intravenously at least 10 minutes before fiberoptic bronchoscopy. The only disadvantage of atropine is that it crosses the blood–brain barrier and can cause central nervous system effects whereas glycopyrrolate does not. Please refer to Chapter 8 for a more complete discussion of these two antisialagogues.

Sedation can be extremely beneficial in gaining the patients cooperation during the performance of a fiberoptic bronchoscopy. **Sedative drugs, if used at all, should be judiciously titrated to the desired effect with continual assessment of the patient's level of consciousness, while at the same time avoiding respiratory depression.** Ketamine given in small doses (0.5 to 1.0 mg/kg) has the advantage of producing minimal respiratory depression and may be preferable to opioids in some cases. Other agents that have been successfully used for sedation during fiberoptic intubations include midazolam, propofol, fentanyl, dexmedetomidine, and remifentanil.[4,16] Please refer to Chapter 8 for a more complete discussion of the pharmacologic adjuncts to intubation. **Avoid sedation if the patient has a tenuous airway, labored respirations, a distended abdomen, or is vomiting.**

AIRWAY ANESTHESIA

Adequate anesthesia of the airway is extremely important when intubating an awake patient. In order to establish a quiet larynx devoid of reflexes, it is extremely helpful, prior to attempting fiberoptic bronchoscopy, to provide anesthesia of the airway. It is especially effective in improving the success rate of individuals who are less experienced at performing fiberoptic intubation. The regional anesthesia technique employed to anesthetize the larynx is the bilateral superior laryngeal nerve block.

Bilateral blockade of the superior laryngeal nerves will provide effective anesthesia of the supraglottic structures. Prepare a 5 mL syringe attaching a 21 gauge needle and filling it with 1% or 2% lidocaine solution. Identify the hyoid bone by palpation. Slide your finger laterally to identify the superior cornua. Clean and prepare the skin over the superior cornua bilaterally. Insert the needle and advance it until it contacts the superior cornua of the hyoid bone. Contact with the bone can be made easier by extending the patient's head and gently palpating the hyoid bone with the thumb and forefinger of one hand. By applying gentle pressure to one side, the opposite cornua comes into closer contact with the skin and is subsequently easier to contact with the needle. Walk the needle tip inferiorly and off the bone. Advance the needle 3 to 4 mm and through the thyrohyoid membrane (**Figures 21-2 & 21-3**). **Aspirate before injecting the local anesthetic solution to confirm that the needle has not entered the external carotid artery.** Inject 2 to 3 mL of lidocaine. Repeat the procedure on the contralateral side. The hyoid bone may not be palpated due to obesity, infections, or masses. In those instances, a superior laryngeal nerve block should not be attempted.[17]

It remains an unresolved controversy whether to abolish the laryngeal reflexes of a patient considered to have a "full stomach." In considering this option, one must weigh the risk of abolishing the laryngeal reflexes and rendering the patient potentially vulnerable to gastric aspiration versus leaving the laryngeal reflexes intact and thus causing significant discomfort for the patient. When deliberating whether or not to proceed with a regional block of the larynx in a patient considered to be at risk for gastric aspiration, bear in mind that aspiration of gastric contents occasionally does occur in patients with intact laryngeal reflexes. Instrumentation of the airway in patients with an intact gag reflex can induce vomiting.

The larynx and trachea can be effectively anesthetized by performing a transtracheal injection of 4 mL of lidocaine. Clean and prepare the surface of the skin over the cricothyroid membrane. Prepare a 20 gauge intravenous catheter-over-the-needle on a 5 mL syringe containing 2 to 3 mL of sterile saline. Prepare a second syringe containing lidocaine solution. Insert the catheter-over-the-needle on the syringe containing sterile saline perpendicular through the skin in the midline over the cricothyroid membrane (**Figures 21-2 & 21-4**). Advance the syringe until the tip of the catheter-over-the-needle is in the trachea. The lumen of the trachea is identified by the loss of resistance. Aspirate air into the syringe, as evidenced by the presence of bubbles in the saline, to confirm that the catheter-over-the-needle is within the trachea. **Care should be taken to not advance the catheter-over-the-needle too far and perforate the posterior**

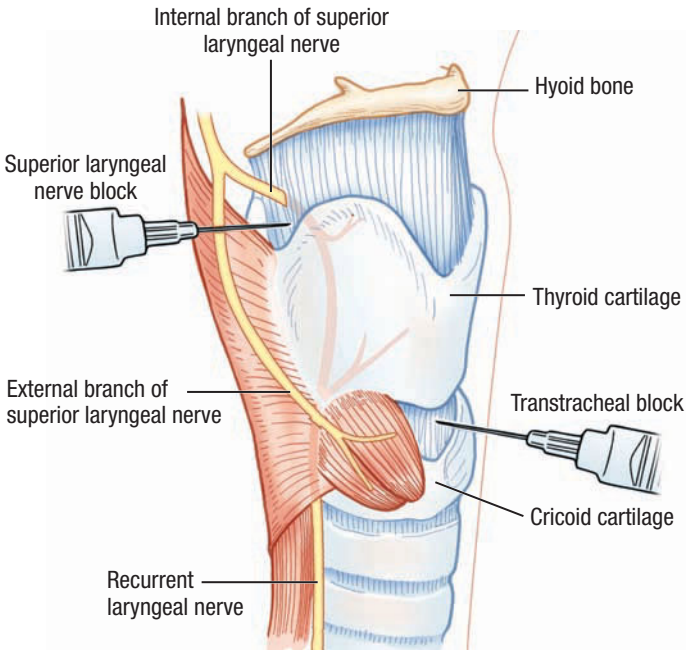


FIGURE 21-2. The anatomy of the larynx. The syringes demonstrate the superior laryngeal nerve block and the transtracheal block.

trachea, as this could result in a pneumomediastinum.[18] Securely hold the syringe in place and advance the catheter into the trachea. Securely hold the catheter hub at the skin. Withdraw the needle and syringe. Attach the syringe containing lidocaine to the catheter. Briskly inject 3 to 4 mL of lidocaine through the catheter and into the tracheal lumen. This will cause the patient to cough and disperse the local anesthetic solution throughout the trachea and larynx. Remove the syringe and catheter. The physician performing this block should be wearing a gown, a face mask, and eye protection to prevent exposure to the respiratory secretions when the patient coughs.

The nasal passages, pharynx, and larynx can be anesthetized by several other techniques. If the nasal passageways are the anticipated route for intubation, they should be prepared by shrinking and anesthetizing the nasal mucosa. Cocaine (4%) applied topically

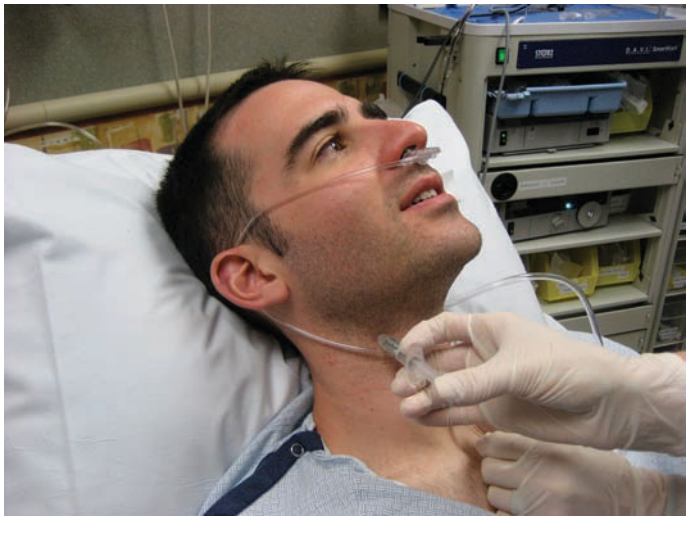


FIGURE 21-3. The recurrent laryngeal nerve block. The needle is inserted and advanced just below the superior cornua of the hyoid bone.



FIGURE 21-4. Transtracheal anesthesia of the trachea and larynx. The catheter enters the trachea through the midline of the cricothyroid membrane.

(maximum dose 200 mg) has the advantage of providing profound vasoconstriction and anesthesia to the nasal passageways. Similar effects can be provided by applying 0.25% to 1.0% phenylephrine topically to the nasal mucosa, followed by lidocaine 4% via cotton-tipped applicators. These applicators should be gently placed, one at a time, through the middle meatus and back to the inferior turbinate. A nasal passage that accommodates four to five single cotton-tipped applicators will usually allow passage of a 7.0 mm ET tube.[9] Also effective in providing profound vasoconstriction of the nasal mucosa is the use of three to four sprays of atomized oxymetazoline (Afrin®) into one or both nares.

Once the antisialagogues have taken effect, the tongue and pharynx can be anesthetized. Place a tongue blade on the patient's tongue and apply topical anesthetic spray (**Figure 21-5**). Benzocaine or lidocaine spray will usually provide effective anesthesia for the posterior pharynx within 30 seconds. They can be administered from a commercially available spray container or using an atomizer device. There are reports of methemoglobinemia from the overzealous use of benzocaine.[19] Its use should be limited to several short sprays.

Alternatively, the patient can swish 2% viscous lidocaine in their mouth for several minutes to provide effective anesthesia. One of the most effective methods of blocking the glossopharyngeal nerve is the "lollypop method." Create a lollypop by soaking sterile gauze in lidocaine ointment and taping it to a tongue depressor. Place the lidocaine lollypop into the patient's posterior mouth while setting up for the bronchoscopy. Advance the lollypop 1 cm every 2 minutes until the patient's posterior pharynx is completely anesthetized.



FIGURE 21-5. Anesthetizing the posterior oropharynx with atomized lidocaine solution.

As an alternative, nebulized 4% lidocaine administered at least 20 minutes prior to fiberoptic bronchoscopy will usually provide adequate anesthesia of the supraglottic structures. A second alternative is the "spray as you go" technique.[20] Once the epiglottis is visualized through the fiberoptic bronchoscope, instill 3 to 4 mL of 2% lidocaine through the working channel of the scope and onto the epiglottis and the surface of the vocal cords. This will induce coughing and temporarily obliterate the view of the laryngeal structures. Allow 2 to 3 minutes for the anesthetic solution to exert its effect before proceeding with fiberoptic bronchoscopy.

After anesthesia is accomplished, place a suction catheter into the oropharynx. This will clear the airway of secretions and blood that can impair the visual image. It will also determine the adequacy of the topical anesthesia for preventing coughing and gagging.

TECHNIQUES

Prepare the fiberoptic bronchoscope. Attach the light source. Check the focus of the image by holding the tip of the insertion cord 1 to 2 cm over a printed page. Adjust the eyepiece until the letters on the image are clear. Note how the image appears as you move toward and away from the page. Briefly use the angulation lever to move the tip of the insertion cord and learn its movements. **The most difficult aspect of mastering fiberoptic bronchoscopy is learning to simultaneously angle the tip, rotate the scope, and advance the insertion cord.**[21] It requires repetition and practice to develop these skills before attempting to intubate a patient.

Before placing of the fiberoptic bronchoscope insertion cord into the ET tube, let the insertion cord hang toward the floor to straighten the inner fiberoptic strands. Identify the plane in which the angulation lever moves the tip. When fiberoptic bronchoscopes are stored coiled in a case, over time the insertion cord may develop a curve. Slightly rotate the fiberscope to the right or left until the angulation of the tip is in the midline plane. Look through the eyepiece and note the position of the directional arrow (▼) on the anterior edge of the image that correlates with the midline.

To prevent fogging, apply an antifog solution to the insertion cord tip or place the tip in warm water before inserting the fiberoptic bronchoscope into the patient's nose. Warming the ET tube with warm water just prior to placing it on the insertion cord will soften the tube and may make the later advancement of the ET tube through the mouth or nares easier.

Apply a thin film of silicone spray or a water-soluble lubricant over the insertion cord to facilitate passage of the ET tube over the flexible cord. Insert the flexible insertion cord completely through the ET tube, taking care not to get any of the lubricant on the lens tip. The insertion tip should exit the distal tip of the ET tube. Do not place the tip of the insertion cord through the Murphy eye of the ET tube. Lubricate the ET tube liberally.

Estimate the distance from the patient's mouth to their glottis. Place the tip of the insertion cord by the patient's ear. Mark the point the insertion cord touches the patient's mouth. The distance from the mouth to the ear is approximately the distance from the mouth to the glottic opening. Add 3 cm to this length if performing the procedure through the nose instead of the mouth.

Hold the fiberoptic bronchoscope in your dominant hand with the angulation lever operated by the thumb and the suction port (if used) covered by the index finger. The other end of the scope should be held between the index finger and the thumb of the nondominant hand. Place the nondominant hand at the patient's nose or mouth. There should be no slack in the fiberoptic bronchoscope between the two hands. The removal of slack from the insertion cord makes more precise rotary movements of the tip possible.

NASAL INTUBATION

Nasal fiberoptic intubation has several advantages over the oral route. For those less experienced at fiberoptic bronchoscopy, nasal fiberoptic bronchoscopy is usually easier to perform because less angulation of the tip is required. Once inserted, nasal ET tubes are better tolerated by patients and are associated with a lower incidence of accidental extubation. Disadvantages include a higher incidence of bacteremia, middle ear infection, epistaxis, and alar necrosis.[9] **Nasal intubation, unlike oral intubation, may produce bacteremia; therefore appropriate endocarditis prophylaxis should be provided for those at risk.**

Examine the patient to determine which is the most patent nostril. Insert and navigate the insertion cord's tip along the posterior floor of the nares (**Figure 21-6**). Continue to advance the insertion cord and ET tube as a unit until the ET tube enters the oropharynx (**Figure 21-7**). This will serve to minimize patient discomfort and the risk of epistaxis early in the procedure. Occasionally, loss of view and maneuverability of the insertion cord tip occur in the oropharyngeal area as the tip encounters the pharyngeal mucosa. Pulling the patient's tongue forward with gauze, using the jaw-thrust maneuver, or simply advancing the insertion cord a few centimeters further will usually bring pharyngeal structures back into view. Continue to advance the tip of the insertion cord until the epiglottis is visualized (**Figure 21-7**). Maneuver the insertion cord tip with the lever until the glottis comes into view (**Figure 21-8**). Continue to advance the insertion cord tip through the vocal cords and to a point approximately 3 cm above the carina. Advance the ET tube over the insertion cord and into the trachea to the appropriate depth.

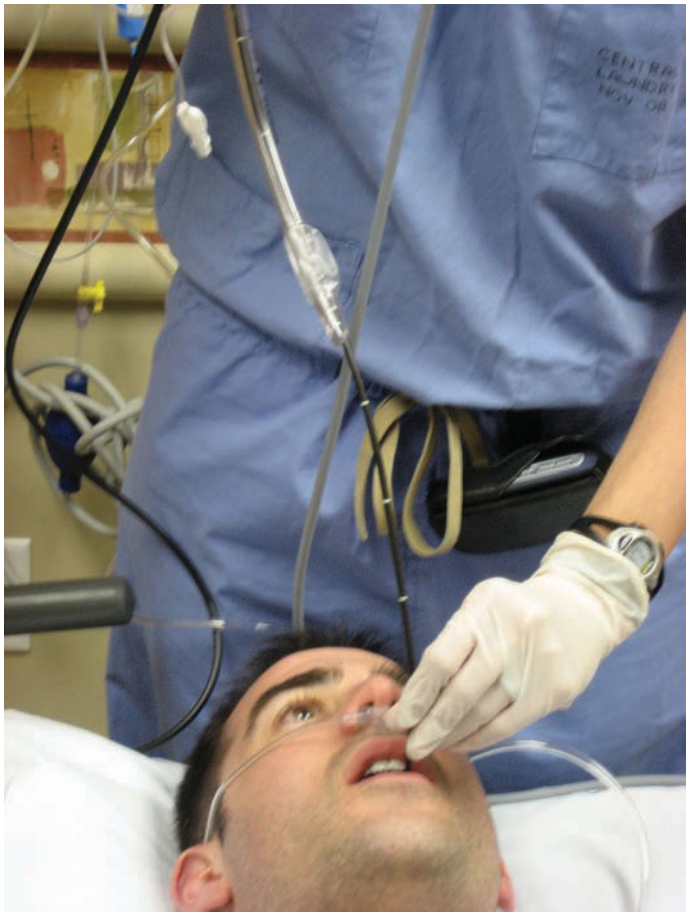


FIGURE 21-6. The technique of placing the fiberoptic bronchoscope insertion cord into the nares. Note the position of the ET tube over the proximal portion of the insertion cord.

The distance from the nares to the epiglottis is usually about 15 to 17 cm. At this position, the epiglottis should be visible. **If the 15 cm mark has been passed, it is very likely that the insertion cord has entered the esophagus.** If that is the case, withdraw it to 12 cm and redirect the tip upward with a slight downward movement of the angulation lever.[21] This will usually bring the glottic opening into view (**Figure 21-8**). Occasionally, the epiglottis will obscure the glottic opening. Position the tip of the insertion cord just above the tip of the epiglottis, then advance it a few millimeters posterior to the epiglottis while angulating the tip of the insertion cord slightly anterior by pressing down on the angulation lever. This will bring the glottic opening into view. Simultaneously rotate, angulate, and advance the insertion cord tip toward and past the vocal cords.

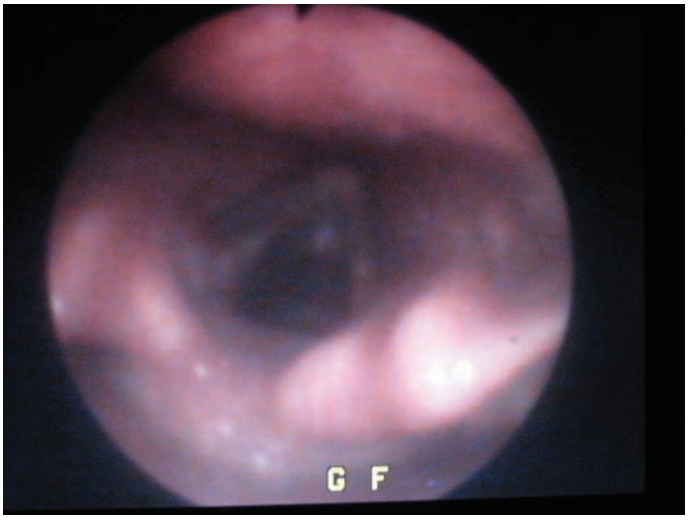


FIGURE 21-8. Visualization of the glottis through the flexible fiberoptic bronchoscope just prior to its insertion cord passing through the vocal cords.

An alternative technique would be to advance the ET tube through the nares until the tip is just past the soft palate. This is usually at a depth of 10 to 12 cm. The insertion cord is then passed through the ET tube and through the vocal cords (**Figure 21-9**). The ET tube is then advanced over the insertion cord into the trachea. This approach has the advantage of bringing the tip of the insertion cord directly midline and toward the epiglottis. However, this can cause some patient discomfort early on in the procedure and may decrease patient cooperation before the insertion cord has entered the trachea.

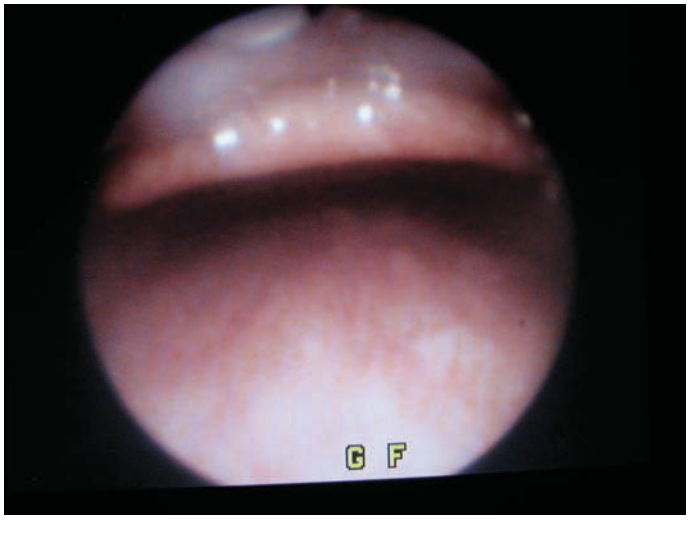


FIGURE 21-7. Visualization of the epiglottis (at the top of the photo) through the flexible fiberoptic bronchoscope.



FIGURE 21-9. The ET tube has been inserted into the nares and advanced into the oropharynx. The insertion cord is advanced through the ET tube.

There is the potential for epistaxis, making visualization of laryngeal structures difficult if not impossible. Despite the application of topical anesthesia to the nasal passages, they are difficult to anesthetize completely. For the awake patient, passage of the ET tube is often the most uncomfortable part of the fiberoptic intubation procedure.

Occasionally, some operators have difficulty passing the insertion cord through the vocal cords. There are several causes for this. The tip of the insertion cord may remain angulated and abut against the wall of the trachea. The vocal cords may not be properly anesthetized and may have closed reflexively. Finally, the insertion cord tip may be abutting the arytenoid cartilages or the pyriform sinus. If inadequate anesthesia is the cause, inject 2 mL of either 2% or 4% lidocaine through the working channel of the insertion cord and wait several minutes for it to take effect. Additionally, having the patient inspire deeply will bring the vocal cords into greater opposition. Once the insertion cord tip has passed the vocal cords, bring the tip into neutral position with a light downward motion of the angulation lever.

Once past the vocal cords, advance the insertion cord tip further to bring the bifurcation of the trachea at the carina into view. The trachea can easily be identified anteriorly by the cartilaginous rings and posteriorly by the smooth mucosa of the posterior wall. Advance the ET tube over the insertion cord and into the trachea. The arytenoids or the interarytenoid soft tissues can impede advancement of the ET tube past the vocal cords and into the trachea. If the ET tube advancement is inhibited, withdraw it slightly, rotate it 90° counterclockwise, and reattempt intubation.[22] If this maneuver fails, rotate the ET tube so that its bevel faces either posteriorly or to the left and laterally. The inability to advance the ET tube occurs with greater frequency when the diameter of the insertion cord is significantly smaller than that of the ET tube or with oral fiberoptic intubation, due to the greater curve that the ET tube must assume for it to enter the trachea.[21] If these maneuvers are unsuccessful, consider substituting a smaller ET tube, a spiral-bound ET tube, or an ET tube with a flexible tip.[23]

Occasionally, when the trachea is not anesthetized, the patient's subsequent coughing and the associated muscular contractions of the trachealis muscle will collapse the trachea almost completely. This makes it difficult to discern if the insertion cord tip is actually in the trachea or whether to advance the insertion cord or ET tube into the trachea. Wait until the trachealis muscle relaxes and then continue with the procedure.

To prevent endobronchial intubation in adults, which can occur with flexion of the head, confirm that the tip of the ET tube is 3 cm above the carina. This is accomplished by advancing the tip of the insertion cord to the carina with the thumb and forefinger of the nondominant hand. Mark the point on the insertion cord where it exits the ET tube. Withdraw the insertion cord until the distance on the insertion cord between the marked point and the tracheal tube connector is 4 cm. While looking through the eyepiece, advance the ET tube until its tip is visible. This places the tip of the ET tube at approximately 3 cm above the carina.

Occasionally, difficulty is encountered while attempting to pass the ET tube through the nares and nasal cavity. This might be caused by a deviated nasal septum, enlarged turbinates, a nasal spur (which can also tear the ET tube cuff), or nasal polyps. Selection of an ET tube that is too large, inadequate lubrication, or failure to presoften the ET tube can be the cause. Reattempt insertion with a well-lubricated, presoftened ET tube that is 0.5 to 1.0 mm smaller. Alternatively, try placing a 5.0 mm inner diameter (ID) ET tube in a 7.0 mm ID ET tube as discussed below.

ORAL INTUBATION

Begin by noting any loose or broken teeth. After ensuring an adequate sensory block by the absence of a gag reflex, insert an oral intubating airway into the patient's mouth. These devices are placed in the patient's mouth like any other oral airway. They allow for the midline passage of the insertion cord and protect the delicate glass fibers within it from the patient's teeth.

Technical problems exist in attempting oral fiberoptic intubation. As stated earlier, oral fiberoptic intubation requires that the insertion cord tip traverse a more acute angle to reach the vocal cords than it would by the nasal route. If one can safely do so, maximally extending the patient's head at the atlantooccipital joint will bring the oropharyngeal and laryngeal axes more closely in line. This maneuver will reduce the angle that the insertion cord tip must traverse.

In performing an oral fiberoptic intubation, the ET tube becomes hung up on the vocal cords more frequently than with the nasal route. A technique believed to significantly improve the first-time pass rate with oral fiberoptic bronchoscopic intubation is to pass a lubricated 5.0 mm ID ET tube through a 7.0 mm ID ET tube that has been cut to 24 cm. This should leave 2 cm of the 5.0 mm ID ET tube protruding from the distal end. It is believed that the close approximation of the diameters of the 5.0 mm ID ET tube and the fiberoptic bronchoscope allows easier passage of the scope. After the 5.0 mm ID/7.0 mm ID ET tube complex is in place, withdraw the 5.0 mm ID ET tube, leaving the 7.0 mm ID ET tube in the trachea.[24]

ALTERNATIVE TECHNIQUES

Alternative techniques that have been shown to be as effective as fiberoptic intubation for intubating patients with unstable cervical spines include the Bullard laryngoscope[25] and the lighted stylet.[26] Blind nasotracheal intubation is as successful as nasal fiberoptic intubation in anesthetized patients with unstable cervical spines.[27] The Glidescope, a video laryngoscope, causes less cervical spine movement than direct laryngoscopy.[28]

A combined technique using oral fiberoptic intubation through a LMA or alternative supraglottic airway can be extremely helpful in instances where there is severe oropharyngeal bleeding or when direct laryngoscopy is not possible.[7,29] After confirming successful placement of the LMA, place a self-sealing bronchoscopy elbow over the proximal end of a 6.0 mm ID ET tube. Advance the ET tube tip through the LMA until the LMA grille is encountered (resistance will be felt). Inflate just enough air into the ET tube cuff to provide a seal for positive-pressure ventilation via the ET tube. Advance the insertion cord through the ET tube and into the trachea under direct visualization. Deflate the ET tube cuff. Advance the ET tube over the insertion cord and into the trachea until the ET tube adapter meets the adapter of the LMA. Inflate the ET tube cuff and confirm ventilation through the ET tube.

Because standard ET tubes are not long enough to allow removal of the LMA, longer ET tubes have been developed. If you do not have access to a specially made ET tube, use a nasal Rae tube, which is 6 cm longer than a standard ET tube. If a longer ET tube is not available, another ET tube can be temporarily lengthened by removing the adapter of the 6.0 mm ID ET tube and placing the tip of a 5.0 mm ID ET tube into the lumen of the 6.0 mm ID ET tube. This maneuver lengthens the ET tube enough that the LMA cuff can be deflated and withdrawn, leaving the 6.0 mm ID ET tube correctly placed in the trachea. Additionally, ventilation can be maintained the entire time simply by using a bag-valve device connected to the 5.0 mm ID ET tube adapter. After removing the LMA, remove the 5.0 mm ID ET tube from the 6.0 mm ID ET tube, replace the adapter, and resume ventilation.[30] After removing the LMA and establishing ventilation, always confirm by fiberoptic bronchoscopy that the ET tube is correctly positioned.

An alternative to the traditional LMA is the intubating LMA or ILMA. The ILMA is a valuable resource in patients with an anticipated difficult airway.[31]

ASSESSMENT

The placement of an ET tube should be followed by an assessment to ensure its proper positioning. Please refer to Chapter 12 for a more complete discussion. This includes visual inspection of chest rise and lack of abdominal movement with ventilation, fogging in the ET tube for at least six breaths, auscultation, and end-tidal CO_2 monitoring. This should be followed by a chest X-ray to confirm proper positing of the ET tube within the trachea.

AFTERCARE

The steps of ensuring proper placement of the ET tube and securing the tube are the same as for any patient who has undergone orotracheal intubation (Chapter 11).

COMPLICATIONS

Many of the complications associated with fiberoptic intubation are the same as those seen with direct laryngoscopy (Chapter 11). The most severe complication is hypoxemia from a prolonged procedure or delays due to an inexperienced bronchoscopist. Use the suction channel on the bronchoscope to provide oxygenation to the patient during the procedure. Epistaxis can be minimal or significant enough to complicate the procedure. Bleeding can be minimized by using the correct ET tube size and pretreatment with a nasal vasoconstrictor and anesthetic. Failure to intubate can be due to narrow nasal or airway passages, blood or vomitus limiting the fiberoptic field of view, or an inexperienced bronchoscopist.

While the insertion cord is passed through the glottis and into the trachea under direct vision, the ET tube is passed blindly over the insertion cord tip. It is thus possible to cause injury to the arytenoids, resulting in permanent hoarseness, particularly if the ET tube bevel faces anteriorly. However, in a recent randomized control trial, there was no difference in the incidence of vocal cord injury for nasotracheal fiberoptic intubation versus orotracheal intubation.[32] The ET tube may also become blocked in the nasal cavity or larynx, resulting in epistaxis, nasal turbinate fracture, and tearing of the ET tube cuff[1,9] Sinusitis and otitis media are known complications from nasal intubation.[9]

SUMMARY

Awake intubation under direct visualization in spontaneously breathing patients by either the oral or nasal route is possible with the fiberoptic bronchoscope. Intubation by means of the fiberoptic bronchoscope is an option to consider when direct laryngoscopy is difficult, or impossible. In some instances, awake fiberoptic intubation may be preferable to other emergency intubation techniques that render the patient unconscious and apneic. Fiberoptic intubation is associated with a high success rate when performed by appropriately trained individuals. Training and practice are required to develop and master the necessary skills.[33] Appropriate patient selection, preparation, and physician patience are essential for a safe and successful fiberoptic intubation.

The benefits of performing regional anesthesia of the oropharynx, larynx, and trachea prior to fiberoptic intubation are a quiet visual field and improved patient acceptance. Oral fiberoptic intubation may be performed in conjunction with an LMA. It should be emphasized that while in most instances fiberoptic intubation is an extremely safe and effective means of securing the airway, one must be prepared to implement an alternate plan for securing the airway and for providing oxygen to the lungs in the case of failure or sudden deterioration of the patient's condition.

22 Nasotracheal Intubation

Ned F. Nasr, Raed Rahman, and Isam F. Nasr

INTRODUCTION

Nasotracheal intubation is a relatively simple procedure that is performed rapidly without the aid or risks of neuromuscular blockade.[1] This method of intubation is sometimes favored in difficult airway cases, especially when oral access is limited or impossible. Such conditions include trismus, oral injuries, and obstructive oral processes such as angioedema. Nasotracheal intubation is also the method of intubation preferred by some authors for acute epiglottitis.[2]

Nasotracheal intubation is well tolerated by most patients and produces less reflex salivation than orotracheal intubation, thus leading to fewer attempts at self-extubation. The nasotracheal tube is more easily stabilized and is generally easier to care for than an orotracheal tube. This method prevents biting of the tube by the patient and manipulation by the patient's tongue.[2,3]

INDICATIONS

Nasotracheal intubation is indicated in any patient with spontaneous respirations, especially those whose period of intubation is anticipated to be brief.[1–3] It is indicated in patients who are unable to lie supine due to respiratory distress from severe asthma, chronic obstructive pulmonary disease (COPD), or congestive heart failure. It is also indicated in patients who are unable to open their mouths due to facial trauma, mandibular trauma, or trismus. Nasotracheal intubation can be performed in patients with limited airway patency due to obstruction from neoplasm or tongue swelling. Nasotracheal intubation is an appropriate method of intubation in patients who require neck immobilization for suspected cervical spine injuries as well as patients who are unable to move their necks due to cervical kyphosis, severe arthritis, or postradiation fibrosis. Because they are often intubated for a short time, patients with severe alcohol intoxication or drug overdose whose level of consciousness is decreased are good candidates for nasotracheal intubation.[1–3] Nasotracheal intubation may be performed in patients who have contraindications to the use of succinylcholine (**Table 11-2**).

CONTRAINDICATIONS

Nasotracheal intubation is contraindicated in patients with apnea, severe facial or maxillofacial fractures, basilar skull fractures, head injury with an elevated intracranial pressure, recent nasal surgery, nasal or nasopharyngeal obstruction (nasal polyps), patients receiving thrombolytics or parenteral anticoagulants, and in the presence of a coagulopathy.[1–3]

Nasotracheal intubation should not be performed in neonates, infants, or very young children. The more anterior and cephalic position of the airway in these age groups makes blind passage of an endotracheal (ET) tube almost impossible. A patient must provide a degree of cooperation during the procedure. A crying, kicking, and struggling child who must be restrained is not a candidate for nasotracheal intubation.

EQUIPMENT

- Nasal mucosa vasoconstrictor (4% cocaine, 0.05% oxymetazoline, or 0.25% phenylephrine)
- Nasal mucosa anesthetic (viscous lidocaine, cocaine, benzocaine spray, or xylocaine spray)
- Nasopharyngeal airways, multiple sizes

- Laryngoscope handle
- Laryngoscope blades, various sizes and types
- ET tubes, various sizes (avg female 7.0–7.5 and avg male 7.5–8.0)
- Endotrol tubes, various sizes (Mallinckrodt Medical, St. Louis, MO)
- Magill forceps
- Suction apparatus
- Topical anesthetic (4% cocaine or 2% lidocaine with epinephrine)
- Gauze strips
- Water-soluble lubricant or anesthetic jelly
- Bag-valve device
- Face mask
- Oxygen source and tubing

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative if time permits. All procedural steps should be clearly outlined, with the understanding that an orotracheal intubation may be necessary should the Emergency Physician fail to secure the airway nasotracheally. Since this is a lifesaving procedure, a signed consent may not be necessary, but a procedure note should be included in the medical record.

Prepare the patient with preoxygenation, hemodynamic monitoring, pulse oximetry, and intravenous access. Place the patient supine and in the "sniffing" position if there is no suspicion of a cervical spine injury. If the patient needs to remain sitting due to respiratory distress, also place them in the sniffing position.

Examine the patient's nostrils. Choose the larger and more patent nostril for the intubation. The choice of the nostril to use is not an exact science.[11] Look into each nostril and determine which one is more patent. Estimate the airflow through each nostril. Occlude one nostril and instruct the patient to exhale with their mouth closed. Repeat the process with the other nostril. Ask the patient which nostril they feel is more patent. This test can be repeated after the application of a vasoconstrictor agent. There is no evidence suggesting one nostril is better than the other (i.e., left vs. right) for intubation in a patient with normal anatomy.

Prepare the mucous membranes. Apply a topical vasoconstrictor to shrink the nasal mucosa followed by a topical anesthetic to the nasal mucosa. Cocaine is preferred if not contraindicated, because it is a single agent that acts as both a vasoconstrictor and an anesthetic. Dilate the nasal passage by serial dilation. Liberally lubricate a series of increasingly larger-size nasopharyngeal airways. Insert and then remove the smallest nasopharyngeal airway. Continue to insert and remove each successively larger nasopharyngeal airway until the nasal passage is dilated. This procedure can take 2 to 3 minutes. If time is an issue, insert a gloved and lubricated pinky finger into the nostril to dilate it. For routine nasotracheal intubations of healthy adults, serial dilation of the nasal passages can be bypassed in patients with large nostrils.[6] Next, apply a topical anesthetic spray to the palate and oropharynx.

Choose an ET tube. The proper size tube should be at least 0.5 to 1.0 mm smaller than the size chosen for orotracheal intubation of the same patient. If possible, soften the ET tube by placing it in warm saline or warm water before use to reduce epistaxis and nasal damage.[7] Apply a 10 mL syringe to the inflation port and inflate the cuff. Check the integrity of the cuff. Deflate the cuff and leave the syringe attached. Lubricate the ET tube.

TECHNIQUES

BLIND PLACEMENT OF AN ET TUBE

The technique of blind nasotracheal intubation was first described by Magill in 1930. The technique essentially remains the same with some modifications to increase the success rate and limit complications. This technique is technically more difficult than the placement under direct vision described below. **Its major advantages are that the patient's mouth does not have to be opened and minimal to no cervical spine movement is required.** This procedure may be performed while the patient is sitting or supine. Prepare the patient as mentioned previously.

Stand to the right side of the patient's bed and facing them. Insert the ET tube into the nostril with the bevel facing the septum (**Figures 22-1 and 22-2A**). If the patient's right nostril is being used, insert the ET tube concave side down (**Figure 22-1A**). If the patient's left nostril is being used, insert the ET tube concave side up

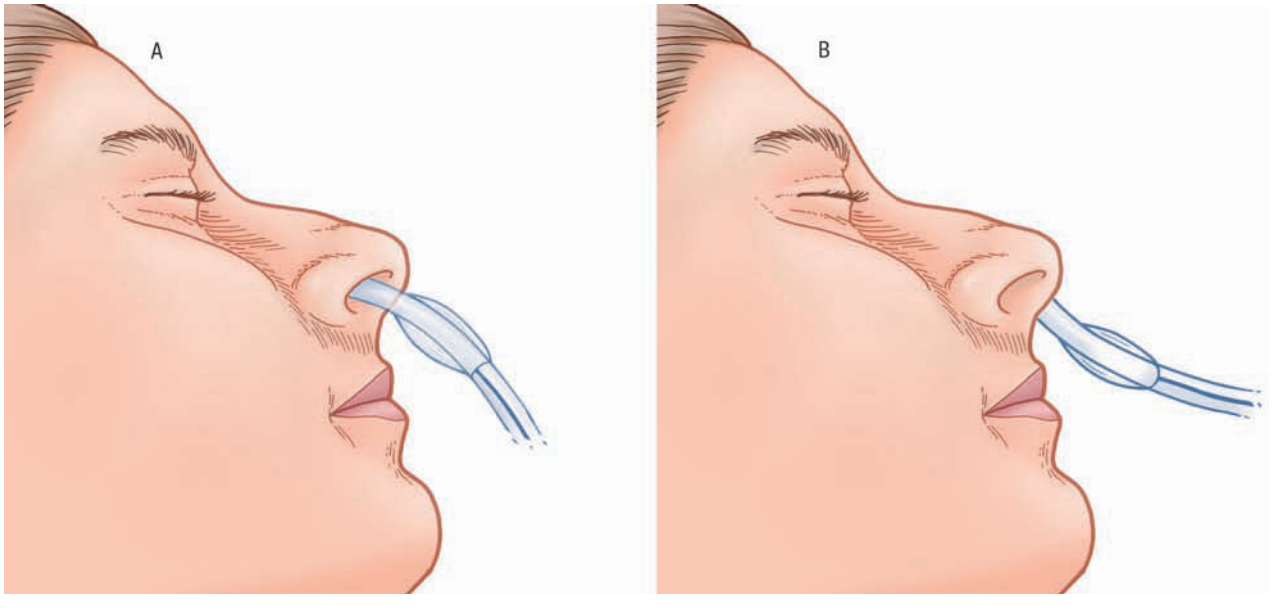


FIGURE 22-1. Insertion of the nasotracheal tube. The bevel of the ET tube should face the septum. **A.** Placement in the right nostril with the concave side of the tube downward. **B.** Placement in the left nostril with the concave side upward. When the tip of the tube enters the nasopharynx, rotate it 180°.

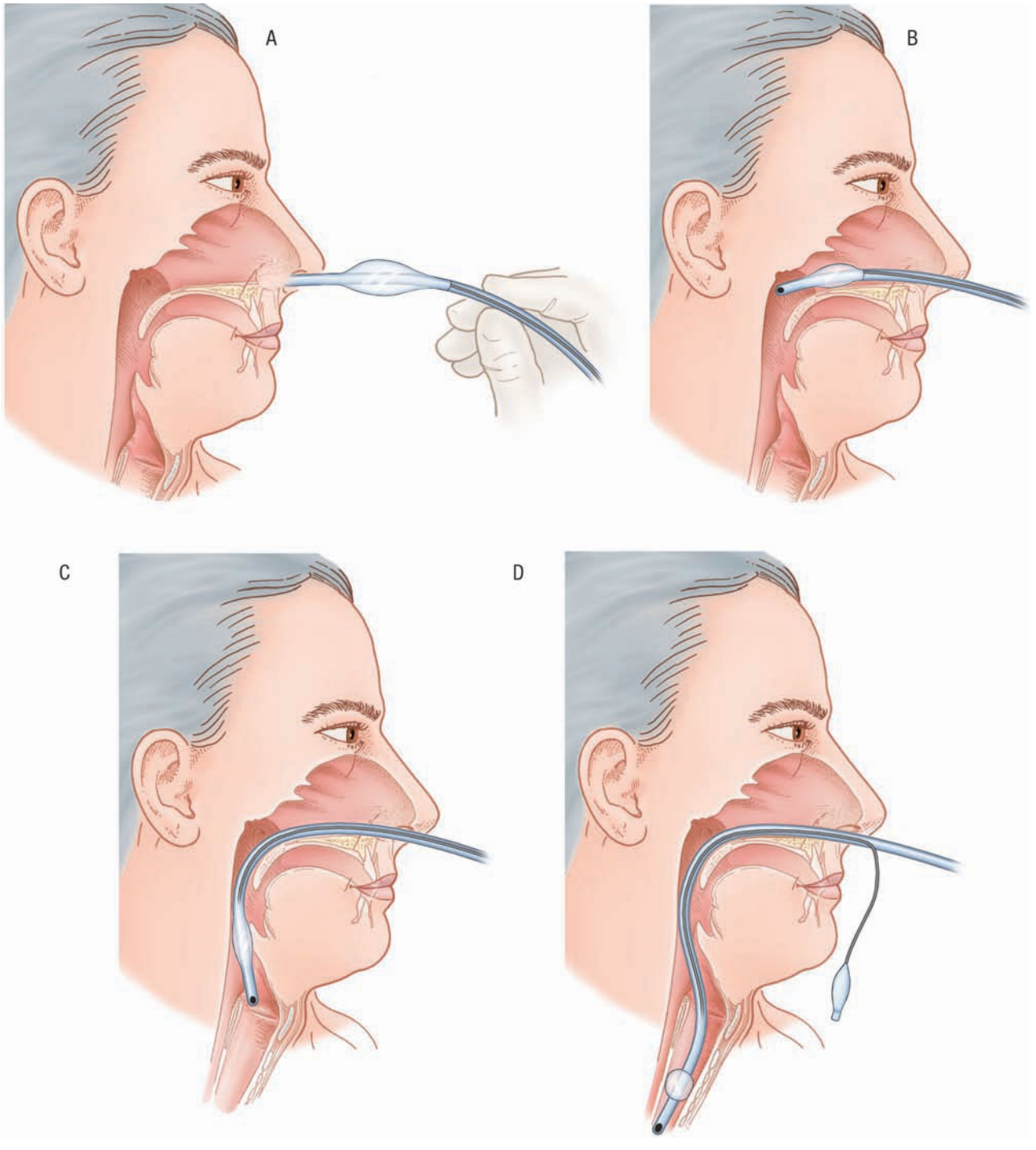


FIGURE 22-2. Blind nasotracheal placement. **A.** The nasotracheal tube is placed within the nasal cavity. **B.** The tube is advanced along the floor of the nasal cavity and into the nasopharynx. **C.** The tube is advanced into the laryngopharynx. **D.** At the start of inspiration, the tube is advanced through the vocal cords and into the trachea.

(**Figure 22-1B**). Advance the ET tube with gentle pressure along the nasal floor to pass it through the nasal cavity (**Figure 22-2B**). If any resistance is felt, slightly withdraw the ET tube. Readvance the tube with a slight twisting motion to bypass the obstruction. If resistance is still met, withdraw the ET tube, prepare the other nostril, and insert the tube into the other nostril.

When the ET tube is inserted approximately 5 to 7 cm, the tip will be past the choana and in the nasopharynx (**Figure 22-2B**). Continue advancing the ET tube as resistance is met while the tube makes a 90° change of direction into the oropharynx. A slight twisting motion may be required to advance the ET tube. A loss of resistance signifies that the ET tube has made the curve. Stop advancing the ET tube and rotate it so that the tube's natural curve is concave upward and in the same curvature of the airway. If the ET tube will not curve from the nasopharynx into the oropharynx, several options are available. These include trying the other nostril, using an ET tube 0.5 mm smaller and reattempting intubation through the original nostril, or using an Endotrol tube (described in the next section).

Advance the ET tube through the oropharynx and into the laryngopharynx (**Figure 22-2C**). Listen for breath sounds through the proximal end of the ET tube while advancing it. The breath sounds

and air movement will be maximal when the tip of the ET tube is just above the glottis. As soon as an exhalation is heard, the patient will take a breath and advance the ET tube. **The vocal cords are opened their widest during inspiration, and this will facilitate passage of the ET tube.**

The patient will often cough or gag as the ET tube traverses the vocal cords. At this point, breath sounds should be audible from the proximal end of the ET tube and it should fog with each breath. If the patient is able to groan or speak, the esophagus has been intubated. Withdraw the ET tube and reinsert it during inspiration. The application of posteriorly applied pressure on the trachea (Sellick's maneuver) will occlude the esophagus and may allow easier ET intubation.

If resistance to the advancement of the ET tube is felt, it may be caught in the hypopharynx. Common sites for the tip of the ET tube to get caught are the arytenoid cartilage, piriform sinus, vallecula, and the vocal cords. Withdraw the ET tube 3 to 4 cm, slightly rotate the ET tube, and readvance it.

Inflate the ET tube cuff. Confirmation of ET tube placement should be assessed by auscultating both lungs while ventilating the patient with a bag-valve device through the nasotracheal tube. Adjust the position of the tube until both lungs are being ventilated equally and secure the tube (**Figure 22-2D**). Continue to ventilate the patient.

BLIND PLACEMENT OF THE ENDOTROL TUBE

The indications, contraindications, and patient preparation are the same as described above. The Endotrol tube is an ET tube whose tip can be controlled. It looks like a cuffed ET tube but has a plastic ligature along the inner side that is connected to a ring on the proximal end of the ET tube (**Figure 22-3**). Pulling of the ring exerts tension on the plastic ligature, leading to an increase in the curvature of the tip of the ET tube. This will project the tip anteriorly and inferiorly (**Figure 22-4**). The procedure for inserting the Endotrol tube is the same as that for inserting an ET tube. Changing the curvature of the tip will aid in passage of the tube from the nasopharynx to the oropharynx and from the hypopharynx into the trachea. If the ring is sitting firmly against the nares after intubation, the tip of the tube may be exerting continuous pressure on the anterior tracheal mucosa. Cut the ligature and remove the ring.

PLACEMENT UNDER DIRECT VISION

The technique begins with nasotracheal intubation, followed by direct laryngoscopy. The placement of a nasotracheal tube using direct visualization must be performed with the patient supine. The indications and precautions are similar to those for orotracheal intubation (Chapter 11). This method should be considered in the event of an oral injury that renders an orotracheal tube a nuisance or if blind nasal intubation is unsuccessful.



FIGURE 22-3. The Endotrol endotracheal tube. The curvature can be changed by pulling on the ring to facilitate intubation.

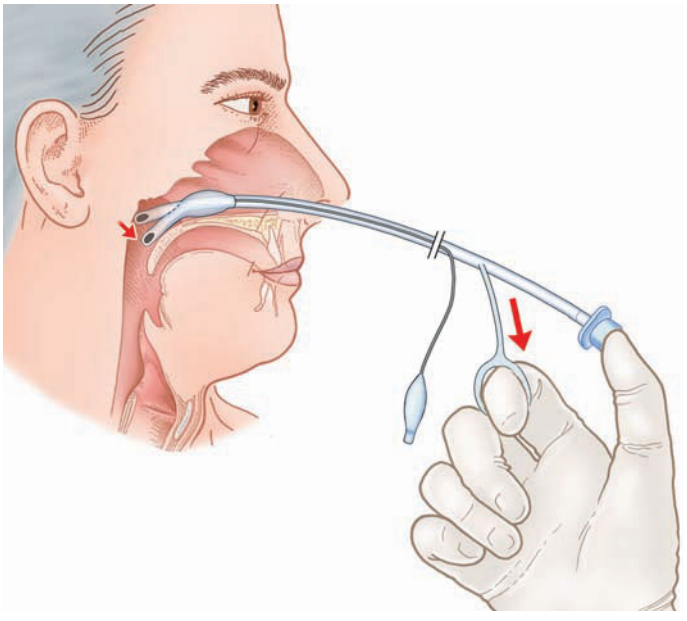


FIGURE 22-4. Blind nasotracheal placement of an Endotrol tube. Tension exerted on the ring of the tube causes the curvature of the tube to increase (*arrow*).

This procedure is initially performed as previously described. Once the tube is inserted into the hypopharynx, direct laryngoscopy is performed. Using the left hand, grasp the laryngoscope and insert the blade. Visualize the patient's epiglottis and vocal cords as well as the ET tube. Using a Magill forceps with the right hand, grasp the ET tube just above the cuff (**Figure 22-5**). **Never grasp the cuff, as it is delicate and can easily be damaged by the Magill forceps.** Have an assistant grasp the proximal end of the ET tube and gently advance it while the physician simultaneously guides the tip through the vocal cords (**Figure 22-5**). Remove the Magill forceps and the laryngoscope. Inflate the cuff, secure the tube, and ventilate the patient.

BLIND DIGITAL NASOTRACHEAL INTUBATION

A technique was developed that combines blind nasotracheal intubation and digital orotracheal intubation.[12] This technique starts with the procedure of blind nasotracheal intubation. If not successful, insert the index and middle fingers of the nondominant hand into the patient's mouth. Slide these fingers posteriorly over the tongue to palpate the epiglottis. Grasp the tip of the ET tube between the two fingers (**Figure 22-6A**). Pull the ET tube anteriorly and behind the epiglottis (**Figure 22-6A**). Use the nondominant hand to advance the ET tube further into the patient's nose, thus advancing the tip into the trachea (**Figure 22-6B**).

ASSESSMENT

The position of the ET tube should be confirmed by end-tidal CO_2 monitoring, fogging in the ET tube for at least six ventilations, loss of voice, auscultation over the chest and the epigastrium, and a chest X-ray. Please refer to Chapter 12 for a more detailed discussion regarding confirmation of endotracheal intubation.

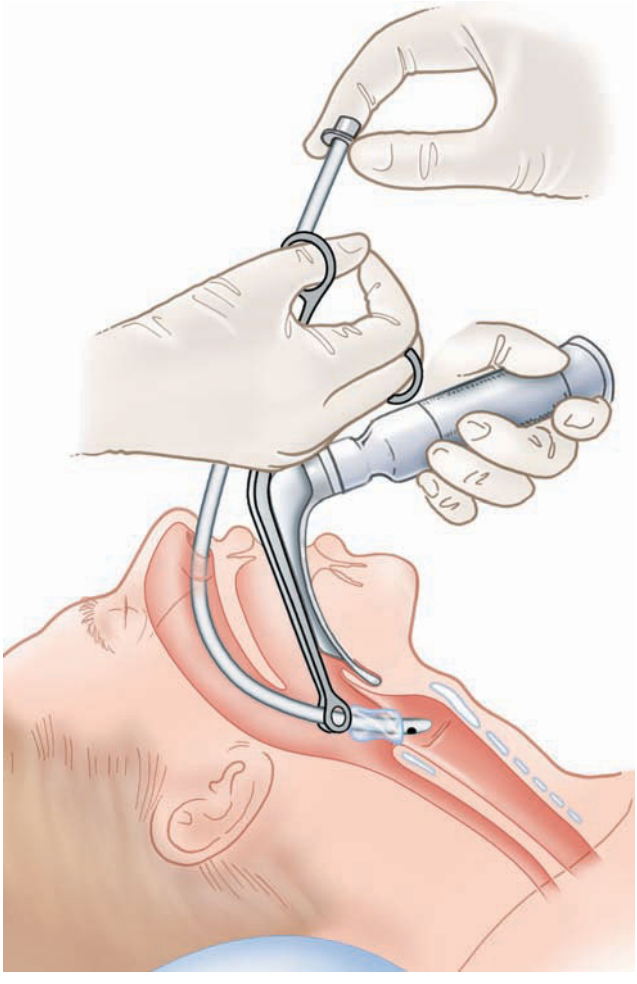


FIGURE 22-5. Nasotracheal intubation under direct visualization.

AFTERCARE

The ongoing care of the patient should proceed as with any other intubation technique.

COMPLICATIONS

The immediate complications of nasotracheal intubation include epistaxis, laryngeal and tracheal trauma, mucosal avulsion, retropharyngeal laceration, turbinate avulsion, intracranial placement, bacteremia, esophageal intubation, and prolonged attempts to place the tube.[4,5] Many of these can be prevented by choosing the appropriate size ET tube, ensuring adequate nasal mucosal vasoconstriction, and applying a liberal amount of lubricant to the ET tube. Risk factors for epistaxis should be assessed on every patient prior to nasotracheal intubation.[8] Long-term complications include maxillary sinusitis, retropharyngeal abscess, mediastinitis, nasal mucosal necrosis, and cellulitis.[4,5]

PEDIATRIC CONSIDERATIONS

Very little literature is available regarding nasotracheal intubation on children. In the past, this approach was an option for patients with epiglottitis and acute laryngotracheobronchitis.[9] The most recent data reserve nasotracheal intubation for children with congenital facial anomalies.[10] This technique cannot be recommended for children in the Emergency Department. Their small nostrils limit ET tube size. Large adenoids may make passage of the ET tube difficult and increases the risk of bleeding.

SUMMARY

Nasotracheal intubation is an alternative to orotracheal intubation to secure an airway in the spontaneously breathing patient. It allows awake intubations while the patient maintains protective airway

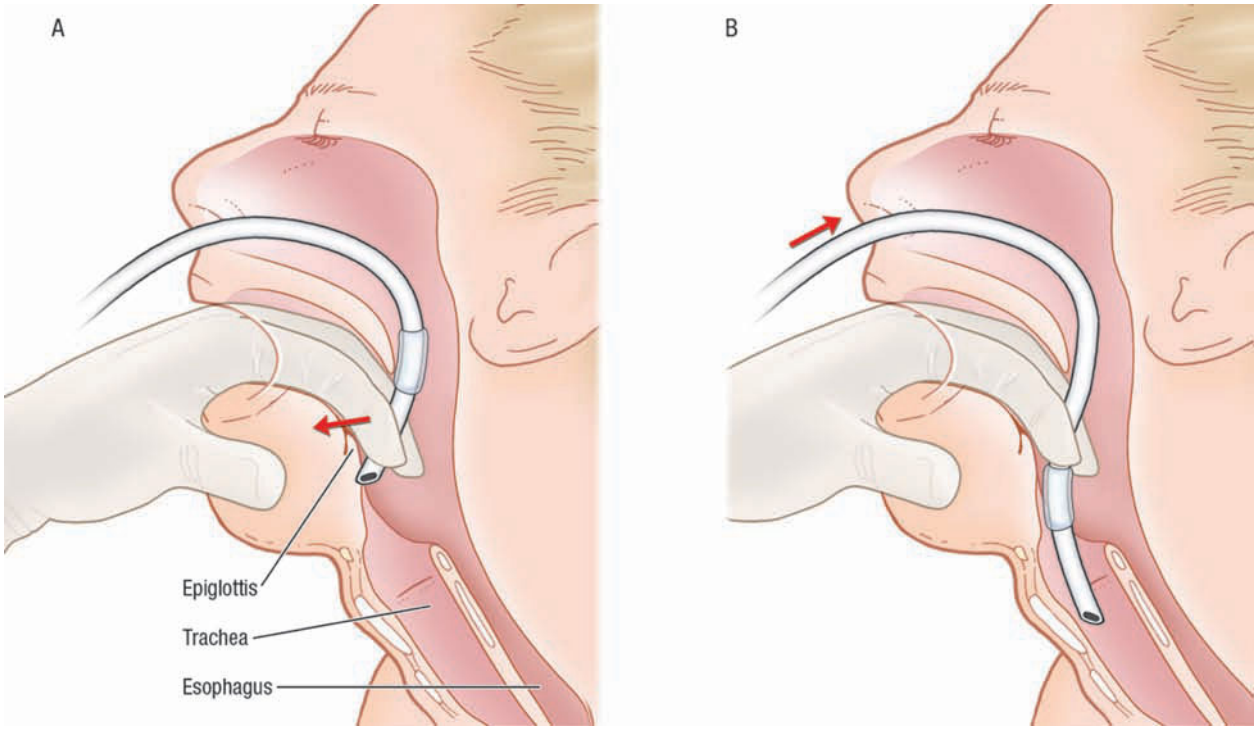


FIGURE 22-6. Blind digital nasotracheal intubation. **A.** The ET tube is grasped with the fingertips and pulled anteriorly (*arrow*) behind the epiglottis. **B.** The ET tube is advanced into the trachea.

reflexes, and it avoids the risks of paralytic agents. It is a fairly simple procedure that should be considered in patients in whom an oral airway is considered difficult and in those with an anticipated short intubation period.

23 Retrograde Guidewire Intubation

Roland Petri

INTRODUCTION

Failure to establish a definitive airway is a significant cause of death and disability among emergency patients. Oral endotracheal intubation via direct laryngoscopy, increasingly often video-assisted, remains the "gold standard" of airway management. Difficult situations arise in which oral endotracheal intubation is impossible, is contraindicated, or fails. Retrograde guidewire intubation is an alternative airway management technique that should be familiar to those involved with emergency airway management.[1]

Retrograde intubation was first described in 1960 by Butler and Cirillo.[2] In 1963, Waters described insertion of an epidural catheter through a cricothyroid puncture as an alternative means of establishing an airway.[3] Powell and Ozdil reported a series of 15 patients in whom retrograde intubation was employed without complications using a plastic catheter rather than an epidural catheter as a guide into the trachea.[4] The current technique of retrograde intubation varies little from these original descriptions.

Retrograde intubation represents one of several alternative maneuvers for securing the difficult airway. While mouth tumors, cervical arthritis, and jaw ankylosis represent rare cases of difficult-to-control airways, maxillofacial trauma continues to represent the most common indication for alternative airway management. Retrograde intubation has proven to be an effective method used by Emergency Physicians and prehospital personnel to establish an airway.

Completion times for retrograde intubation vary based on physician experience. Among healthcare professionals who had no prior experience with the technique but who had just completed a mannequin-aided training course, the mean length of time to intubation was 71 ± 4 seconds.[1] In a second study involving resident physicians after a brief instruction course, 36 of 40 residents (90%) completed retrograde intubation within 150 seconds, with a mean intubation time of 56 ± 6 seconds.[10]

INDICATIONS

The American Society of Anesthesiologists defines a difficult airway as the clinical situation in which a conventionally trained Anesthesiologist experiences difficulty with mask ventilation, difficulty with tracheal intubation, or both.[5] **Retrograde intubation, among other invasive back-up techniques such as cricothyroidotomy, should be considered in any patient in whom endotracheal intubation may be difficult, is contraindicated, or has failed.** It is potentially indicated when airway control is required and less invasive methods have failed. Maxillofacial trauma and cervical spine fractures represent the most common etiologies of a difficult airway.[6] In one report of 19 patients with either maxillofacial trauma or fractures of the cervical spine, six had prior, failed orotracheal intubation attempts. In all of these patients, retrograde intubation was successful on the first attempt.[6] Jaw ankylosis, cervical arthritis, mouth tumors, and muscular dystrophy represent less common but equally challenging airway situations.[4,7]

Another clinically important situation arises when a patient presents with impending ventilatory failure. While retrograde intubation is generally a longer procedure than orotracheal intubation, oxygenation and ventilation can be maintained with a bag-valve-mask device during the procedure. It is useful when bleeding obstructs visualization of the glottis.

A less common indication includes retrograde intubation of a difficult airway in a patient being ventilated with a laryngeal mask airway. This indication exists because withdrawal of the laryngeal mask airway over a blindly placed catheter can result in dislodgement of the catheter, necessitating replacement of the laryngeal mask airway.[8]

CONTRAINDICATIONS

The major contraindication to retrograde intubation is the ability to control the airway with less invasive techniques. Other contraindications include an anterior neck mass, infections, or cancerous process overlying the cricothyroid membrane. Trismus, or the inability to open the mouth, is a contraindication to this technique. Apneic patients who cannot be ventilated with a bag-valve-mask device should receive a cricothyroidotomy and not a retrograde guidewire intubation. Those unfamiliar with the equipment and/or technique should not attempt this procedure. While one case report presents the successful use of a mannequin to teach retrograde intubation to emergency caregivers, familiarity with the procedure is required for optimum patient management.[1]

EQUIPMENT

- 68 to 80 cm spring guidewire with a J tip
- 16 to 18 gauge catheter-over-the-needle (angiocatheter)
- Endotracheal tubes, various sizes
- Sterile saline
- 10 mL syringes
- 18 gauge needles
- Hemostats, 2
- Magill forceps
- Sterile drape
- 20 mL syringe
- Povidone iodine or chlorhexidine solution
- Face mask
- Bag-valve device
- Oxygen source and tubing
- Suction source and tubing
- Yankauer suction catheter
- 1% lidocaine
- 4% viscous lidocaine (optional)
- Spray anesthetic (lidocaine or benzocaine)
- Tape (or a commercially available endotracheal tube holder)

Retrograde guidewire intubation can be performed using a standard commercial retrograde intubation kit (Cook Retrograde Intubation Set, Cook Incorporated, Bloomington, IN). It consists of an 18 gauge needle set, 68 to 80 cm spring guidewire, and an 11 French introducer catheter (**Figure 23-1**). The remainder of the material must be supplied as listed above.

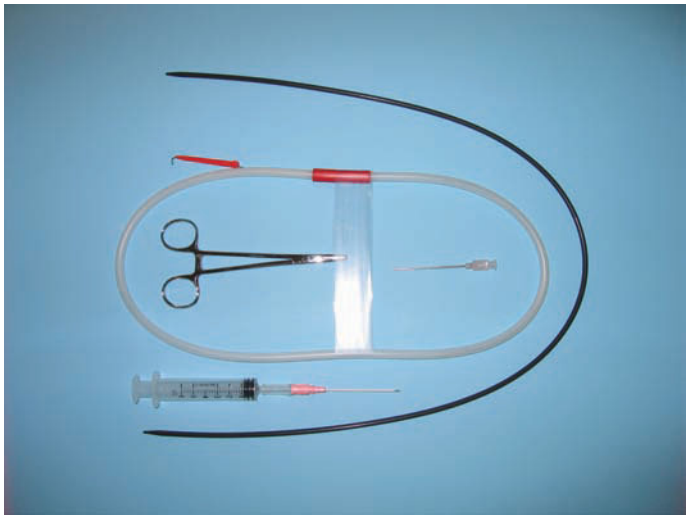


FIGURE 23-1. The retrograde guidewire intubation kit.

PATIENT PREPARATION

If time permits, and the patient is aware of pain, anesthetize the airway. Nebulized viscous lidocaine will anesthetize the airway in 15 to 20 minutes. Alternatively, inject 2 mL of 1% lidocaine percutaneously through the cricothyroid membrane and into the trachea.[6] This may cause the patient to cough and gag, with the subsequent possibility of aspiration. Lidocaine or benzocaine may be sprayed into the pharynx. An alternative anesthetic method includes a superior laryngeal nerve block.[9] Refer to Chapter 21 for details regarding this nerve block.

Clean the patient's neck of any dirt and debris. Identify, by palpation, the hyoid bone, thyroid cartilage, cricoid cartilage, and cricothyroid membrane. Apply povidone iodine to the patient's neck, followed by sterile drapes.

TECHNIQUE

The procedure is relatively simple in theory but difficult to perform "in the heat of battle."[1,10–13] Prepare the equipment. Place the 16 to 18 gauge catheter-over-the-needle onto a 10 mL syringe containing 3 to 5 mL of sterile saline. Select an appropriate size endotracheal tube for the patient. Check the integrity of the cuff. Lubricate the inside and outside of the distal tip of the endotracheal tube liberally. Open the retrograde guidewire kit and/or assemble all equipment. The equipment should be preassembled, prepackaged, sterilized, and stored in an easily accessible site.

Stabilize the patient's larynx with the thumb and middle finger of the nondominant hand (**Figure 25-2**). Identify the cricothyroid membrane with the index finger of the nondominant hand. Leave the index finger on the cricothyroid membrane. Infiltrate lidocaine subcutaneously over the cricothyroid membrane if the patient is awake to minimize discomfort from the percutaneous catheter insertion. Insert the 16 to 18 gauge catheter-over-the-needle guided along the index finger, at a 20° to 30° angle upward and through the cricothyroid membrane (**Figure 23-2A**). Although not recommended, some physicians prefer to use the needle without the catheter. The sharp needle within the trachea can cause significant injury when compared to the soft catheter. **Care should be taken to puncture the cricothyroid membrane just above the cricoid cartilage to avoid injury to the cricothyroid arteries.** The loss of resistance signifies that the needle is in the larynx. **Aspirate air through the saline-filled syringe to confirm correct needle placement** (**Figure 23-2A**). Advance the catheter until the hub is against the skin. Remove the needle and syringe, leaving the catheter pointed upward and through the cricothyroid membrane. If this has not already been done and the patient is awake, inject 2 mL of 1% lidocaine through the catheter to anesthetize the airway.

Advance the guidewire through the catheter and into the oropharynx (**Figures 23-2B & 23-3**). The guidewire may exit the mouth or nose. The preferred site of exit is the mouth, but the nose is acceptable. If it is not visualized, insert a laryngoscope and look for the guidewire. It is often in the oropharynx or hypopharynx. Retrieve it with a Magill forceps. Continue to advance the guidewire through the mouth (or nose) until only 4 to 5 cm of the wire is protruding from the patient's neck. **Carefully remove the catheter while firmly holding the guidewire in place.** Place a hemostat on the guidewire where it enters the skin of the neck (**Figure 23-2C**). This will ensure that the tip does not pull through the skin and into the trachea.

If the kit is being used, select the introducer catheter contained in it. Pass the introducer catheter over the guidewire that is exiting the mouth (or nose). Advance the catheter until resistance is met. This signifies that the tip of the introducer catheter is at the inside of the cricothyroid membrane (**Figure 23-2C**). Advance the well-lubricated endotracheal tube over the introducer and guidewire (**Figure 23-2D**). Continue to advance the endotracheal tube until resistance is met. The tip of the endotracheal tube should be at the inside of the cricothyroid membrane (**Figure 23-2D**). While securely holding the endotracheal tube at the patient's mouth, remove the hemostat from the guidewire. Pull on the proximal end of the guidewire until the distal tip is through the skin and just into the endotracheal tube. **Simultaneously withdraw the guidewire and introducer catheter while advancing the endotracheal tube into the trachea** (**Figure 23-2E**). Inflate the endotracheal tube cuff and confirm proper placement (i.e., auscultation, detection of end-tidal CO_2, fogging in the endotracheal tube, etc.).

A second method can also be used to insert the endotracheal tube. This follows the same technique described above to the point of the guidewire exiting the mouth (or nose), being secured with a hemostat at the neck, and passing the introducer catheter over the guidewire. Remove the hemostat from the guidewire. **While securely holding the introducer catheter at the patient's mouth (or nose), remove the guidewire through the mouth (or nose).** Advance the introducer catheter an additional 2 to 3 cm into the trachea. Lubricate the endotracheal tube liberally. Place the endotracheal tube over the introducer catheter. While holding the introducer catheter securely, advance the endotracheal tube into the patient's trachea. Remove the introducer catheter. Inflate the endotracheal tube cuff and confirm proper placement (i.e., auscultation, detection of end-tidal CO_2, fogging in the endotracheal tube, etc.).

ALTERNATIVE TECHNIQUES

This technique may be performed without a formal retrograde intubation kit as the introducer catheter is not required.[7,12,13] This follows the same technique described above to the point of the guidewire exiting the mouth (or nose) and being secured with a hemostat at the neck (**Figure 23-2C**). Lubricate the endotracheal tube liberally. Insert the guidewire through the Murphy eye and into the endotracheal tube. This allows the distal tip of the endotracheal tube to project approximately 1 cm distal to the site at which the guidewire enters the larynx. As an alternative, some physicians prefer to load the guidewire through the tip of the endotracheal tube (**Figure 23-4**). **Always hold the proximal end of the guidewire to maintain control during the procedure.** Advance the endotracheal

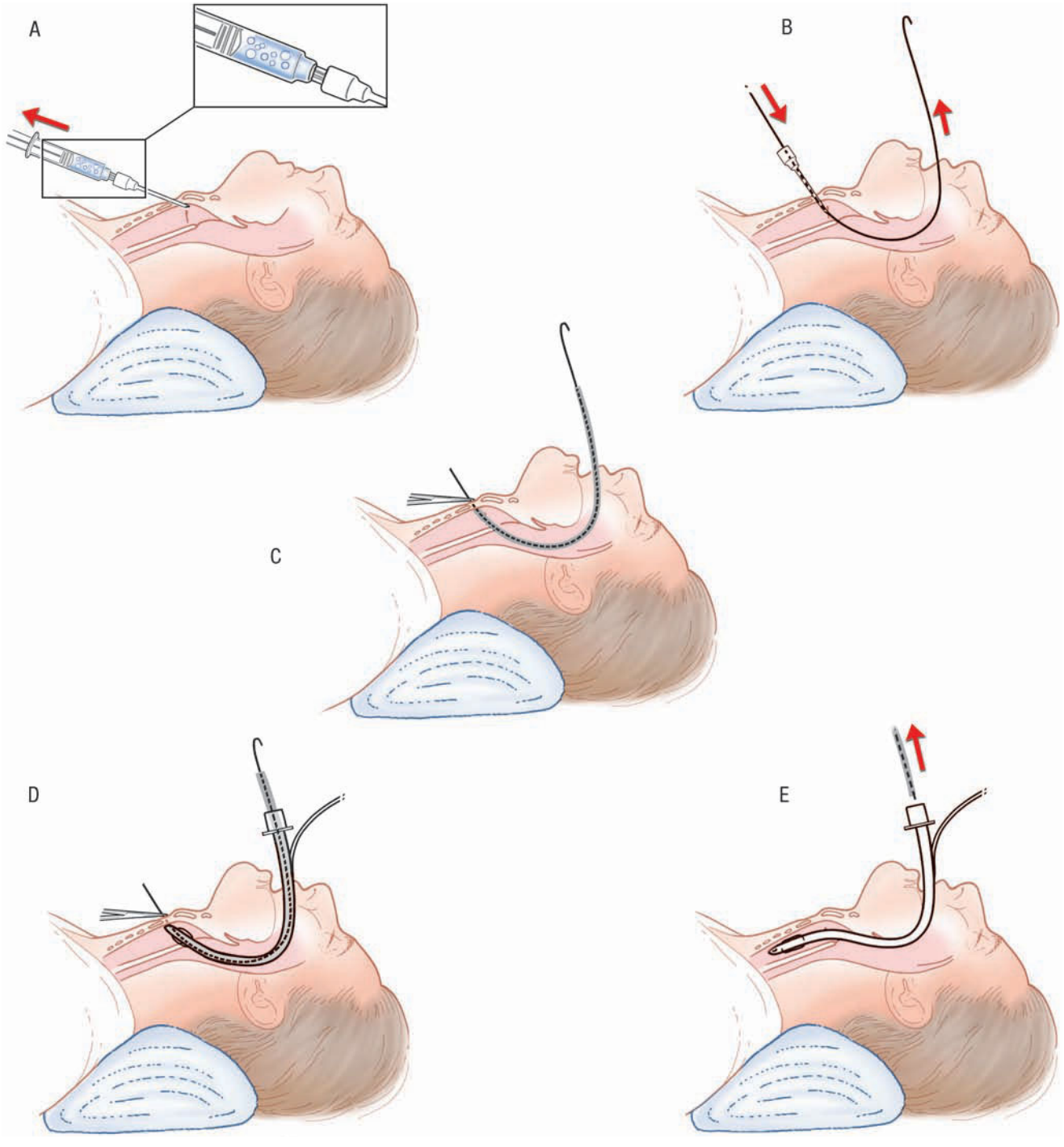


FIGURE 23-2. Retrograde guidewire intubation. **A.** A syringe containing saline is attached to the catheter-over-the-needle. The catheter-over-the-needle is inserted through the cricothyroid membrane. The air bubbles in the syringe indicate air aspirated from the trachea. For clarity, the physician's hand and fingers stabilizing the airway and identifying the cricothyroid membrane are not seen in this illustration. **B.** The needle and syringe have been removed and the catheter remains. The guidewire is fed through the catheter and out the patient's mouth. **C.** The distal guidewire is clamped with a hemostat as it exits the skin of the neck. The introducer catheter is fed over the guidewire and advanced to the cricothyroid membrane. **D.** An endotracheal tube is advanced over the guidewire and introducer catheter until its tip is at the cricothyroid membrane. **E.** The hemostat has been removed. The endotracheal tube is advanced as the guidewire and introducer catheter is removed.

tube over the guidewire until resistance is felt. The tip of the endotracheal tube should be at the inside of the cricothyroid membrane. **Hold the proximal end of the guidewire firmly.** Release the hemostat over the neck. Pull the guidewire through the skin and just into the endotracheal tube. Advance the endotracheal tube until it is at 20 to 21 cm at the teeth for an adult female or 22 to 23 cm at the teeth for an adult male. Hold the endotracheal tube securely at the patient's lips. Withdraw the guidewire through the patient's mouth. Inflate the endotracheal tube cuff and confirm proper placement (i.e., auscultation, detection of end-tidal CO_2, fogging in the endotracheal tube, etc.).

When the endotracheal tube is advanced over the guidewire until resistance is met, the tip should be situated against the inside of the cricothyroid membrane. It is imperative to determine if the tip of

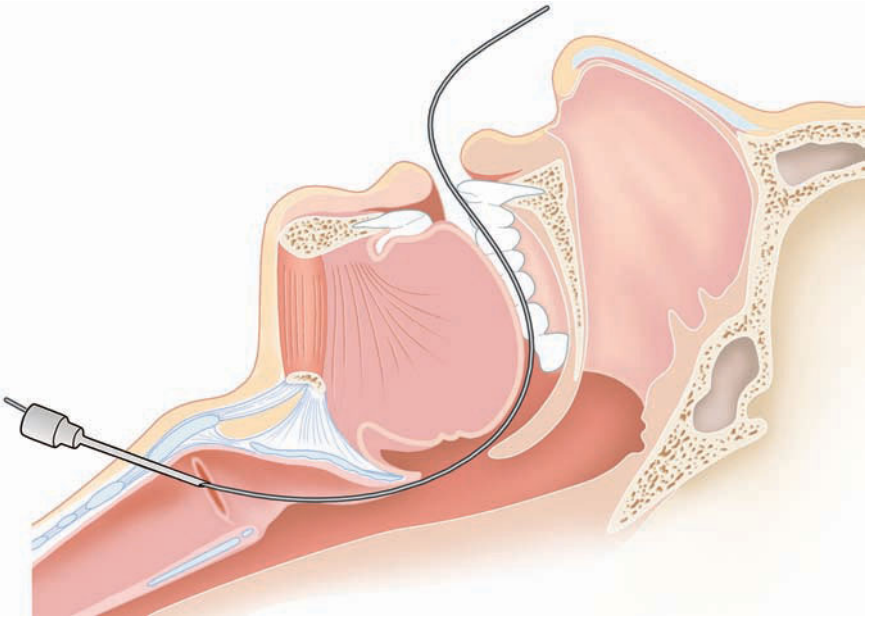


FIGURE 23-3. The guidewire is inserted through the needle (or catheter depending on physician preference) until it exits the mouth.

the tube is in the trachea or caught on the epiglottis, arytenoid cartilage, pyriform recess, vallecula, or vocal cords. If concern exists as to the position of the tip, withdraw the endotracheal tube 2 cm, rotate it 90°, and readvance it into the trachea. As an alternative, a laryngoscope or fiberoptic broncho/nasopharyngoscope can be inserted to help visualize the placement of the endotracheal tube.

Another variation involves the use of the guidewire sheath as an introducer catheter.[12,13] Shorten the sheath by 3 to 5 cm using sterile scissors. The remainder of the technique is the same as described above. The only drawback to this technique is that the curvature of the sheath must be straightened before use to allow easy threading over the guidewire.

In another description, a central venous catheter is used rather than a guidewire.[6] It allows the physician to inject air through the catheter in retrograde fashion to help locate the catheter in the mouth of the severely injured patient with significant intraoral blood or secretions. This technique requires a relatively long central venous catheter. It does allow retrograde intubation without the use of a formal retrograde intubation kit.

Finally, another version uses a lighted stylet attached to the endotracheal tube.[14] The lighted stylet acts as a guide to indicate the tube's location. When the tip of the endotracheal tube enters the glottic opening, a bright, circumscribed glow is readily seen in the anterior neck, below the thyroid prominence. This glow acts as an indicator of correct endotracheal tube placement.

When continuous oxygenation is required throughout the procedure, two possibilities exist.[12] A T-adapter (1260, Deseret, Sandy, UT) can be connected to the needle hub with its side arm for oxygen insufflation. Alternatively, a swivel adapter with a fiberoptic bronchoscopic cap (1/25/09, Portex, Wilmington, MA) can be

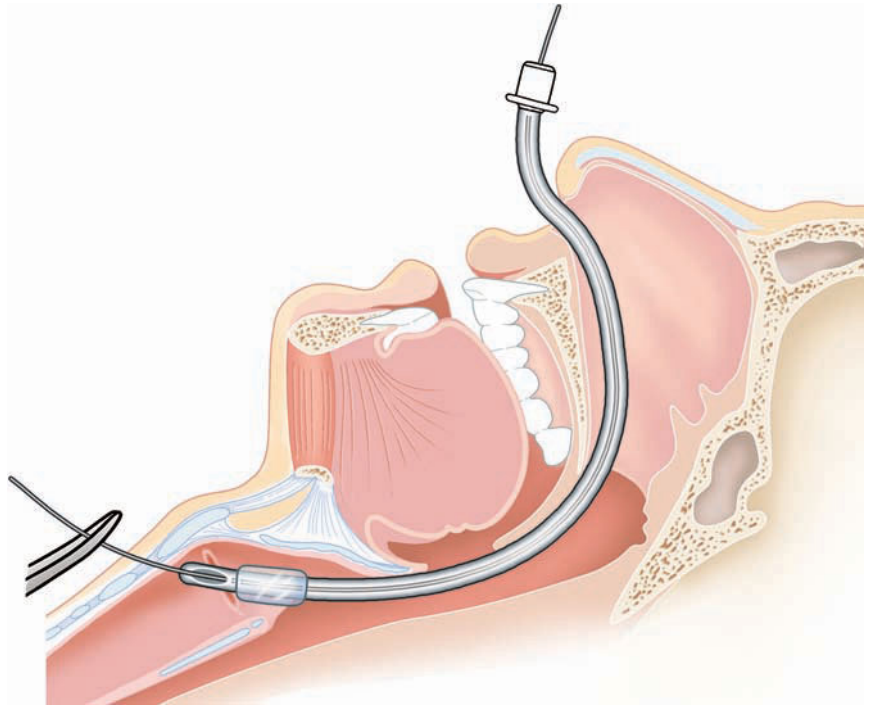


FIGURE 23-4. The endotracheal tube is advanced over the guidewire until the tip is against the cricothyroid membrane.

interposed between the endotracheal tube and the bag-valve-mask device or anesthesia breathing circuit.

ASSESSMENT

Auscultation of both lungs will confirm proper placement of the endotracheal tube and minimize the risk of intubation into the right mainstem bronchus. End-tidal CO_2 has also become part of the postintubation routine. After the procedure is completed, a chest radiograph will confirm the placement of the endotracheal tube tip in relation to the clavicles and carina. Please refer to Chapter 12 for a more complete discussion of the methods to confirm endotracheal intubation.

AFTERCARE

The patient should receive standard wound care and dressing of the skin at the neck entrance site. Wound checks and infection monitoring should continue as with any other surgical procedure. The risk of skin, tracheal, or pharyngeal infection is minimal if sterile technique was followed. If infection develops, wound evaluation and treatment with appropriate antibiotics is warranted.

COMPLICATIONS

Complications of retrograde guidewire intubation include those of standard endotracheal intubation. Complications can occur when the needle traverses the cricothyroid membrane.[10] Hypoxia due to prolonged intubation time or incorrect endotracheal tube placement remains an important complication. Drug reactions or side effects secondary to administered medications must always be considered.

Retrograde intubation is associated with additional complications due to use of the guidewire. One case report discusses a patient with a history of retrograde intubation for coronary bypass surgery who experienced a foreign-body sensation and bloody sputum 2 years after the procedure.[15] Upon radiographic examination, the patient was found to have a 10 cm segment of guidewire fixed in the soft tissue of the puncture site and extending cephalad 2 cm past the true vocal cords.

In one cadaveric study, numerous complications were noted during 40 cricothyroid punctures. Two punctures (5%) occurred below the cricothyroid membrane. One was between the cricoid cartilage and the first tracheal ring. The other was between the first and second tracheal rings. Four cases (10%) showed minor injuries to the thyroid or cricoid cartilage. Three cases (7.5%) showed injuries to the posterior wall of the larynx, epiglottis, or soft palate. No posterior tracheal perforations were found in this study. The clinical importance of these injuries is unclear given the nature of this postmortem study.

Three technical complications from retrograde guidewire intubation have been identified.[10,12] Difficulties inserting the guidewire can be prevented by first aspirating air into a saline-filled syringe to confirm the proper intratracheal needle tip position. Endotracheal intubation over a flexible guidewire necessitates keeping the guidewire taut to minimize the risk of kinking. Unfortunately, this moves the guidewire anteriorly toward the narrowest portion of the glottis and may prevent passage of the endotracheal tube, as the tip can become caught on the epiglottis or the vocal cords. This problem is obviated by the use of the introducer catheter in the retrograde guidewire intubation kit. It lies in the posterior pharynx and glottis and allows for easier passage of the endotracheal tube into the trachea. The tip of the endotracheal tube may flip out of the larynx when the introducer is being removed, because the distance between the vocal cords and the point where the introducer enters and anchors the larynx averages only 1.0 to 1.3 cm in adults.

While complications may occur in association with retrograde intubation, the rate of complications is relatively low. In one study, 20 resident physicians performed retrograde intubation twice each on 40 cadavers.[10] In two cases (5%), the wire was fed caudad into the trachea due to improper angling of the needle. The remaining intubations were performed without complications.

SUMMARY

Retrograde guidewire intubation requires little operator experience or equipment. Multiple reports suggest that this technique is safe, relatively easy to learn, and routinely successful. All physicians involved in the airway management of critically ill and injured patients should be aware of this technique as a potential method to overcome the challenge of a difficult airway. Within the armamentarium of management techniques for the difficult airway, retrograde guidewire intubation should be given due consideration in any situation in which orotracheal intubation is impossible or contraindicated.

Numerous difficult airway management devices and adjuncts have been invented and marketed. Arguably, the various video-assisted laryngoscopy devices have come to dominate the realm of alternative airway management techniques. The role of retrograde guidewire intubation as a difficult airway management approach has further diminished as a consequence. However, retrograde guidewire intubation remains an easy-to-learn and potentially life-saving tool in the Emergency Physician's growing airway management armamentarium.

24 Percutaneous Transtracheal Jet Ventilation

Eric F. Reichman and Aaron Brown

INTRODUCTION

Percutaneous transtracheal jet ventilation (PTTJV) provides emergency ventilatory support in patients who cannot be adequately ventilated with a bag-valve-mask device (with oral or nasal airways), a laryngeal mask airway (LMA), or endotracheally intubated.[1,2,10] This includes patients with upper airway foreign bodies or neoplasms, maxillofacial trauma, laryngeal edema, or infection.[2,3] It is also used electively with general anesthesia for surgery involving the larynx and subglottic areas.[4] PTTJV involves placement of a percutaneous catheter into the trachea and ventilation via a cyclic delivery of tidal volume to the lungs.[5]

ANATOMY AND PATHOPHYSIOLOGY

Early studies of transtracheal ventilation used transtracheal catheters connected to 4 to 5 L/min of oxygen.[6] Oxygenation with this apparatus was adequate, but patients quickly developed hypercarbia due to lack of ventilation.[5] This "apneic oxygenation" also occurs in ventilation through a catheter attached to a bag-valve device.[7] The low pressure and flow of oxygen generated by the bag-valve device result in increases in $PaCO_2$ of 4 mmHg/min and the rapid development of respiratory acidosis.[1,8] Numerous studies have since demonstrated that intermittent jets of pressurized 100% oxygen at 50 pounds per square inch (psi) allows for both oxygenation and adequate ventilation.[8,9]

The anterior neck provides direct access to the airway via the trachea as it extends from the larynx into the lungs (**Figure 24-1**). At

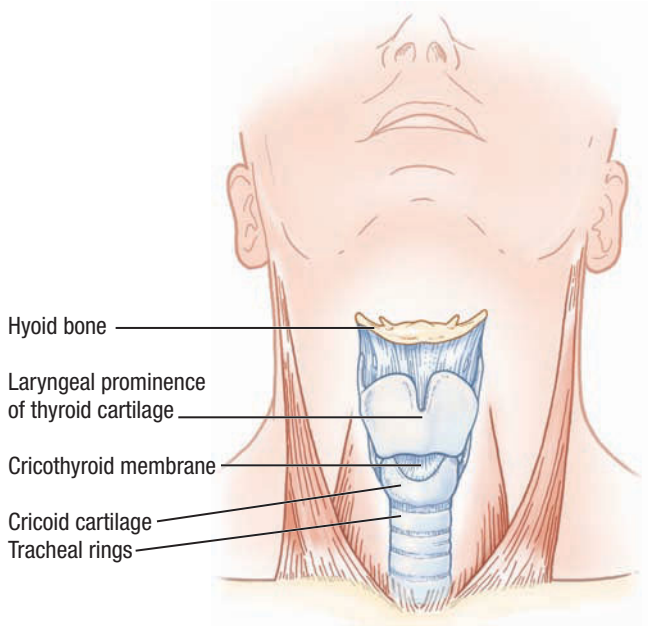


FIGURE 24-1. Airway structures of the neck.

the top of the laryngeal skeleton is the thyroid cartilage, which lies at the level of the fourth and fifth cervical vertebrae. The laryngeal prominence of the thyroid cartilage (more prominent in men) is easily palpated with the thumb and index finger. The cricoid cartilage lies just inferior to the thyroid cartilage at the level of the sixth cervical vertebra. It serves as the junction of the larynx and trachea. Multiple cartilaginous rings support the trachea. Between the cricoid and thyroid cartilages lies the cricothyroid membrane. **The cricothyroid membrane is a palpable membranous depression just inferior to the laryngeal prominence and is the access site for PTTJV.**[11] The cricothyroid artery is a branch of the superior thyroid artery. It travels transversely across the cricothyroid membrane just below the thyroid cartilage. Placement of the catheter through the lower half of the cricothyroid membrane will prevent injury to this small artery.[22]

Once the catheter is placed and appropriately connected to an oxygen source, oxygen is delivered via bulk flow through the cannula into the trachea and lungs. Entrainment of room air translaryngeally via the Venturi principle is negligible, even with minimal upper airway obstruction.[1] Therefore, near 100% O_2 is delivered with each insufflation.

Inhalation occurs through the catheter via a pressurized flow of oxygen. Exhalation occurs passively through the elastic recoil of the lungs and chest wall.[10] The minute ventilation delivered during PTTJV is proportional to the volume of air injected, the driving air pressure, and the degree of upper airway obstruction.[2,12] Animal studies demonstrate that PTTJV delivers more tidal volume than positive-pressure mask ventilation with the same tracheal and transpulmonary pressures despite delivery of oxygen from a pressurized source.[2]

INDICATIONS

PTTJV is indicated as a backup emergent airway in any patient who cannot be endotracheally intubated or ventilated with a bag-valve-mask device despite the use of a jaw-thrust maneuver, oropharyngeal airway, or nasopharyngeal airway or LMA.[1,2,5] It serves as a simple, relatively safe, and effective alternative to cricothyroidotomy.[1,6] This is especially true in pediatric patients below 5 years of age, in whom a cricothyroidotomy is contraindicated. PTTJV is the procedure of choice in the pediatric age group for establishing an emergent airway when endotracheal intubation fails.[7] PTTJV can serve as a quick alternative to a difficult intubation. It is especially valuable in cases of maxillofacial trauma, suspected cervical spine injury, or when nasal intubation is contraindicated or unsuccessful.[5,6,13] PTTJV is also used routinely by Anesthesiologists in the operating room. Electively, transtracheal catheters are placed in patients undergoing surgery of the upper airway, including the larynx and subglottic structures.[7]

This procedure is also indicated in cases of partial upper airway obstruction due to foreign bodies, laryngeal edema, neoplasm, or infection.[2,3] In cases of upper airway foreign bodies, PTTJV not only serves as an emergent airway but can also assist in dislodging the foreign body.[6,7] Animal studies have demonstrated that the expulsion of foreign bodies from the hypopharynx and upper trachea is possible with high-frequency jet ventilation, in effect similar to the Heimlich maneuver.[13] Approximately 30% of the air flow from transtracheal jet ventilation is directed cephalad and can therefore assist in the expulsion of airway foreign bodies.[14]

PTTJV has a large number of advantages when compared to an emergent cricothyroidotomy.[1–21] It is easier and faster to perform. The technique is simpler to learn. The need for a large number of instruments, surgical preparation and technique, and an assistant is eliminated. The complications of bleeding, glottic stenosis, subglottic stenosis, and tracheal erosion are significantly lessened. If the patient survives, PTTJV causes less cosmetic disfigurement. Finally, PTTJV can direct secretions and foreign bodies out of the proximal trachea.

CONTRAINDICATIONS

PTTJV is contraindicated in patients who can be orally or nasally intubated. Anterior neck trauma may be a contraindication to PTTJV. Damage to the larynx or cricoid cartilage is a contraindication to PTTJV. If laryngeal trauma is suspected, catheter placement may result in laryngeal disruption.[5,12] It should not be performed in patients with partial or complete transection of the trachea. Lower tracheal or proximal bronchial tree disruption can result in an increased risk of pneumothorax and pneumomediastinum with high-pressure ventilation.[5,7,12]

Complete airway obstruction is also an absolute contraindication to PTTJV.[5,8,12] Exhalation requires passive recoil of the lungs and chest wall, and a patent airway for outflow of gas. A patient with a complete upper airway obstruction is at an increased risk for barotrauma (i.e., pneumothorax and pneumomediastinum). Numerous studies have been performed to evaluate PTTJV with varying degrees of upper airway obstruction. Ward *et al.* found that progressively increasing airway obstruction up to 80% did not cause barotrauma.[20] **With upper airway obstruction, less air is allowed to escape and more volume is forced into the lungs.** Therefore, tidal volume increases with increasing airway obstruction. Once a patient develops complete upper airway obstruction, auto-PEEP (end-expiratory alveolar pressure above the set level of positive end-expiratory pressure) will develop as air is trapped within the thoracic cavity with no outlet and insufflation of air under pressure continues. This will ultimately result in barotrauma and decreased mean arterial pressure.[19]

EQUIPMENT

- Pressurized oxygen source, wall source or tank at 50 psi
- Povidone iodine solution or Chlorhexidine prep
- Commercially available PTTJV kit or a self-assembled kit from available components
- 12 to 16 gauge, 2 to 3 in catheter-over-the-needle (angiocatheter)



FIGURE 24-2. The manual jet ventilation system (Instrumentation Industries, Bethel Park, PA).



FIGURE 24-4. The Norgren jet ventilation system (Norgren Inc., Littleton, CO).

- Noncompressible high-pressure oxygen tubing
- Valve device (manual push valve, Y connector, T piece)
- 10 mL syringe
- Sterile saline
- Sterile drapes
- Local anesthetic solution (1% lidocaine)
- 3-0 nylon suture
- Needle driver
- Bag-valve device
- 3 mL syringe
- Adult endotracheal tube connector

A PTTJV system can be purchased from a commercial company. It may also be assembled with individual parts.[1] Examples of PTTJV systems are shown in **Figures 24-2, 24-3, & 24-4**. The components of a PTTJV system are quite simple (**Figure 24-5**). The oxygen source may be a wall supply or tank. It should have a pressure regulator that can provide 100% O_2 at 50 psi through noncompressible and high-pressure tubing. Along the tubing there must be a valve (Y connector or manual push valve) to allow intermittent flow of oxygen.[5] The flow into the trachea is regulated by manual control of this valve. Ventilations should be delivered at a rate of 12 to 20 breaths per minute. Oxygen flow rates will vary with catheter size. Flow rates for 20, 16, and 14 gauge catheters at 50 psi are 400, 500, and 1600 mL/s, respectively.[9] The inspiratory time is brief compared to the expiratory time by a ratio of 1:2 to 1:9 seconds.[2,10,15]



FIGURE 24-3. The Manujet jet ventilation system (VBM Medizintechnik, W. Germany).

If a high-pressure system is unavailable, the patient may still be temporarily oxygenated through a transtracheally placed catheter.[23] Attach a 3 mL syringe without the plunger to the catheter. Insert a standard endotracheal tube connector, from a size 5 to 9 mm i.d. endotracheal tube, into the barrel of the syringe. Connect the bag-valve device to the connector and begin ventilation while preparing for more definitive airway control.[6,7,24,25]

The commercially available PTTJV kits are designed to provide 100% oxygen at 50 psi which has been shown to provide both adequate oxygenation and ventilation.[8,9] Several recent studies have compared the effectiveness of a self-made apparatus with the commercial kits. They have shown that flow rates of >15 L/min (regulator wide open) are needed to produce equivalent flow rates.[26] Using flow rates less than 15 L/min will result in failure of ventilation within 60 seconds. Therefore, if a high pressure system is unavailable and a more definitive airway cannot be obtained, a surgical cricothyroidotomy should be performed.[27]

PATIENT PREPARATION

The establishment of PTTJV requires not only proper insertion of the transtracheal catheter, but also a proper setup of the ventilatory equipment. The required equipment should be prepackaged and placed where it is readily accessible. Ensure that the fittings are secure and the tubing is not damaged. Place the patient supine and in the "sniffing" position if no contraindications exist. The patient is most likely already in the proper position, as this technique is most often performed on apneic patients in whom other intubation techniques have failed. Place a rolled towel behind the middle of the neck to hyperextend the neck and allow for better access. Identify by palpation the hyoid bone, thyroid cartilage, cricoid cartilage, and cricothyroid membrane. Clean the anterior neck of any dirt and debris. Apply povidone iodine solution or chlorhexidine

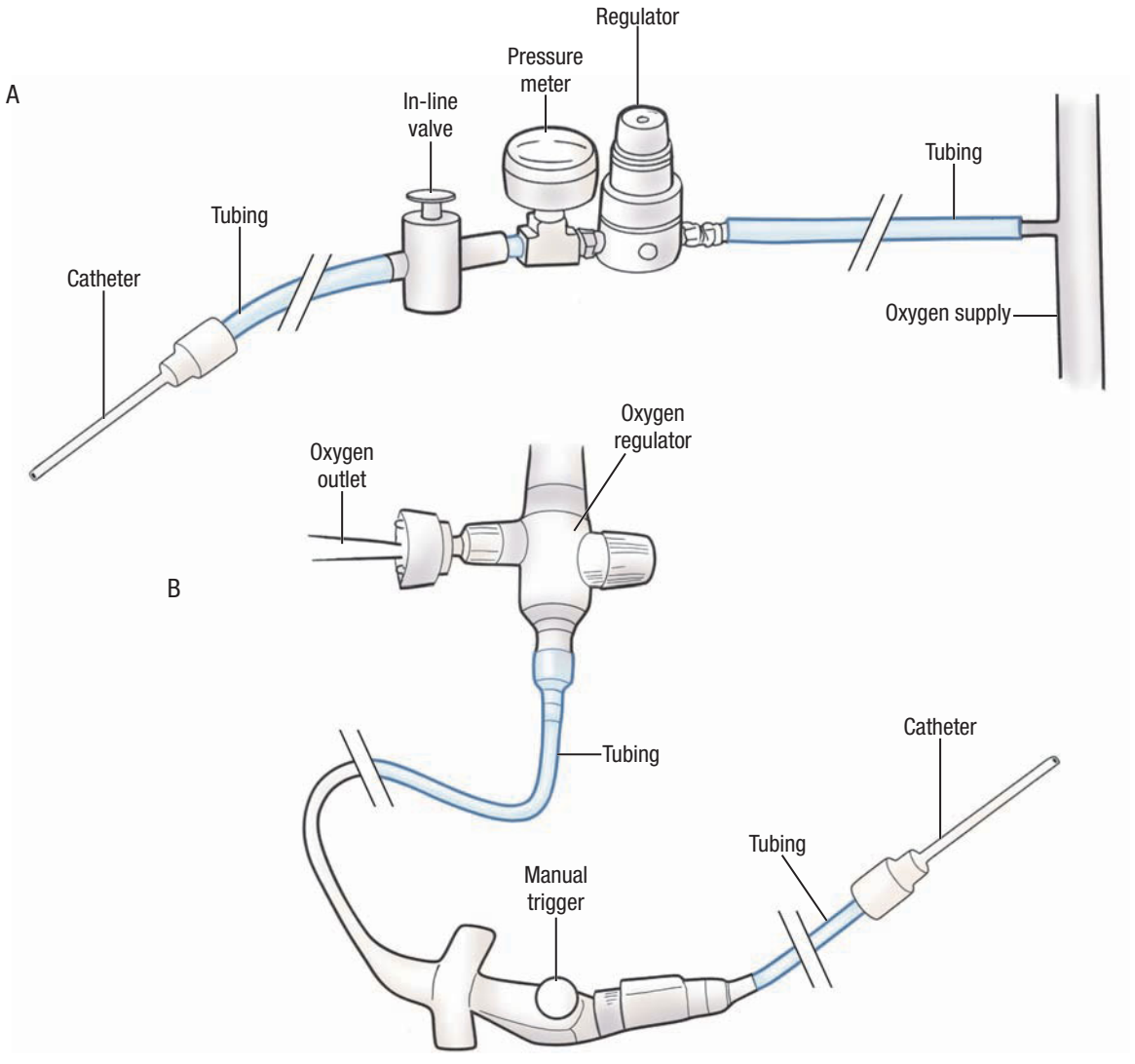


FIGURE 24-5. The components of high-pressure jet ventilation systems. **A.** Modified from Greenfield.[21] **B.** Modified from Patel.[10]

prep to the anterior neck. Prepare the needed equipment. Attach a 12 to 16 gauge catheter-over-the-needle (angiocatheter) to a 10 mL syringe containing 5 mL of sterile saline.

TECHNIQUE

Stand at the side of the bed and adjacent to the patient's head and neck. **Reidentify the anatomic landmarks. This is crucial to perform this procedure.** Using the nondominant hand, place the thumb on one side of the thyroid cartilage and the middle finger on the other side. Use these fingers to stabilize the larynx. Use the index finger to identify the anatomic landmarks.[5,10] Start at the laryngeal prominence (Adam's apple) and work inferiorly. The soft membranous defect inferior to the laryngeal prominence is the cricothyroid membrane. Below this is the firm cartilaginous ring of the cricoid cartilage.

Insert the catheter-over-the-needle (angiocatheter) through the skin, subcutaneous tissue, and inferior aspect of the cricothyroid membrane. **The inferior aspect of the cricothyroid membrane is the preferred site as it avoids injury to the cricothyroid arteries.**[7] Direct the catheter-over-the-needle inferiorly and at a 30° to 45° angle (**Figure 24-6A**). Maintain constant negative pressure within the syringe as it is advanced (**Figure 24-6B**). **Continue to advance the catheter-over-the-needle while maintaining negative pressure until air bubbles are visible in the syringe and a loss of resistance is felt.[5,10] These both signify that the angiocatheter is within the trachea.**

Once placement within the trachea is confirmed, securely hold the needle and advance the catheter until the hub is against the skin (**Figure 24-6C**). Remove the needle and syringe (**Figure 24-6C**). Reattach the syringe without the needle to the catheter. **Aspirate once again to reconfirm placement of the catheter within the trachea.** The 2 to 3 cm catheter should be long enough to pass into the tracheal lumen without sitting against the posterior wall. If the catheter tip directly touches or faces the posterior tracheal wall, there is the risk of forcing air submucosally.[12] Firmly grasp and hold the catheter hub at the skin of the neck. Remove the syringe. Attach the oxygen tubing to the catheter (**Figure 24-6D**). Begin ventilation and continue until a more permanent and secure airway is established.[5] **Watch for adequate chest rise with ventilation and allow for complete elastic recoil of the chest wall before giving the next breath to avoid air trapping and barotrauma.**

ASSESSMENT

PTTJV requires continuous cardiac and pulse oximetry monitoring to evaluate oxygenation. Continuous capnography can be used to assure adequate ventilation. Arterial blood gas samples should be

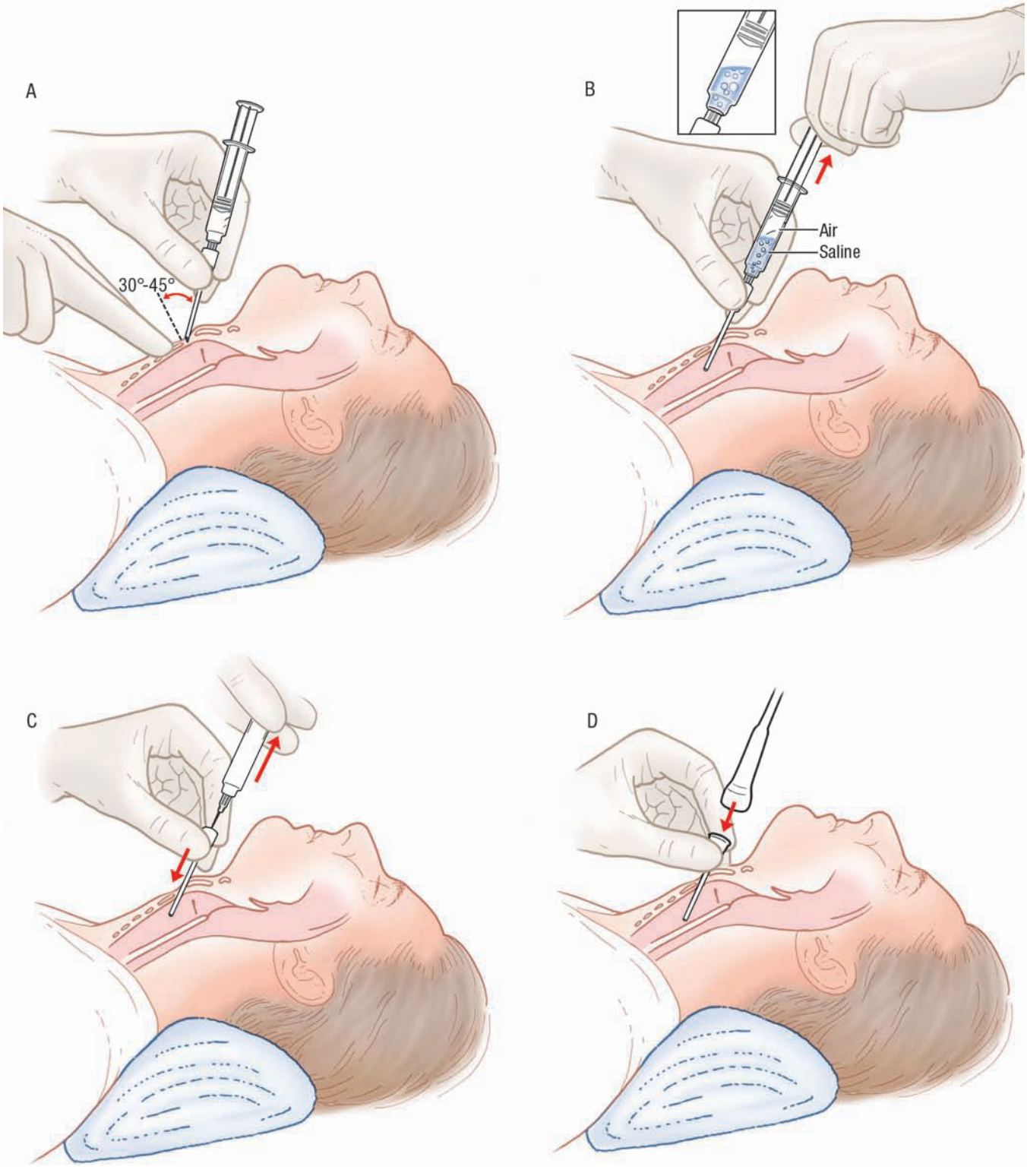


FIGURE 24-6. Insertion of the transtracheal catheter. **A.** The catheter-over-the-needle is inserted 30° to 45° to the perpendicular (*dotted line*) and aimed inferiorly. **B.** Application of negative pressure to a saline-containing syringe during catheter insertion (*arrow*). Air bubbles in the saline confirm intratracheal placement of the catheter. **C.** The catheter is advanced until the hub is against the skin. The needle and syringe are then removed. **D.** High-pressure oxygen tubing is attached to the catheter and ventilation is begun.

obtained periodically to look for hypoxia and hypercarbia. Careful attention must be paid to maintaining a patent upper airway to allow for passive expiration and avoid barotrauma. Oropharyngeal and/or nasopharyngeal airways, or a jaw-thrust maneuver, are often adequate.

The catheter, oxygen tubing, and patient must be continually assessed during PTTJV. Check the catheter tubing at regular intervals for signs of dislodgement or kinking. Examine the patient for crepitus in the neck and torso. If crepitus is present, the catheter tip is most likely directly against or directed toward the mucosa of the

posterior tracheal wall. Oxygen is being forced into the submucosal tissues and tracking subcutaneously. Remove the catheter and reinsert a new one. Obtain a chest radiograph to assess the patient for a pneumomediastinum, pneumopericardium, or pneumothorax that may require decompression. Pulse oximetry and cardiac monitoring and capnography should also be continuously monitored.

AFTERCARE

The catheter and tubing must be secured to prevent accidental dislodgement.[10] One person must continuously hold the hub of the catheter against the patient's skin during PTTJV while a second person secures it. There are three ways to secure the equipment. The first and preferred method is to suture it in place. Place a skin wheal of local anesthetic solution (1% lidocaine) next to the catheter hub. Using 3-0 nylon suture, place a stitch through the skin wheal and tie it securely. Do not cut the suture. Wrap the long end of the suture around the catheter hub two or three times and tie it securely to the tail of the suture. Wrap the long end of the suture around the oxygen tubing, just above the attachment to the catheter hub, two or three times and tie it securely to the tail of the suture. Alternatively, wrap a piece of umbilical or plain tape around the patient's neck, the catheter hub, and the oxygen tubing. A second alternative is to attach a commercially available endotracheal tube holder around the patient's neck and connect it to the oxygen tubing. The catheter will still have to be secured with suture or by being taped to the oxygen tubing and skin.

The patient should be reevaluated for possible endotracheal intubation. Studies have shown that subsequent attempts have been successful. It is possible that the positive pressure used in PTTJV increases the success rate.[10]

COMPLICATIONS

PTTJV is a relatively safe and effective means of establishing an emergent airway in a patient who cannot be intubated or ventilated by another mechanism. Complications are fewer than with a cricothyroidotomy, but they do occur and must be anticipated.

Subcutaneous emphysema occurs most commonly when the transtracheal catheter is misplaced, becomes dislodged into the soft tissues of the neck during ventilation, or is placed against the mucosa of the posterior tracheal wall.[1,5,6] It may also occur if catheter placement is unsuccessful on the first attempt, creating a port for leakage of pressurized air into the subcutaneous tissues of the neck.[5] Frequent examination of the catheter site for evidence of subcutaneous emphysema may provide the earliest clue to catheter malfunction.

Barotrauma may present as a pneumothorax, pneumomediastinum, or pneumopericardium. It may be a result of upper airway obstruction. The exhalation of air is passive and depends on a patent upper airway. **It is therefore important to monitor chest rise and fall as evidence of continued air exchange.**[1] An oropharyngeal airway, nasopharyngeal airway, or jaw-thrust maneuver will often provide adequate upper airway patency.[5] **Assume, until proven otherwise, that any sudden change in the patient's heart rate or blood pressure during PTTJV is secondary to a tension pneumothorax.** There has been a case report of laryngospasm with PTTJV use during an elective surgical procedure.[16] It resulted in sudden desaturation and hypotension that were easily resolved with the administration of a paralytic agent.

Catheter obstruction is another potential complication. Most commonly, the catheter will kink as it traverses the soft tissues of the neck.[1,5] This may occur if the catheter is dislodged or as a result of high-pressure ventilation. The use of a commercially available kink-resistant catheter greatly reduces this risk.

The catheter may be inappropriately placed. Misplacement of the catheter into the submucosa of the larynx can lead to a laryngeal pneumatocele. If this is suspected or identified, remove the catheter and reinsert a new one. The pneumatocele can be aspirated with a needle and syringe after placement of a new transtracheal catheter.[5] Misplacement of the catheter posteriorly through the back of the trachea and perforation of the esophagus is a theoretical concern that has never been reported.[1,5,6]

Pulmonary aspiration is another potential complication of PTTJV. The epiglottis provides no airway protection, and the small transtracheal catheter does not prevent aspiration of secretions or gastric contents into the lungs. Animal studies have demonstrated that pulmonary aspiration in fact did not occur despite variable frequencies of ventilation, variable oxygen flow pressure, and cardiac compressions during cardiopulmonary resuscitation (CPR).[17,18] Studies have shown that the pressurized flow of air through the catheter provides an adequate forceful gas outflow from the lungs which may prevent pulmonary aspiration. [17,18] Secretions and foreign bodies have been shown to stay above the jetting catheter while PTTJV is in progress. **If PTTJV is to be discontinued, great care must be taken to assure complete suctioning and cleansing of the upper airway above the catheter.**[18]

Less serious complications include local hematoma formation at the catheter insertion site, hemoptysis, and cough.[1,5,6] The use of nonhumidified oxygen in the catheter has been reported to cause irritation and erosion to the tracheal mucosa.[1]

SUMMARY

PTTJV is an effective and easy method for establishing an emergent airway in patients who cannot be ventilated with a bag-valve-mask device or intubated. The indications for PTTJV are the same as those for a cricothyroidotomy. Placement of a catheter through the cricothyroid membrane and attached to a high-pressure oxygen source will provide adequate oxygenation and ventilation until a more definitive airway can be established. This is an airway management technique that is rapidly performed and should be considered as a reliable backup rescue technique for the "can't intubate, can't ventilate" patient.

25 Cricothyroidotomy

Eric F. Reichman

INTRODUCTION

Establishment of an airway is of prime importance to survival. The most predictive factor of survival from cardiac arrest is establishment of an airway.[1] Unfortunately, the Emergency Physician is occasionally confronted with an airway that is extremely difficult or even impossible to obtain by endotracheal intubation. Between 1% and 4% of all emergent airways require a cricothyroidotomy.[2–5] Up to 7% of trauma patients who present in cardiopulmonary arrest will require a cricothyroidotomy.[3]

The technique of cricothyroidotomy has been documented in use since the early 1900s. In 1921, Chevalier Jackson condemned its use because of fears of subglottic stenosis.[6,7] Jackson's technique involved incising the cricoid cartilage, which led to the subglottic stenosis. The technique was popularized again in 1966 by Brantigan and Grow, but it was considered primarily an elective procedure.[6,7] **Cricothyroidotomy has since evolved into the**

surgical airway of choice for emergent situations in which other intubation methods have failed or are contraindicated.[2,8] The Emergency Physician using rapid sequence induction to intubate patients should be knowledgeable and skilled in performing a cricothyroidotomy.[3] The success rate of a cricothyroidotomy ranges from 96% to 100%.[4,9]

A cricothyroidotomy has numerous advantages over a tracheostomy.[6,10,11] A cricothyroidotomy is easier, faster, and safer to perform. It can be performed in less than 2 minutes. It can be performed by those with little or no surgical training. It does not require the support of an operating room and a large amount of equipment. The anatomic landmarks are superficial, easily seen, and easily palpated. The procedure does not require a deep dissection, as the structures are located subcutaneously. The cricothyroid membrane is not covered by any structures that would interfere with the procedure. Because the cricothyroid membrane is in the upper part of the neck, there is less chance of injuring the esophagus. A cricothyroidotomy can be performed with the patient's neck in a neutral position. This is especially important in those with potential cervical spine injuries. The procedure has fewer associated complications than a tracheostomy. Although not a concern when securing an airway, the skin incision will heal with a smaller and less noticeable scar.

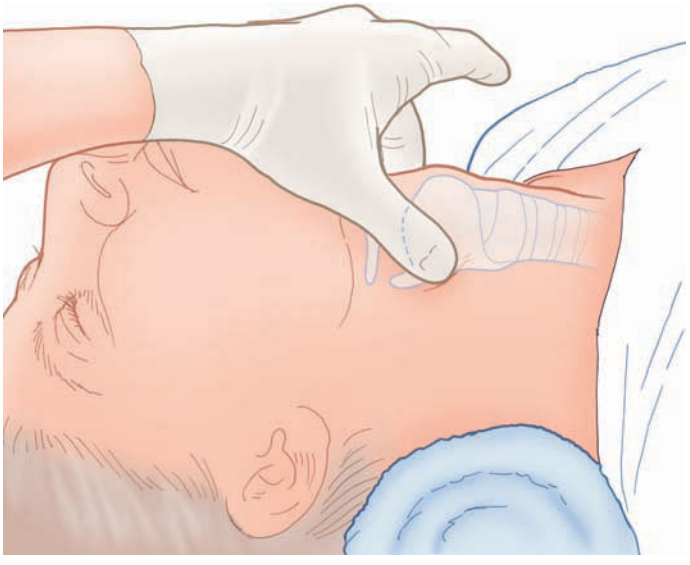


FIGURE 25-2. Proper hand positioning to identify the airway structures of the neck.

ANATOMY AND PATHOPHYSIOLOGY

The cricothyroid membrane is located between the thyroid cartilage superiorly and the cricoid cartilage inferiorly (**Figure 25-1**). **The cricothyroid membrane must be identified by palpation of the surrounding cartilaginous structures.** Using the nondominant hand, place the thumb on one side of the thyroid cartilage and the middle finger on the other side (**Figure 25-2**). Palpate the laryngeal prominence (Adam's apple) with the index finger. **It is important to locate the hyoid bone superiorly to ensure that the incision is not superior to the vocal cords.** Moving inferiorly, the index finger will fall into a hollow, which is the location of the cricothyroid membrane. The next structure palpated is the firm cartilaginous ring of the cricoid cartilage, followed by the tracheal rings.

The cricothyroid membrane itself is a thin membrane measuring 2 to 3 cm in width and only 9 to 10 mm in height.[8,11] It is located approximately 1 cm below the true vocal cords.[11] There is relatively little subcutaneous tissue overlying the cricothyroid membrane. There are few to no vascular structures overlying the cricothyroid membrane. The anterior cricothyroid arteries travel from lateral to medial over the superior border of the cricothyroid membrane. The anterior jugular veins may lie immediately superior and lateral to the cricothyroid membrane. Farther lateral and posterior are the great vessels of the neck. Posterior to the larynx and trachea is the esophagus. It is therefore important not to make the incision too deep, thus risking an esophageal intubation or injury.

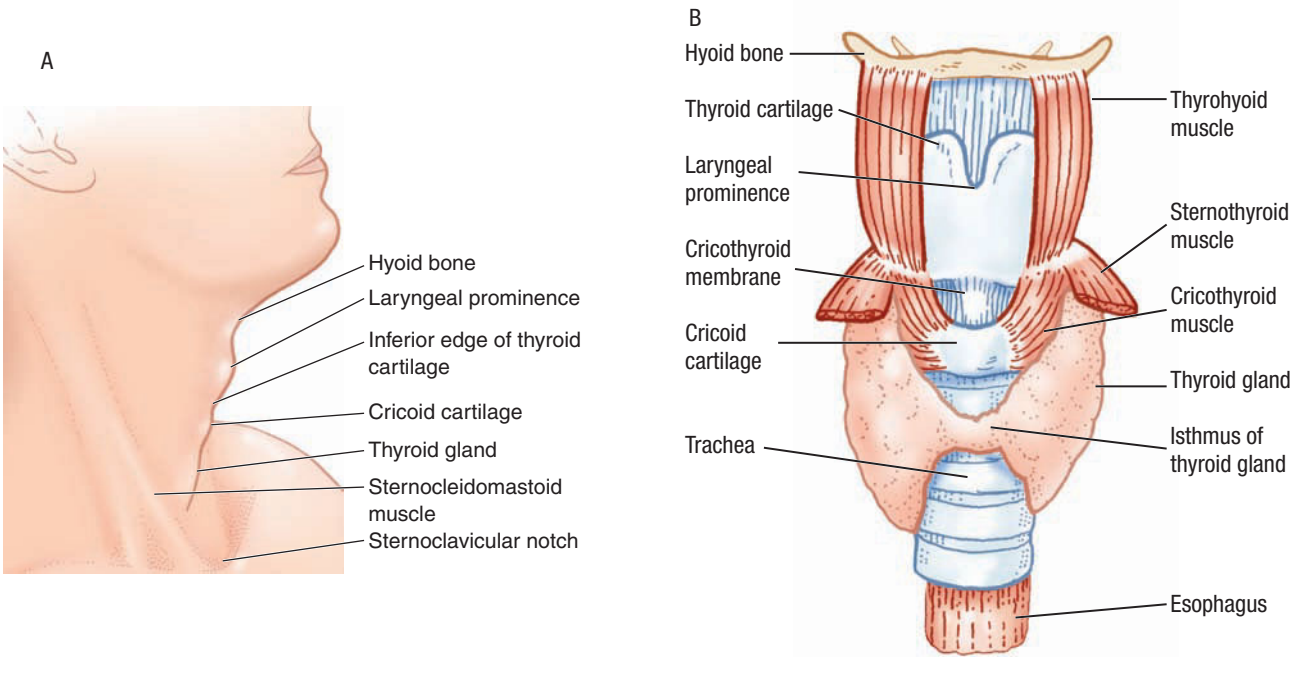


FIGURE 25-1. Anatomy of the airway in the neck region. **A.** Topographic anatomy. **B.** The framework of the airway.

INDICATIONS

The most frequent indication for an emergent or urgent surgical airway is the inability to intubate endotracheally with less invasive techniques. These less invasive techniques may have failed or been contraindicated.[10] **Attempts at orotracheal or nasotracheal intubation should be made prior to attempts at creating a surgical airway.**[4,8] A common reason for the failure of orotracheal intubation is not using rapid sequence induction and the patient's clenched teeth precluding intubation.[9] Other common reasons for failure to establish endotracheal intubation include severe neck or facial injury resulting in distortion of the normal anatomy, edema, masseter spasm, laryngospasm, cervical spine injury, deformities of the mouth and/or pharynx, upper airway hemorrhage, large amounts of vomitus in the oropharynx, and upper airway obstruction.[8,9,11] **Although endotracheal intubation should be attempted first, it is prudent to have the surgical airway supplies nearby if it is suspected that the patient may have a difficult airway.** The old saying among Anesthesiologists "A surgical airway is better than a deceased patient with a good-looking neck" holds quite true.

Needle cricothyroidotomy is the emergent "surgical" airway of choice in a patient younger than 8 to 10 years of age.[11,12] In young children, the cricothyroid membrane as well as the surrounding structures are much smaller and more difficult to access. It is easier to injure one of the cervical vessels or the esophagus when a standard cricothyroidotomy is performed in a child. Subglottic stenosis is a common late complication following cricothyroidotomy in children.[12] A needle cricothyroidotomy is a safer alternative and allows for adequate oxygenation and ventilation until a formal tracheostomy or other method of endotracheal intubation can be performed. Unfortunately, the small caliber of the catheter may not provide adequate oxygenation and ventilation in an adult.

CONTRAINDICATIONS

There are a few absolute contraindications to performing a cricothyroidotomy. The most important is if the patient can be endotracheally intubated by less invasive methods. Partial or complete transection of the airway is a contraindication to a cricothyroidotomy. In these cases, a tracheostomy is the preferred method to secure the airway. Finally, this procedure should not be performed in cases of significant injury or fracture of the cricoid cartilage, larynx, and/or thyroid cartilage.

There are some situations where the performance of a cricothyroidotomy may be less desirable. The presence of laryngeal pathology (e.g., tumor, fracture) may preclude the performance of a cricothyroidotomy and necessitate a high tracheostomy.[11,13] If a patient has been previously intubated endotracheally for a prolonged period, there is a higher incidence of long-term complications following a cricothyroidotomy.[13] While this does not prevent the performance of a cricothyroidotomy, one should consider an early revision to a tracheostomy to minimize these complications. Other relative contraindications to performing a cricothyroidotomy are the presence of a coagulopathy, massive neck swelling, or a hematoma in the neck; all of which increase the risk of bleeding and distortion of the anatomy. Finally, unfamiliarity with the technique may lead to increased complications.[11]

EQUIPMENT

General Supplies

- Sterile gloves, gowns, and drapes
- Face mask and eye protection
- 1% lidocaine local anesthetic solution
- Syringes, 5 and 10 mL
- Needles, 18 to 27 gauge
- Bag-valve-mask device
- Oxygen source and tubing
- Suction source, tubing, and catheter
- Pulse oximeter
- Noninvasive blood pressure cuff
- Cardiac monitor
- End-tidal CO_2 monitor

Surgical Cricothyroidotomy

- Povidone iodine or chlorhexidine solution
- #11 scalpel blade on a handle
- Trousseau tracheal dilator or curved 6 in hemostat
- Tracheal hook
- Hemostats, 4 small
- Needle driver
- Suture scissors
- Tracheostomy tubes, sizes #4 and #6
- Endotracheal tubes, various sizes
- Tracheostomy tape (twill tape)
- 3-0 sutures for hemostasis (e.g., Dexon, Vicryl, or chromic)
- 3-0 nylon sutures for skin closure
- 1 in tape (or a commercially available endotracheal tube holder)
- Gauze 4 × 4 squares
- Iodoform gauze ribbon
- Percutaneous cricothyroidotomy kit, adult and pediatric sizes

Needle Cricothyroidotomy

- Povidone iodine or chlorhexidine solution
- 14 gauge catheter-over-the-needle (angiocatheter), 2 in long
- 5 mL syringe
- Tape
- Percutaneous transtracheal jet ventilator (Chapter 24)

The equipment should be prepackaged in a sterile tray that is readily accessible. Some institutions maintain separate cricothyroidotomy and tracheostomy trays. Others have one tray that contains the equipment necessary to perform both procedures. If a cricothyroidotomy tray is not immediately available, a thoracotomy tray usually contains all the required equipment to perform this procedure.

Should the Emergency Department stock surgical cricothyroidotomy kits, percutaneous cricothyroidotomy kits, or both? The answer to this will depend on Emergency Physician preference, hospital stores, and available budget. The Melker Universal Emergency Cricothyroidotomy Catheter Set (Cook Inc., Bloomington, IN) may resolve this issue for some Emergency Departments. This single-use, disposable kit contains all the equipment required to perform both types of cricothyroidotomies. The convenience of having all the required equipment readily available in one kit can clearly justify the cost. Unfortunately, this kit is only available in one adult size.

PATIENT PREPARATION

A cricothyroidotomy is most commonly an emergent procedure. There is little if any time to explain this to the patient and obtain their consent. If there is sufficient probability that an awake and



FIGURE 25-3. Patient positioning with a rolled towel under their neck and upper shoulders.

stable patient will require a surgical airway, informed consent may be obtained.

The patient should be appropriately monitored with electrocardiography (ECG), end-tidal CO_2 monitoring, noninvasive blood pressure cuff, and pulse oximetry. The patient preparation is exactly the same as that for orotracheal intubation. As for any situation where airway manipulation is to occur and the patient's protective airway reflexes are blunted or ablated, a fully functioning suction apparatus with a variety of catheters must be immediately available.

Place the patient supine with their head in a neutral position. Place a rolled towel under the patient's upper shoulders and neck if no contraindications exist (**Figure 25-3**). This position offers excellent exposure, stabilizes and prevents the airway structures from moving, and lengthens the cricothyroid membrane. While it is not impossible to perform a cricothyroidotomy with a cervical collar on the patient, it is very difficult. If the patient is at risk for a cervical spine injury, it is preferable to remove the collar while an assistant maintains in-line stabilization of the head and neck in a neutral position. An additional assistant should maintain the airway and provide ventilatory support with a bag-valve-mask device.

In the ideal situation, the skin of the anterior neck should be prepped with povidone iodine or chlorhexidine solution and sterile drapes placed to isolate a surgical field. The Emergency Physician performing the procedure should be clad in a mask, a sterile gown, and gloves. The circumstances in which the procedure is usually performed often require that the airway be obtained rapidly. In these cases, a quick spray of povidone iodine or chlorhexidine and sterile gloves will suffice.

TECHNIQUES

During the performance of this procedure, one or two assistants should be maintaining the airway by providing ventilation and oxygenation with a bag-valve-mask device or a supraglottic airway device. The right-handed Emergency Physician should be standing at the patient's right side. The position is reversed for the left-handed Emergency Physician.

Stabilize the large thyroid cartilage in place with the thumb and middle finger of the nondominant hand (**Figure 25-2**).[8,14] **The immobilization of the larynx cannot be overemphasized. If the larynx is not secure and thus the landmarks are lost, the procedure will fail. Identify the anatomic landmarks necessary to perform this procedure. This is critical to the performance of a cricothyroidotomy.** Place the index finger over the laryngeal prominence (Adam's apple). Move the index finger inferiorly to identify the cricothyroid membrane, cricoid cartilage, and tracheal rings (in this order). Move the index finger superiorly until it falls back into the cricothyroid membrane. Leave the index finger over the cricothyroid membrane. Using the index finger of the dominant hand, confirm that the nondominant index finger is situated over the cricothyroid membrane. If the patient is awake and stable, infiltrate the area of the incision with local anesthetic solution after the landmarks are identified.

TRADITIONAL TECHNIQUE

Make a 2 to 3 cm transverse incision, centered in the midline, through the skin and subcutaneous tissue (**Figures 25-4 & 25-5A**). Continue the incision through the cricothyroid membrane. As one gains skill with this procedure, all layers may be incised simultaneously with one incision. The beginner should proceed with some caution because there is a small risk of incising through the posterior wall of the airway.[8,11] **The incision should be no longer than 3 cm or 1.5 cm on either side of the midline, as this represents the width**

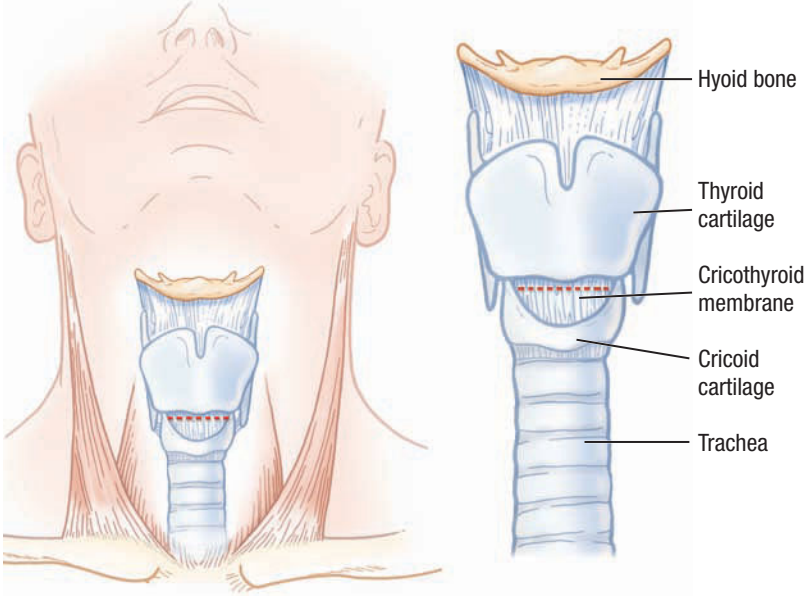


FIGURE 25-4. The cricothyroidotomy site. The dotted line represents the incision over the cricothyroid membrane.

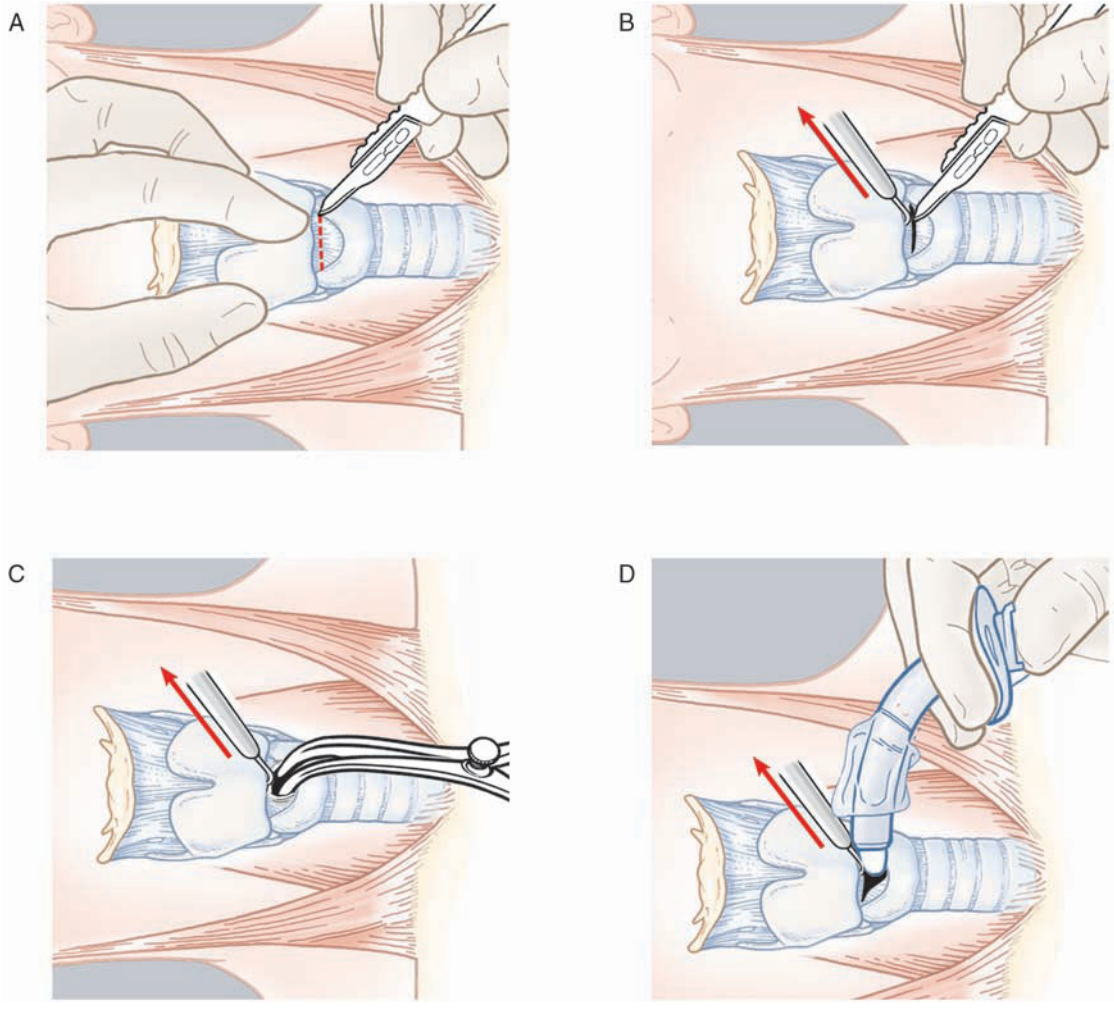


FIGURE 25-5. A surgical cricothyroidotomy. **A.** The nondominant hand stabilizes the cricothyroid membrane. A transverse incision is made through the skin, subcutaneous tissue, and cricothyroid membrane. **B.** A tracheal hook has been inserted over the scalpel blade to grasp the inferior border of the thyroid cartilage. The hook is lifted anteriorly and superiorly to control the airway (*arrow*). **C.** A Trousseau dilator is inserted into the incision and opened to dilate the incision site. **D.** A tracheostomy tube is inserted through the cricothyroid membrane.

of the cricothyroid membrane.[7,14] Longer incisions risk injury to the anterior jugular veins that lie just lateral to the thyroid cartilage.[11]

Longitudinal incisions in the midline are not recommended. They take longer to perform and require repositioning after the skin incision. The primary indication for a longitudinal skin incision is in the patient with a suspected laryngeal injury and distortion of the anatomic landmarks.[11] In these cases, the longitudinal incision permits the extension of the incision inferiorly in order to perform a high tracheostomy.

Once the cricothyroid membrane has been incised and the airway entered, a hiss of air with ventilations and bubbling should be noted through the wound. This is true if the patient is ventilating spontaneously or with the assistance of a bag-valve-mask device. **Do not remove the scalpel.** Insert the tracheal hook along the scalpel and grasp the inferior border of the thyroid cartilage (**Figure 25-5B**). Elevate the tracheal hook to retract the thyroid cartilage anteriorly and superiorly.[4,5] The scalpel may now be removed. The incision site must be expanded to accommodate the passage of an endotracheal tube or a tracheostomy tube. While controlling the airway with the tracheal hook, insert the jaws of a Trousseau dilator (or 6 in hemostat) through the cricothyroid membrane in the midsagittal plane (**Figure 25-5C**). Open the jaws of the instrument to dilate the opening in the sagittal plane.[4,5,7,8] Rotate the dilator 90° within the incision. Open the jaws of the dilator to dilate the incision in the transverse plane. Remove the dilator while continuing to maintain control of the airway with the tracheal hook.

Select a tracheostomy tube that is of an appropriate size for the patient. Instruct an assistant to lubricate the obturator and outer cannula, then insert the obturator into the outer cannula. While maintaining control of the airway with the tracheal hook, insert the tracheostomy tube perpendicularly (90°) to the skin (**Figure 25-5D**). Continue to advance the tracheostomy tube with a semicircular motion and inferiorly until the flange is against the skin. The tracheostomy tube should pass with minimal difficulty. Remove the tracheal hook. Securely hold the outer cannula. Remove the obturator, insert the inner cannula, inflate the cuff of the tracheostomy tube, connect the bag-valve device, and ventilate the patient.[4] Confirm the intratracheal position of the tube by auscultating bilateral breath sounds, noting the absence of breath sounds over the stomach, and a colorimetric or quantitative end-tidal CO_2 assessment.

ALTERNATIVE SURGICAL TECHNIQUE

An alternative surgical approach to a cricothyroidotomy was first developed by Oppenheimer.[17] It is simpler, more rapid, and easier to perform than the traditional technique described above

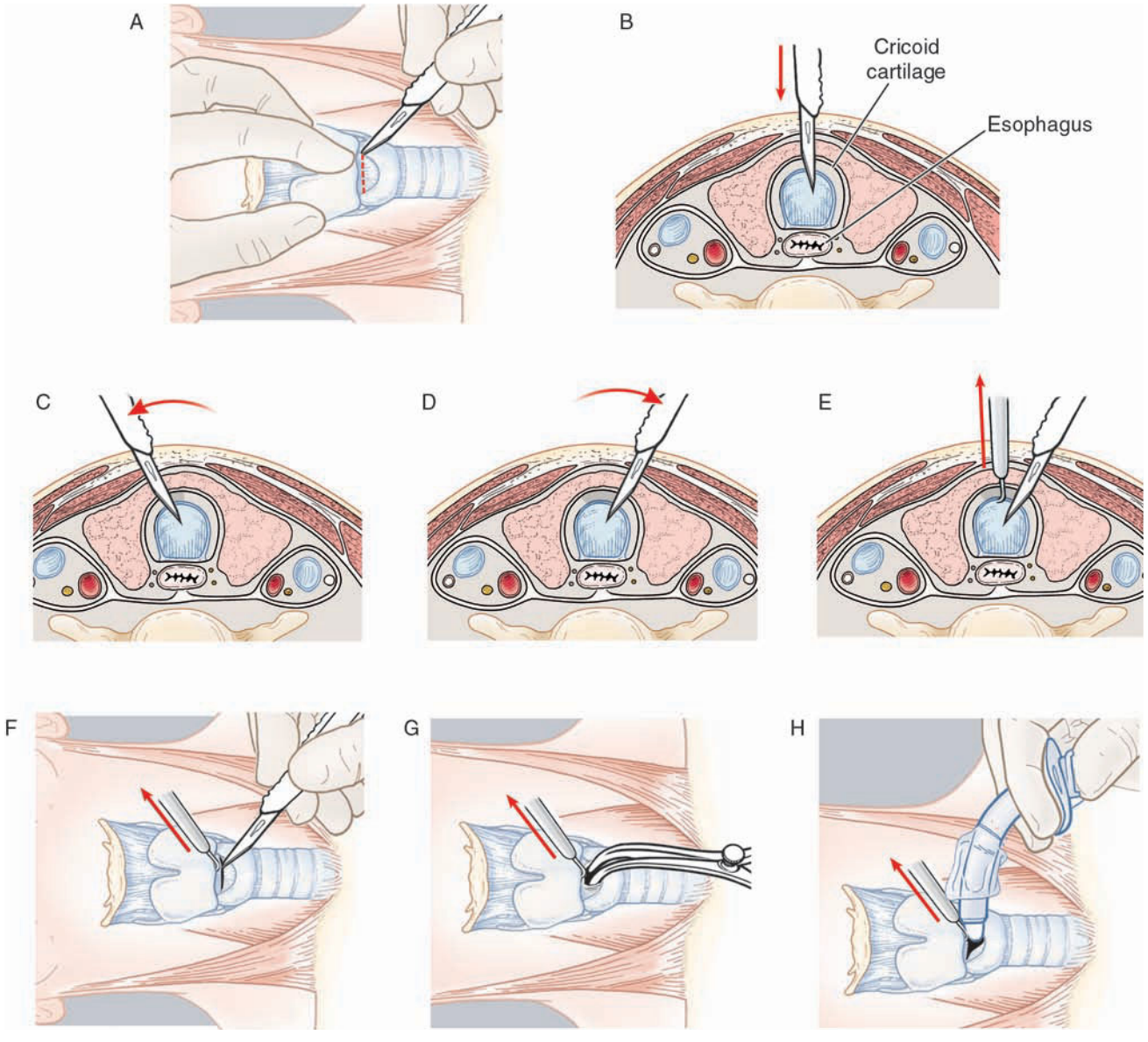


FIGURE 25-6. An alternative method to perform a surgical cricothyroidotomy. **A.** The thyroid cartilage is secured while a stab incision is made in the cricothyroid membrane. **B.** The scalpel blade penetrates the midline and enters the airway. **C.** The incision is extended laterally from the midline. **D.** The scalpel is rotated 180° and extends the incision to the other side. **E.** A tracheal hook is inserted in the midline and grasps the inferior border of the thyroid cartilage. **F.** The thyroid cartilage is lifted anteriorly and superiorly to control the airway (*arrow*). After the airway is controlled, the scalpel is removed. **G.** A Trousseau dilator is inserted into the incision, and the jaws are opened to dilate the incision. **H.** A tracheostomy tube is inserted into the trachea using a semicircular motion.

(**Figures 25-6 & 25-7**). The technique has been modified from the original description.[18]

Clean, prepare, and drape the neck as mentioned previously. Position the nondominant hand with the thumb on one side of the thyroid cartilage and the middle finger on the other side (**Figures 25-6A & 25-7A**). Identify the anatomic landmarks as described previously. Leave the nondominant index finger over the cricothyroid membrane. If the patient is awake, infiltrate local anesthetic solution subcutaneously over the cricothyroid membrane.

Guide a #11 surgical blade along the nondominant index finger and into the cricothyroid membrane using a stab incision (**Figures 25-6A, B, & 25-7B**). **Do not insert the scalpel blade more than 1.5 to 2.0 cm to prevent it from injuring the esophagus.** It is recommended to hold the scalpel just above the blade with the thumb and index finger to prevent it from plunging too deep.[18] Air or bubbles from the incision signify that the tip of the scalpel blade is inside the trachea. **Do not remove the scalpel blade.** Move it laterally 0.75 cm to extend the incision (**Figures 25-6C & 25-7C**). Rotate the scalpel blade 180° and extend the incision 0.75 cm in the opposite direction (**Figures 25-6D & 25-7D**). **Do not remove the scalpel blade. Removing the scalpel from the incision will result in losing the landmarks and the location of the incision through the cricothyroid membrane.**

With the scalpel blade in place, insert a tracheal hook into the midline of the incision (**Figures 25-6E & 25-7E**). Grasp the inferior border of the thyroid cartilage with the tracheal hook. Lift the tracheal hook upward and superiorly to elevate and control the airway (**Figures 25-6F & 25-7F**). **Remove the scalpel from the incision only after the airway is controlled with the tracheal hook.**

The incision site must be expanded to accommodate the passage of an endotracheal tube or a tracheostomy tube. While controlling the airway with the tracheal hook, insert the jaws of a Trousseau dilator (or 6 in hemostat) through the cricothyroid membrane in the midsagittal plane (**Figures 25-6G & 25-7G**). Open the jaws of the

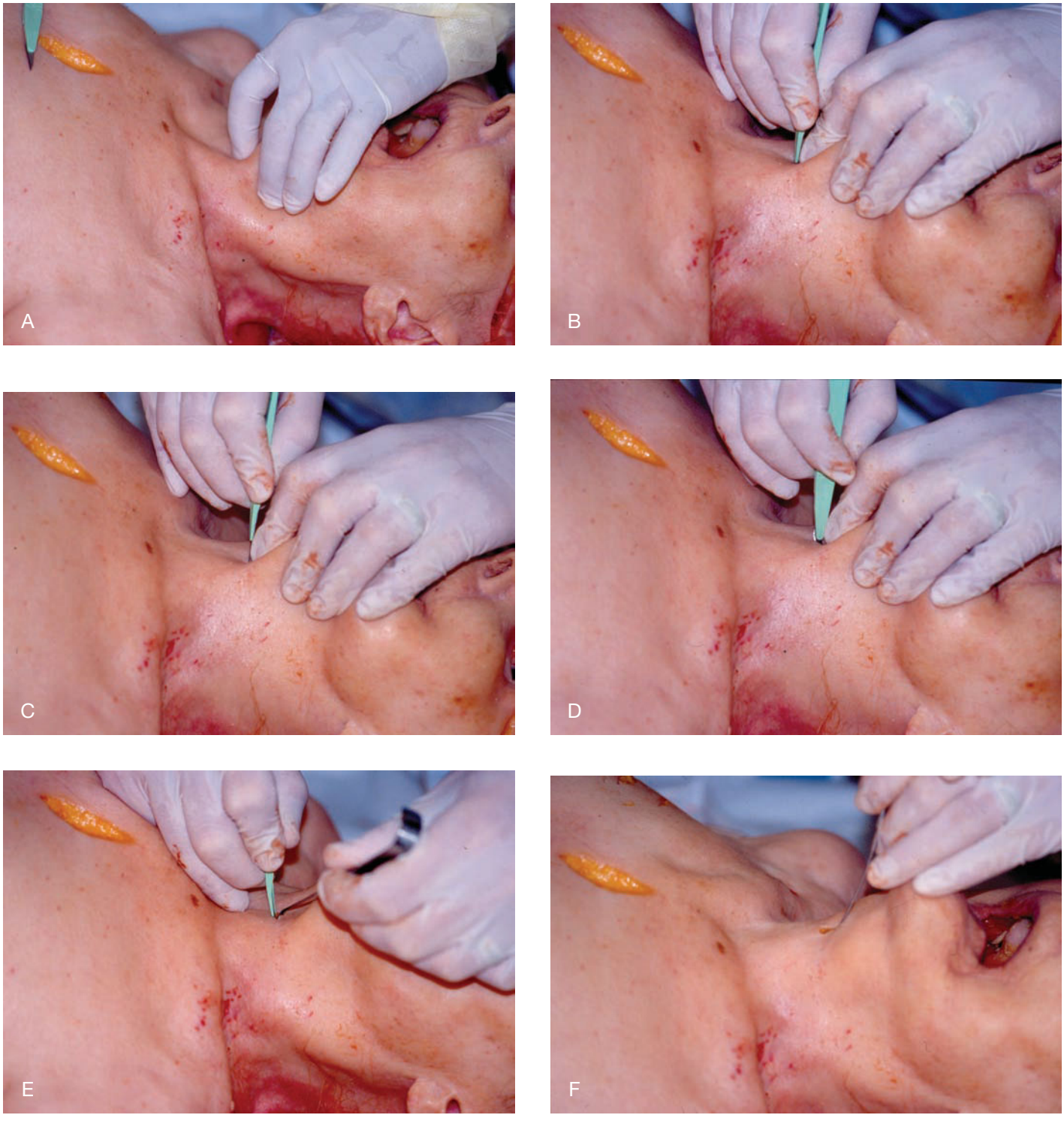


FIGURE 25-7. The alternative method performed on a cadaver. **A.** The larynx is stabilized and the Emergency Physician's index finger overlies the cricothyroid membrane. **B.** A stab incision is made into the cricothyroid membrane using the finger as a guide. **C.** The incision is extended toward the Emergency Physician. **D.** The scalpel is rotated 180° and the incision is extended away from the Emergency Physician. **E.** A tracheal hook is inserted over the scalpel blade to grasp the inferior border of the thyroid cartilage. **F.** The tracheal hook is lifted upward and superiorly to control the airway. The scalpel has then been removed.

instrument to dilate the opening in the sagittal plane (**Figure 25-7H**). Rotate the dilator 90° within the incision (**Figure 25-7I**). Open the jaws of the dilator to dilate the incision in the transverse plane (**Figure 25-7J**). Insert an endotracheal tube or a tracheostomy tube through the incision and into the trachea (**Figures 25-6H & 25-7K**). Hold the tube securely against the skin and remove the tracheal hook. The remainder of the procedure is as described previously.

PATIENTS WITH MASSIVE NECK SWELLING

Patients may present with massive neck swelling secondary to hemorrhage, hematoma, edema, or subcutaneous emphysema after trauma.[19] These patients often have no palpable anatomic landmarks in the neck, making it difficult to create a surgical airway. The traditional surgical methods used to perform a cricothyroidotomy











FIGURE 25-7. (*Continued*) **G.** The Trousseau dilator is inserted into the cricothyroid membrane. **H.** The jaws of the dilator are opened in the sagittal plane to widen the incision. **I.** The dilator is rotated 90°. **J.** The jaws of the dilator are opened to open the incision transversely. **K.** An endotracheal tube is inserted through the incision and into the trachea.

are not usable due to hemorrhage and difficulty in identifying the anatomic landmarks. However, a technique has been developed to perform a cricothyroidotomy in these patients.[20–22]

To use this technique, the location of the hyoid bone must be determined (**Figure 25-8A**). A piece of suture, string, or tracheal tie is required. Place one end of the suture at the angle of the patient's mandible. Stretch the suture along the mandible and note where it contacts the tip of the chin (**Figure 25-8A, line 1**). Cut the suture at the point where it contacts the tip of the chin. Fold the suture in half. Place one end of the folded suture on the tip of the chin. Pull the other end of the folded suture tight to make a 90° angle to line 1 (**Figure 25-8A, line 2**). An imaginary line should be drawn from the free end of the folded suture to the angle of the patient's mandible (**Figure 25-8A, line 3**). This third line is the line used to identify the hyoid bone.

Insert a #11 scalpel blade through the midline of the neck in an upward and posterior direction along line 3 (**Figure 25-8B**). Advance the scalpel blade until it meets resistance as it contacts the hyoid bone. Alternatively, a spinal needle can be inserted along line 3 until it contacts the hyoid bone (**Figure 25-8C**). Then, insert the #11 scalpel along the track of the spinal needle until the hyoid bone is also contacted. **Do not remove the scalpel.** Insert a

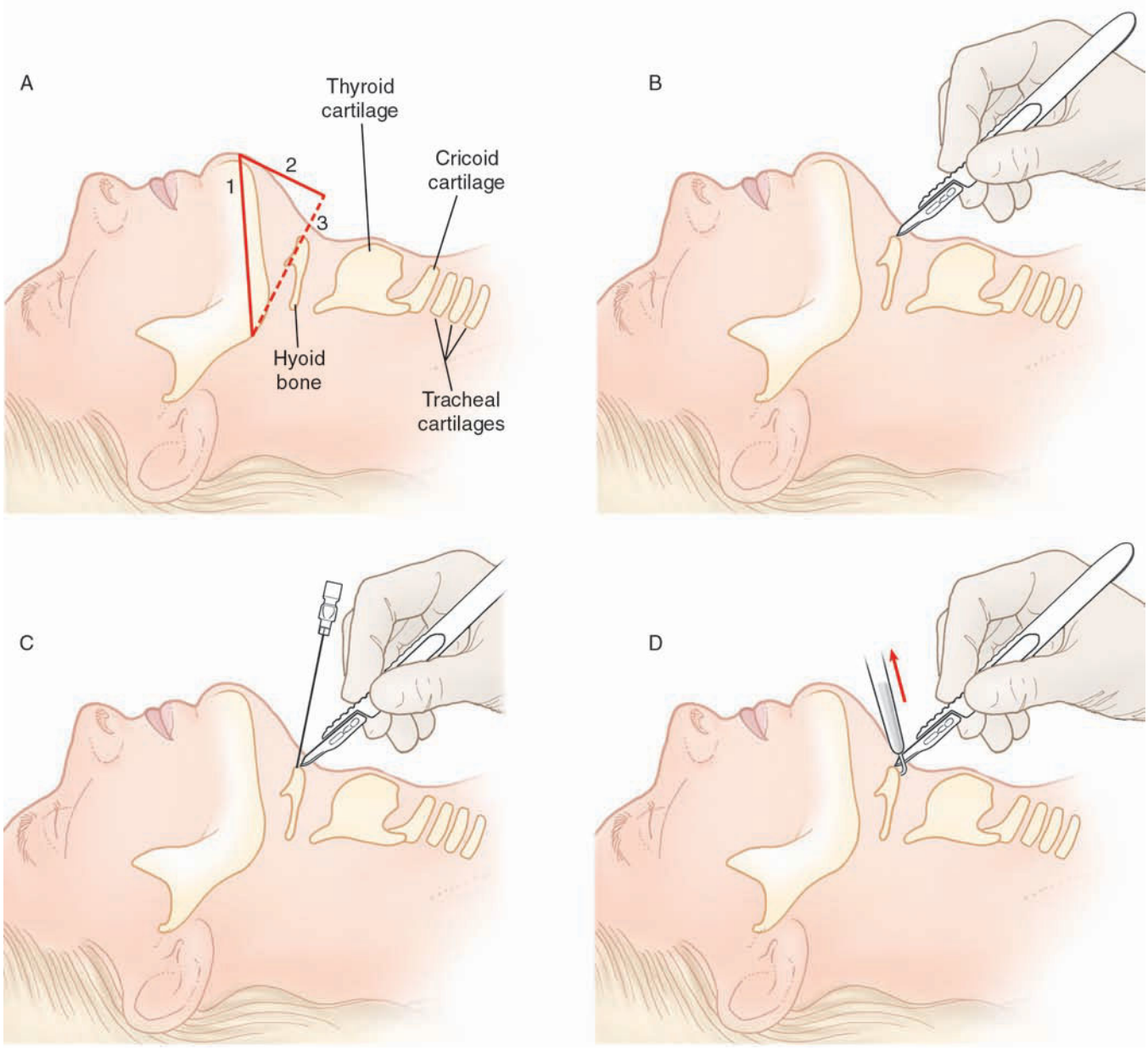


FIGURE 25-8. Cricothyroidotomy in a patient with neck swelling. **A.** Locate the hyoid bone. Line 1 is from the angle of the mandible to the tip of the chin. Line 2 is half the length of line 1 and perpendicular to it. Line 3 is from the end of line 2 to the angle of the patient's mandible. **B.** A #11 scalpel blade is inserted in the midline and aimed along line 3 until it contacts the hyoid bone. **C.** An alternative method. A spinal needle is used to locate the hyoid bone. A #11 scalpel blade is inserted along the tract of the spinal needle until the hyoid bone is contacted. **D.** A tracheal hook is inserted along the scalpel blade and used to grasp the hyoid bone. The tracheal hook is lifted (*arrow*) anteriorly and superiorly to elevate and control the airway.

tracheal hook along the scalpel blade until the hyoid bone is contacted. Move the tip of the tracheal hook under the hyoid bone (**Figure 25-8D**). Lift the tracheal hook anteriorly and superiorly to elevate and control the airway (**Figure 25-8D**). **Do not release the hold of the tracheal hook on the hyoid bone.** Remove the scalpel from the incision.

Make an incision inferiorly and in the midline starting at the site the tracheal hook exits the skin. **The incision should extend directly inferiorly without regard to the anatomy of the neck. Do not release the tension on the tracheal hook.** Identify the cricothyroid membrane. Make a transverse incision through the cricothyroid membrane. Dilate the opening and insert a tracheostomy tube or an endotracheal tube into the trachea as described previously.

SELDINGER TECHNIQUE

A percutaneous cricothyroidotomy kit is available from several manufacturers. One of the more commonly used kits is the Melker Percutaneous Cricothyrotomy Set (Cook Inc., Bloomington, IN). It is a self-contained kit that may be used in the prehospital setting, Emergency Department, or Operating Room. It contains percutaneous needles, a catheter-over-the-needle, a syringe, a #15 scalpel blade, adult and pediatric airway catheters, dilators that fit inside the airway catheters, a 30 cm flexible guidewire, and a tracheal tie (**Figure 25-9**). The dilator was developed to fit inside the airway catheter (**Figure 25-10**). The dilator and airway catheter are inserted as a unit during the procedure.

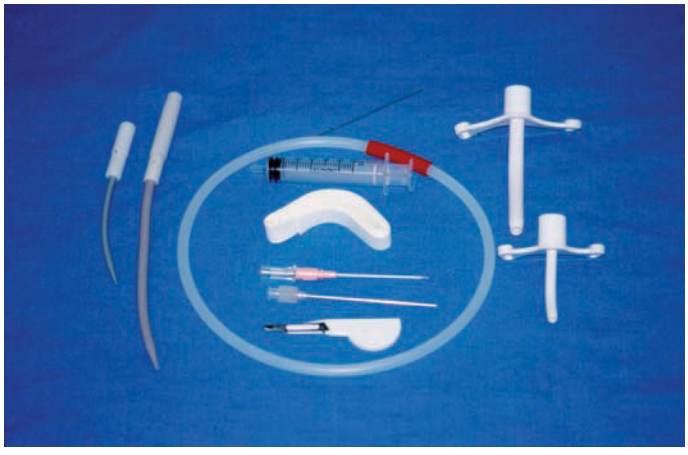


FIGURE 25-9. The percutaneous cricothyroidotomy kit (Cook Critical Care, Bloomington, IN).

The percutaneous cricothyroidotomy kit can be used to establish an airway using a modification of the Seldinger technique.[23–25] This technique can be used to establish an airway in about the time it takes to create a surgical cricothyroidotomy.[23,24] For those with little surgical experience, a percutaneous cricothyroidotomy is a simpler and quicker technique with which to establish an airway than traditional surgical methods. The technique is quite similar to inserting a central venous line.[28]

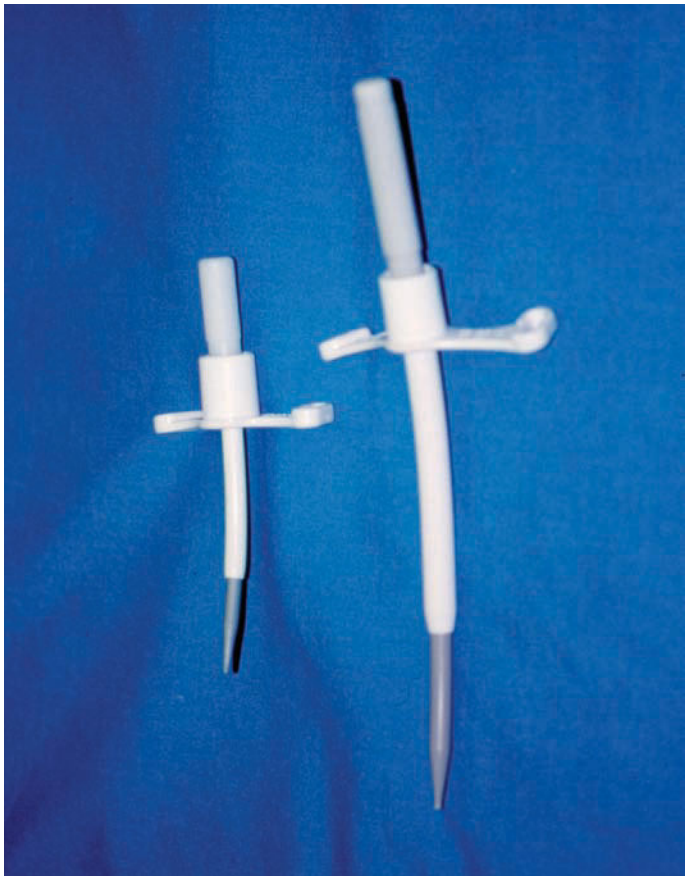


FIGURE 25-10. The dilator is placed inside the airway catheter to form a unit. The pediatric unit (*left*) and the adult unit (*right*) are both contained within each percutaneous cricothyroidotomy kit.

Clean, prep, drape, and anesthetize the patient's neck as mentioned previously. Lubricate the dilator liberally and insert it through the airway catheter (**Figure 25-10**). Lubricate the airway catheter and dilator after it has been assembled into a unit. Stabilize the trachea with the nondominant hand and identify the landmarks as previously described. Leave the nondominant index finger over the center of the cricothyroid membrane.

Make a stab incision just through the skin over the center of the cricothyroid membrane with the #11 scalpel blade (**Figure 25-11A**). Insert the catheter-over-the-needle attached to a 5 mL syringe containing saline through the skin incision and aimed inferiorly (**Figure 25-11B**). Insert and advance the catheter-over-the-needle at a 30° to 45° angle to the skin (**Figure 25-11B**). Advance the catheter-over-the-needle while applying negative pressure to the syringe. Stop advancing the catheter-over-the-needle when the airway has been entered. This will be signified by a loss of resistance and air bubbles in the syringe (**Figure 25-11B**).

Hold the syringe securely and advance the catheter over the needle until the hub is at the skin of the neck. Hold the catheter hub securely against the skin of the neck and remove the needle and syringe. Insert and advance the guidewire through the catheter and into the trachea (**Figure 25-11C**). Grasp the guidewire securely and remove the catheter over the guidewire (**Figure 25-11D**). **Do not release your grasp on the guidewire in order to prevent it from completely entering the patient's airway.**

Insert the dilator/airway catheter unit over the guidewire and into the trachea in a semicircular motion (**Figure 25-11E**). The tip of the dilator is rigid. **Insert it gently to prevent injury to or perforation of the posterior tracheal wall.** Continue to advance the unit until the flange is against the skin of the neck. Hold the airway catheter securely. Remove the guidewire and dilator as a unit, leaving the airway catheter in place (**Figure 25-11F**). Begin ventilation of the patient and secure the airway catheter as previously described.

NEEDLE CRICOTHYROIDOTOMY

A needle cricothyroidotomy, rather than a surgical cricothyroidotomy, should be performed in children less than 8 years of age. The latter is technically more difficult. The child has a laryngeal prominence that is difficult to palpate as it is not well developed. The cricothyroid membrane is small and often will not allow the passage of an airway tube. The larynx is anatomically positioned relatively higher than in an adult and is more difficult to access. A commercially available kit (ENK Oxygen Flow Modulator Set, Cook Inc., Bloomington, IN) or commonly available equipment in the Emergency Department may be used to perform this procedure.

Stand at the side of the bed and adjacent to the patient's head and neck.[11] **Reidentify the anatomic landmarks. This is crucial to performing this procedure.** Using the nondominant hand, place the thumb on one side of the thyroid cartilage and the middle finger on the other side. Use these fingers to stabilize the larynx.[8,14] Use the index finger to identify the anatomic landmarks.[4,5,11] Start at the laryngeal prominence (Adam's apple) and work inferiorly. The soft membranous defect inferior to the laryngeal prominence is the cricothyroid membrane. Below this is the cartilaginous ring of the cricoid cartilage.

Attach a 12 to 16 gauge catheter-over-the-needle (angiocatheter) onto a 10 mL syringe containing 5 mL of sterile saline. Insert the catheter-over-the-needle through the skin, subcutaneous tissue, and inferior aspect of the cricothyroid membrane. The inferior aspect of the cricothyroid membrane is the preferred site, as use of it avoids injury to the cricothyroid arteries. Direct the catheter-over-the-needle inferiorly and at a 30° to 45° angle (**Figure 25-12A**). Maintain constant negative pressure within the syringe as it is advanced

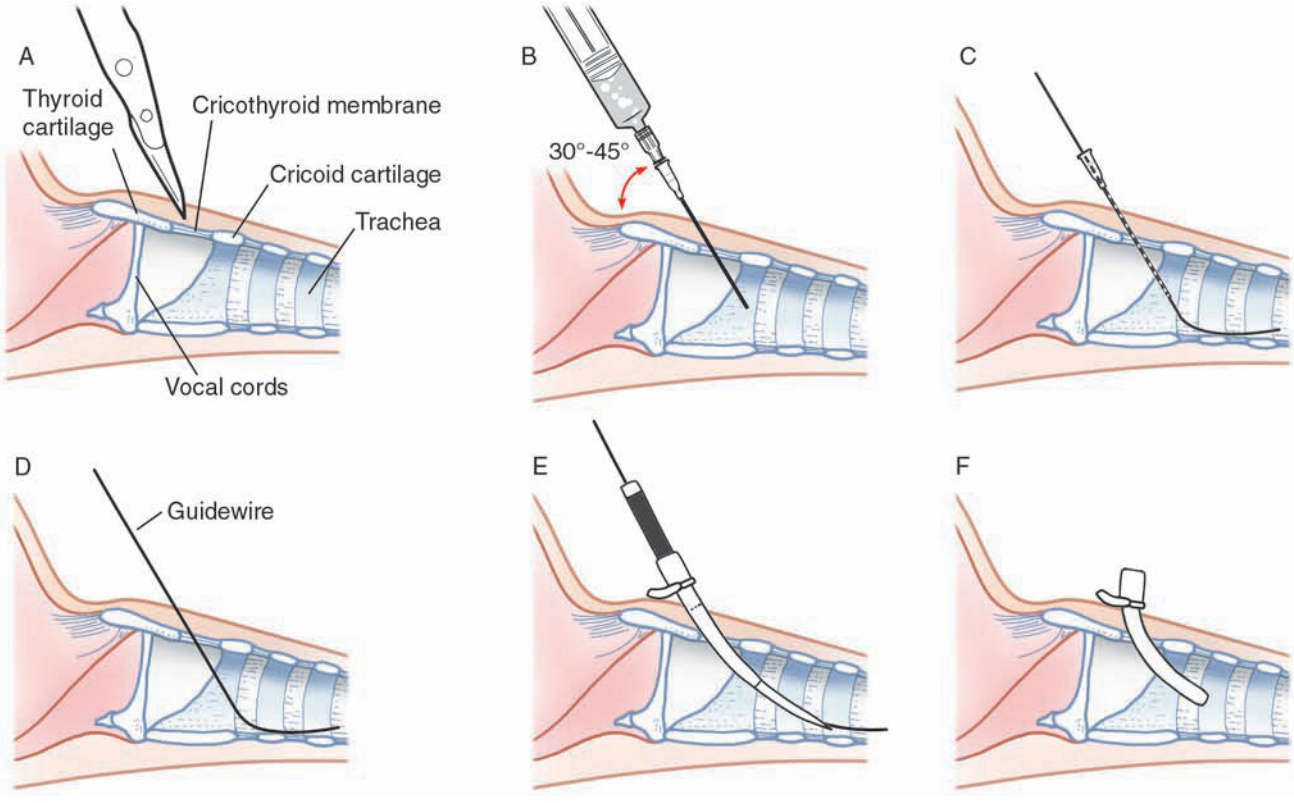


FIGURE 25-11. The percutaneous cricothyroidotomy. **A.** A stab incision is made in the midline over the cricothyroid membrane. **B.** A catheter-over-the-needle is inserted at a 30° to 45° angle to the skin and advanced in a caudal direction. Negative pressure is applied to a saline-containing syringe during catheter insertion. Air bubbles in the saline confirm intratracheal placement of the catheter. **C.** The catheter has been advanced until the hub is against the skin. The needle and syringe have been removed. A guidewire is inserted through the catheter. **D.** The catheter has been removed, leaving the guidewire in place. **E.** The dilator/airway catheter unit are advanced over the guidewire. **F.** The guidewire and dilator have been removed, leaving the airway catheter in place.

(**Figure 25-12B**). Continue to advance the catheter-over-the-needle while maintaining negative pressure until air bubbles are visible in the syringe and a loss of resistance is felt. These both signify that the catheter-over-the-needle is within the trachea.

Once placement within the trachea is confirmed, securely hold the needle and advance the catheter until the hub is against the skin (**Figure 25-12C**). Remove the needle and syringe (**Figure 25-12C**). Reattach the syringe without the needle to the catheter. Aspirate once again to reconfirm placement of the catheter within the trachea. The 2 to 3 cm catheter should be long enough to pass into the trachea without sitting against the posterior wall. If the catheter tip directly touches or faces the posterior tracheal wall, there is the risk of forcing air submucosally. Grasp and hold the catheter hub firmly at the skin of the neck. Remove the syringe. Attach the oxygen tubing to the catheter (**Figure 25-12D**). Begin ventilation and continue until a more permanent and secure airway is established.

At this point, the patient may be oxygenated and ventilated by two methods. The first involves inserting the adapter piece from a #3.0 endotracheal tube to the catheter hub and then connecting it directly to the bag-valve device or a ventilator. This method allows for the confirmation of breath sounds and provides better ventilation of the patient.

The second method of oxygenation involves direct connection of the high-flow oxygen tubing to the hub of the catheter. This method requires cyclic ventilation for 1 to 2 seconds followed by exhalation for 4 to 5 seconds.[12] This method provides adequate oxygenation but less adequate ventilation and is more labor-intensive. The complete details of percutaneous transtracheal jet ventilation can be found in Chapter 24.

Once breath sounds are confirmed, the catheter can be secured to the skin. This may be done with nylon sutures or strips of adhesive tape. The patient should undergo orotracheal intubation or a formal tracheostomy as soon as possible because of the risk of dislodging the catheter and the suboptimal ventilation associated with this technique.

ALTERNATIVE TECHNIQUES

If a tracheostomy tube is not available, an endotracheal tube can be used. The endotracheal tube is much longer than is needed. Remove the 15 mm connector from the proximal end of the endotracheal tube. Cut the endotracheal tube with scissors just above where the tubing to inflate the cuff enters the tube. Place the 15 mm connector on the shortened endotracheal tube. The procedure to insert an endotracheal tube is the same as that for a tracheostomy tube.

A cricothyroidotomy is a seldom performed procedure. A tracheal hook may not be immediately available or found when one is required. A simple alternative is to make one using a 16 or 18 gauge needle, a 10 mL syringe, and a hemostat or needle driver (**Figure 25-13**). Securely apply the needle onto the syringe. Use the hemostat or needle driver to place two 90° bends in the distal needle (**Figure 25-13**). The syringe acts as a handle and the bent needle as a tracheal hook.

Numerous other percutaneous cricothyroidotomy kits are available. The QuickTrach (Rusch Inc. of Teleflex Medical, Research Triangle Park, NC) is a preassembled, one-piece device (**Figure 25-14**). The Bivona Nu-Trake (Smiths Medical, Inc., Gary, IN) is also preassembled, but requires the use of an obturator

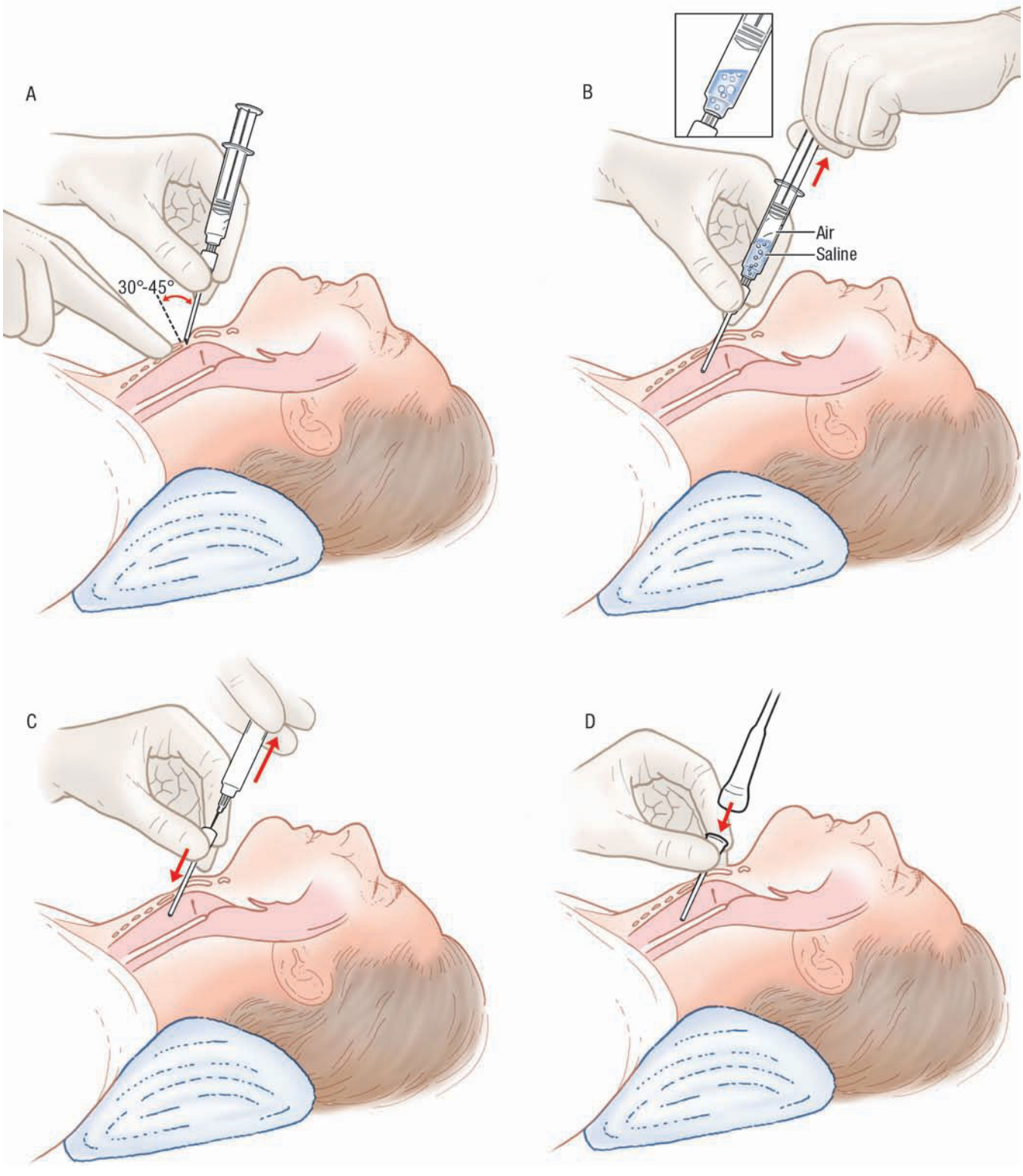


FIGURE 25-12. Needle cricothyroidotomy. **A.** The catheter-over-the-needle is inserted 30° to 45° to the perpendicular (*dotted line*) and aimed inferiorly. **B.** Application of negative pressure (*arrow*) to a saline-containing syringe during catheter-over-the-needle insertion. Air bubbles in the saline confirm intratracheal placement of the catheter. **C.** The catheter is advanced until the hub is against the skin. The needle and syringe are then removed. **D.** High-pressure oxygen tubing is attached to the catheter and ventilation is begun.

(**Figure 25-15**). These devices are quick, simple to use, and do not require the use of a guidewire or the Seldinger technique. These are more likely to be used in the prehospital setting than in the Emergency Department.

The use of a bougie or endotracheal tube introducer may aid the performance of a surgical cricothyroidotomy.[26] Begin the procedure as described previously. Once the airway is controlled with the tracheal hook, insert a bougie or endotracheal tube introducer through



FIGURE 25-13. A "homemade" tracheal hook.

the incision, directed inferiorly, and into the trachea. The bougie or endotracheal tube introducer will provide tactile feedback as it crosses the tracheal rings. Advance the tracheostomy tube or endotracheal tube over the bougie or endotracheal tube introducer and into the trachea. The major advantages of these devices are their lengths. It will not pull out and it will ensure that the tract is not lost.

Several quick assembly and low cost needle cricothyroidotomy setups can be put together quickly with commonly available equipment in the Emergency Department.[27] Insert a catheter-over-the-needle as previously described. Remove the needle, leaving the angiocatheter through the skin and into the airway. Attach and connect the following components in the listed order to the hub of the angiocatheter. The first consists of a 3.5 mm endotracheal tube respiratory adapter and a bag-valve device. The second consists of a 10 mL syringe without the plunger, a 7.0 mm endotracheal tube inserted into the syringe, and a bag-valve device. The third consists of a 3 mL syringe without the plunger, a 7.0 mm endotracheal tube respiratory adapter, and a bag-valve device. The fourth consists of the cut distal 10 cm of an intravenous infusion tubing, a 2.5 mm endotracheal tube respiratory adapter, and a bag-valve device.

ASSESSMENT

Immediately after securing the tracheostomy tube, confirm its proper positioning by auscultation of bilateral breath sounds, chest rise, and end-tidal CO_2 monitoring. Obtain a chest radiograph to confirm the position of the tube and rule out the presence of a pneumothorax.[12]



FIGURE 25-14. The Rusch QuickTrach.



FIGURE 25-15. The Bivona Nu-Trake.

AFTERCARE

The tracheostomy tube should be held in place firmly while the patient is ventilated with a bag-valve device or a ventilator.[11] **Do not release the hold on the tracheostomy tube until it is secured.** Obtain hemostasis of the wound edges by grasping any bleeding vessels with a hemostat and place an absorbable 3-0 suture over the vessel. If the skin incision is significantly larger than the tracheostomy tube, pack the wound with iodoform gauze. Secure the tracheostomy tube by placing twill tape (tracheostomy tape) through one end of the flange, around the patient's neck, and through the other end of the flange.[11,12] An alternative is to suture the four corners of the tracheostomy flange to the patient's skin using 3-0 nylon suture.

If an endotracheal tube was inserted, it should also be secured. Wrap tape around the endotracheal tube as it exits the incision site. Wrap the tape around the patient's neck and back onto the endotracheal tube. Alternatively, a commercially available endotracheal tube holder can be used to secure the tube.

The tracheostomy or endotracheal tube can be removed easily when the indication for airway control no longer exists. This usually occurs after the patient is orotracheally intubated, nasotracheally intubated, or has a formal tracheostomy performed. After removal of the tube, place an occlusive dressing, such as petroleum gauze, over the incision until it heals. If the patient is predicted to require ventilatory management for more than 7 days, it is advised that the cricothyroidotomy be converted to a formal tracheostomy to minimize the risk of long-term complications.

COMPLICATIONS

Complications following a cricothyroidotomy can be classified as early or late based on when they occur. Early complications will be recognized either immediately after insertion of the tracheostomy tube or within a few hours. Late complications may not be apparent for weeks to months following the procedure.

The most serious early complication is malposition of the tracheostomy tube within the soft tissues of the neck. If the tube is not within the trachea, the patient cannot be ventilated or oxygenated. This, fortunately, is easily recognized on auscultating the chest. It can be remedied by removing the tracheostomy tube and replacing it in its proper location. The tube may also be misplaced above or below the cricothyroid membrane. Placement above the cricothyroid membrane often results from inadequate palpation of landmarks and is associated with an incision into the larynx. The airway

should be converted to a tracheostomy once this malposition is recognized.[6] Placement below the cricoid cartilage has been estimated to occur in 10% of cricothyroidotomies.[2] There is no specific treatment required for this other than the recognition that the patient actually has a high tracheostomy.

Laryngeal injury may occur if the tracheostomy tube that is inserted is larger than the cricothyroid membrane. The cricothyroid membrane is only 9 to 10 mm in height in the average adult.[8,11] Placement of a tracheostomy tube with a larger outer diameter may cause a fracture of the thyroid cartilage. It is important that the tracheostomy tube placed is no larger than a #6.0 or a #7.0.[8,11] Placement of a larger tube is also associated with an increased incidence of subglottic granulation and stenosis.[2,4]

Incisional bleeding occurs in 4% to 8% of patients following a cricothyroidotomy.[2,4,6,8,15] This may result from transection of the anterior jugular veins if the incision extends too far laterally. Bleeding is usually easily treated by point ligation of the bleeding vessels and packing around the tracheostomy tube with iodoform gauze. A small amount of bleeding or oozing from the cricothyroid arteries can be tamponaded by packing iodoform gauze around the tracheostomy tube.

An emergent cricothyroidotomy is usually performed in less than sterile circumstances. There is thus a risk of developing a wound infection.[15] This is usually the result of skin flora. It can often be treated with wet-to-dry saline dressing changes. Occasionally, the infection will not resolve until the cricothyroidotomy tube has been removed, either by decannulation or conversion to a formal tracheostomy. Antibiotics are usually not required.

Late complications take two general forms: progressive airway obstruction and chronic voice changes. Patients with progressive airway obstruction present with slowly increasing stridor and dyspnea weeks to months after the procedure. This usually results from subglottic stenosis and granulation tissue formation at the site of the stoma.[2,6,13] It is unclear whether this complication results from the cricothyroidotomy or the tracheostomy tube. The majority of these patients have had prolonged endotracheal intubations before the cricothyroidotomy or prolonged tracheostomy placement after the cricothyroidotomy.[2,13,14,16] In one series, patients with a cricothyroidotomy for a prolonged period (average 72 days) had a 52% incidence of chronic obstruction compared to no obstruction in patients with cricothyroidotomy for a shorter period (average 27 days).[16] Another study recommended that the tracheostomy tube be removed by the fourth day to minimize these long-term complications.[9]

A final late complication is that of voice changes. This has been described in up to 25% of patients that received a cricothyroidotomy.[6,13–15] Again, many of these patients had other methods of airway management either before or after the cricothyroidotomy. Voice changes tend to be somewhat nonspecific. Patients will complain of hoarseness, decreased volume, and fatigue. These changes may be due to small amounts of granulation tissue at the stoma site and generally resolve over time.[4]

SUMMARY

A cricothyroidotomy is a potentially lifesaving airway management technique. It is an important procedure for the Emergency Physician to be skilled in, as it may represent the only access to the patient's airway. It can be used to provide oxygenation and ventilation to a patient when other less invasive airway control methods have failed or are contraindicated. It is a relatively safe, simple, and reliable procedure that can be performed within a few minutes. A self-contained percutaneous cricothyroidotomy kit is commercially available and simple to use. Knowledge of the anatomy of the anterior neck is essential in order to minimize complications.

26 Tracheostomy

Teresa M. Romano and Christopher J. Haines

INTRODUCTION

Control of the airway is the first priority in the resuscitation of a critically ill patient and must be accomplished before any other intervention can proceed. Emergency Physicians are equipped with multiple nonsurgical techniques and devices to secure an airway including orotracheal intubation, nasotracheal intubation, and laryngeal mask airways. Unfortunately, there are cases in which these methods become impossible or are contraindicated. In these instances, a surgical airway must be obtained and can be accomplished by performing a cricothyroidotomy or tracheostomy. Cricothyroidotomy is described in Chapter 25. This chapter will focus on the indications, technique, and complications for a tracheostomy.

A tracheotomy is the surgical creation of an opening into the trachea, while tracheostomy refers to the more permanent procedure of bringing the tracheal mucosa into contact with the skin of the neck.[1,2] The most traditional role for a tracheostomy is as an elective procedure done in patients with the need for a prolonged artificial airway. The role of a tracheostomy for emergent airway access has diminished as newer, safer, and equally effective techniques have evolved.

Familiarity with the methods to perform a tracheostomy is still valuable. Knowledge of proper techniques, possible indications, limitations, and likely complications will guide one's judgment in critical moments, when it most counts. Understanding the procedure for a tracheostomy will allow Emergency Physicians to properly care for a problem or complication when a patient with a tracheostomy tube presents to the Emergency Department.

ANATOMY AND PATHOPHYSIOLOGY

A surgical approach to the airway relies upon a sound knowledge of the anatomy of the neck and a safe approach to the trachea. **A careful review of this anatomy illustrates how critical it is to remain in the midline in order to avoid morbidity and mortality.** External landmarks are useful in identifying the significant structures of the airway (**Figure 26-1**).[3,4] The laryngeal prominence is a useful guide to the thyroid cartilage. The cricoid cartilage can be identified as a ring just inferior to the thyroid cartilage. In the absence of edema or

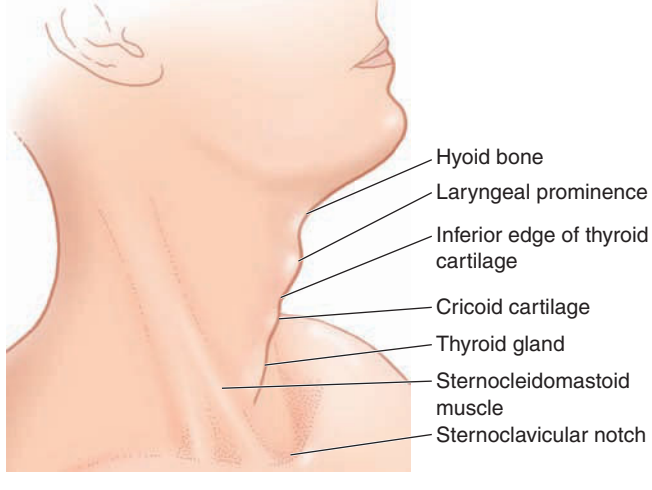


FIGURE 26-1. Lateral view of the topographic anatomy of the neck.

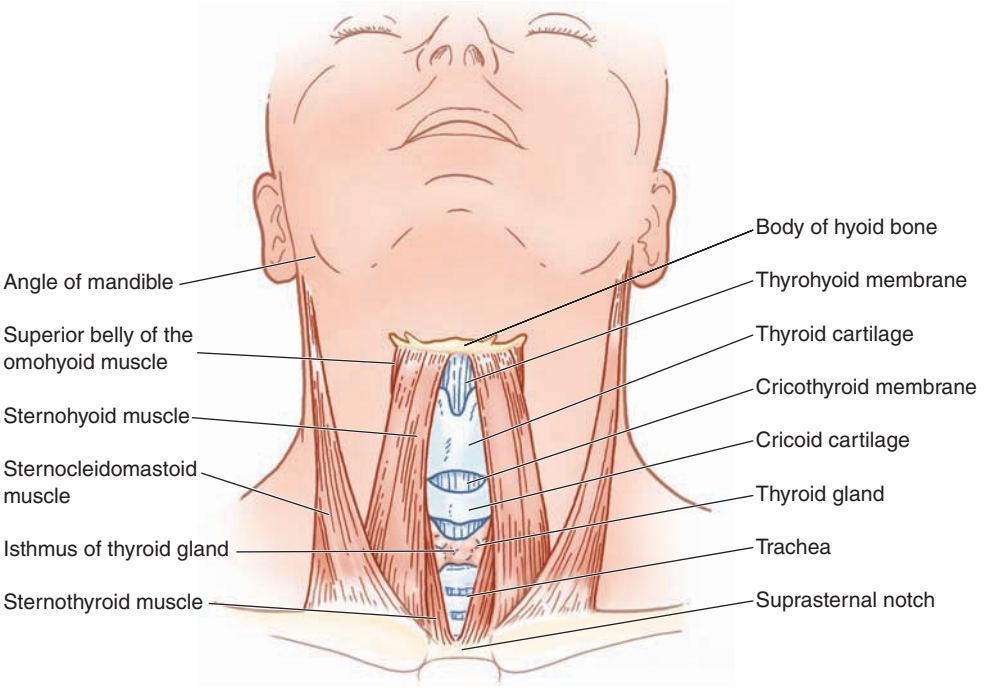


FIGURE 26-2. The superficial muscles and airway structures in the neck.

a hematoma, a finger marched down the midline from the cricoid cartilage can palpate and identify the cartilaginous rings of the trachea. In an emergent situation, these external landmarks may be all a physician has to guide the establishment of a surgical airway.

The neck is a complex three-dimensional structure with numerous vital structures coursing through a small space (**Figures 26-2** through **26-6**). The cervical portion of the airway is anterior, superficial, and midline. It is covered by skin, subcutaneous tissue, and numerous muscles (**Figure 26-2**). The basic cartilaginous framework of the airway begins superiorly at the hyoid bone and continues inferiorly with the larynx and trachea (**Figure 26-3**). The external skeleton of the larynx comprises the hyoid bone, thyroid cartilage, and cricoid cartilage.[5] The hyoid bone is a U-shaped structure attached to the mandible, tongue, and base of the skull by muscles. It is the most stable portion of the airway. Even in the presence of pathology, the hyoid bone is remarkably constant in position and can be considered a stable landmark.[6–8]

The larynx is easy to identify externally. The prominent thyroid cartilage forms the laryngeal prominence (Adam's apple) at its inferior pole (**Figure 26-3**). It is a freely mobile structure that is anchored by muscles and moves with deglutition. Airway manipulation done on an awake patient will need to fix the larynx to avoid involuntary movement of the larynx from reflex swallowing. The thyroid cartilage is attached to the cricoid cartilage via the cricothyroid membrane (**Figure 26-3**). This is the site for a cricothyroidotomy and can be identified by palpating a slight indentation inferior to the laryngeal prominence. The cricoid is signet ring-shaped and is the only complete cartilaginous ring in the airway. Procedures should avoid damage to the cricoid cartilage, fearing a loss of stability in the airway. The cricotracheal ligament attaches the cricoid cartilage to the trachea.

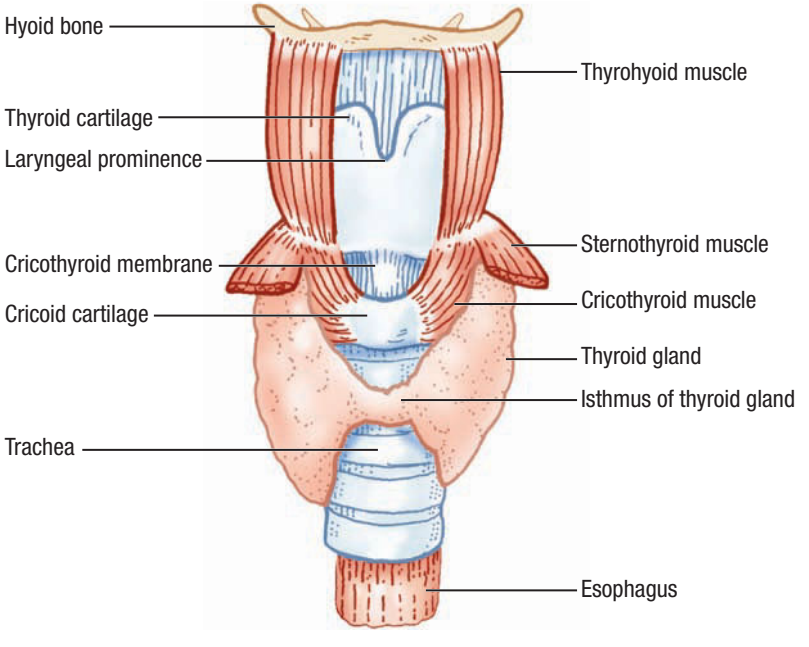


FIGURE 26-3. The framework of the airway in the neck.

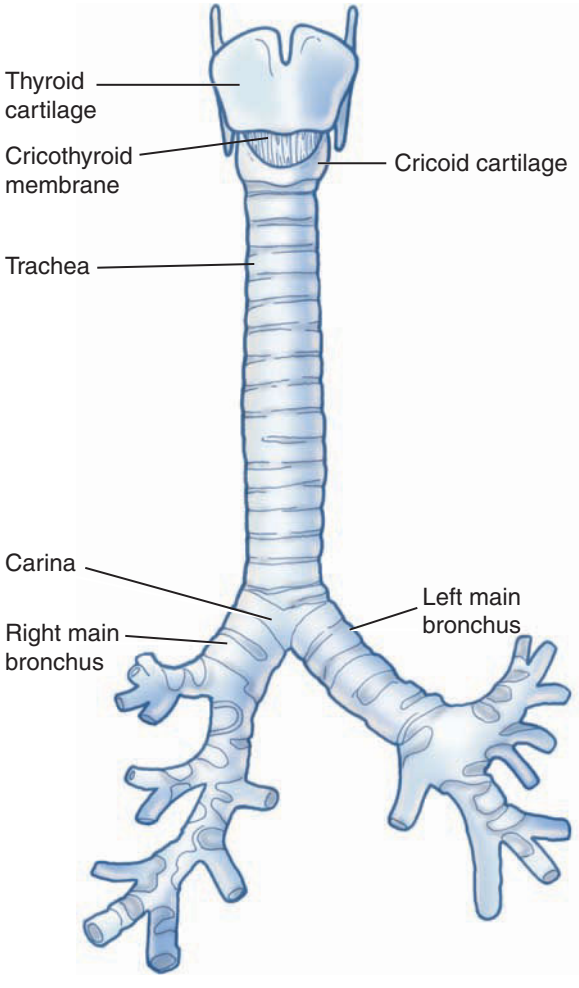


FIGURE 26-4. The cartilaginous framework of the airway.

The trachea is a cartilaginous and membranous tube that is approximately 10 to 11 cm long and 2 to 2.5 cm wide in the average adult. In the pediatric patient, the length and width of the trachea will vary depending on the size and age of the child.[9] It extends from the neck into the thorax, where it ends at the carina by dividing into the right and left mainstem bronchi (**Figure 26-4**). It is made up of 16 to 20 incomplete U-shaped cartilaginous rings anteriorly and laterally. The posterior portion is comprised of a fibromuscular membrane. This membrane attaches the cartilaginous rings to one another and imparts great elasticity in the trachea.[2] Full extension of the neck adds significant length to the supraclavicular trachea. This feature should be taken advantage of when performing a tracheostomy.[10]

The trachea is bordered anteriorly by skin, subcutaneous tissue, platysma muscle, pretracheal fascia, and the thyroid gland (**Figure 26-5**). The pretracheal fascia is the anterior portion of the deep cervical fascia. It descends from the thyroid and cricoid cartilages and splits to enclose the thyroid gland, trachea, and esophagus. The pretracheal fascia continues downward into the thorax and mediastinum. Anterior to the trachea, it is very thin and inconsequential. Laterally, it is extremely thick and blends with the carotid sheath.

The thyroid gland lies anterior to the second through fourth tracheal rings and is inevitably encountered during a tracheostomy. It is a richly vascular structure (**Figure 26-6**) that receives its blood supply from the superior thyroid artery (a branch of the external carotid artery) and the inferior thyroid artery (a branch of the thyrocervical trunk). These vessels anastomose into a rich plexus on the anterior surface of the thyroid gland. These major arteries do not usually cross the midline.

Unfortunately, the midline is not always free of blood vessels. An unpaired thyroid ima artery will occasionally be found in the midline to supply the isthmus of the thyroid gland. The anterior thyroid veins often form a vascular arch across the midline and just inferior to the thyroid gland. A hastily performed tracheostomy or one carried out under difficult conditions may encounter significant hemorrhage from transected vessels.

A number of vital structures surround the trachea and are at risk for injury during a tracheostomy. Their positions relative to one another are best appreciated in a cross-sectional view of the neck (**Figure 26-5**). The deep strap muscles, the sternohyoid and sternothyroid, run adjacent to the trachea and may have to be reflected away for adequate visualization (**Figure 26-2**). The right and left lobes of the thyroid gland encase the upper trachea (**Figures 26-5 & 26-6**) with the thyroid isthmus crossing anteriorly from the second to the third tracheal rings.[2] Close to the thyroid lobes, the recurrent laryngeal nerves run vertically on both sides of the trachea. These nerves are particularly vulnerable when dissection is extended laterally.[11] The common carotid artery, internal jugular vein, and vagus nerve are contained by the carotid sheath and lie adjacent to the thyroid gland. The carotid sheath lies extremely close to the trachea

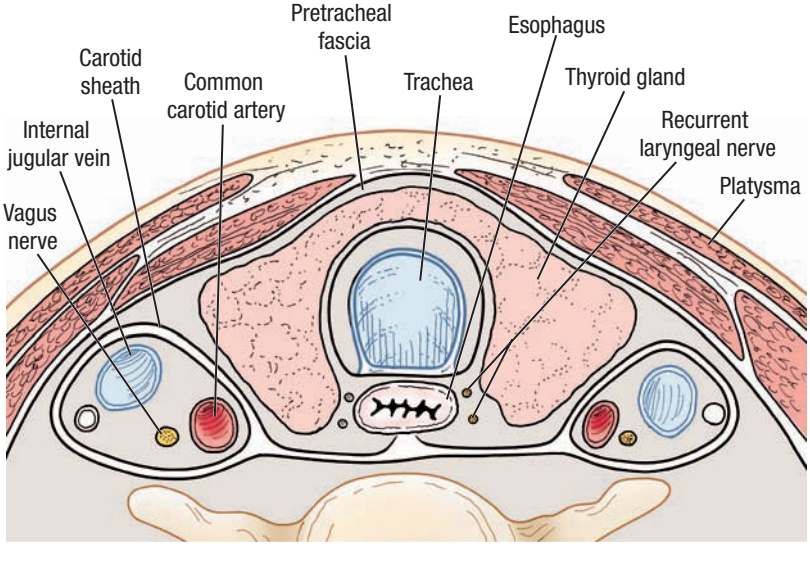


FIGURE 26-5. Cross-sectional anatomy of the neck at the level of the isthmus of the thyroid gland.

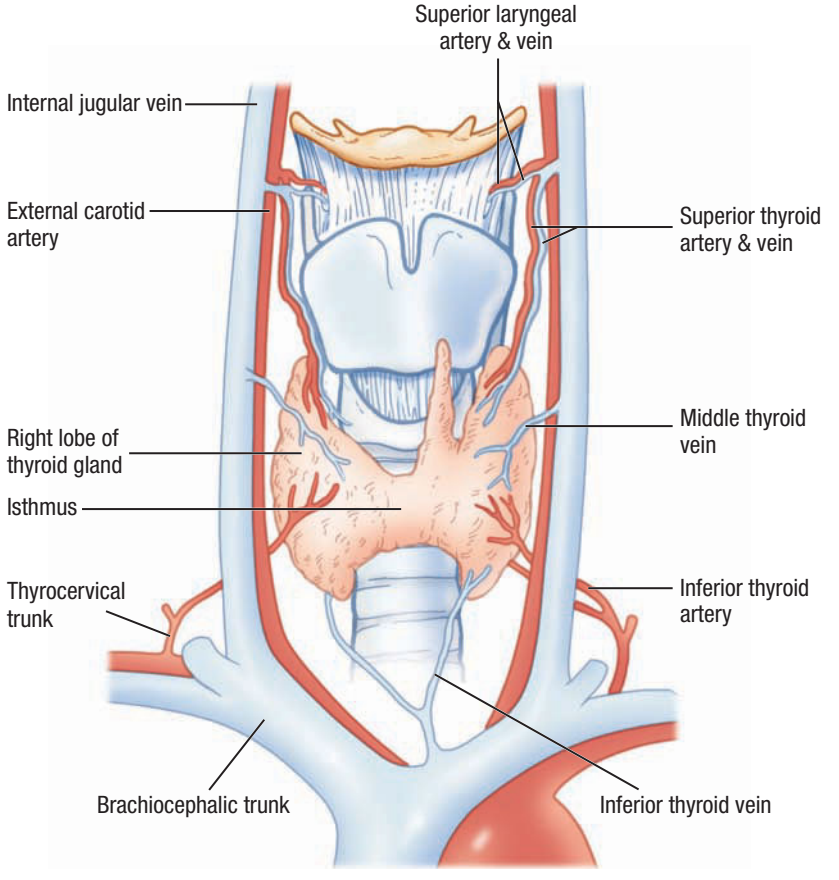


FIGURE 26-6. Vascular structures supplying and surrounding the thyroid gland.

in infants and have been mistaken for the trachea in emergent situations.[11] The innominate or brachiocephalic artery crosses left to right immediately anterior to the trachea, while the esophagus lies immediately posterior to the trachea. Erosion of the anterior tracheal wall can occur with prolonged tracheostomy tube placement leading to a tracheoinnominate artery fistula. The parietal pleura can be found on either side of the trachea at the sternal notch and is also at risk of injury during a tracheostomy.

INDICATIONS

The tracheostomy is an ancient and time-honored technique for securing and maintaining an artificial airway. The American Academy of Otolaryngology—Head and Neck Surgery has proposed specific clinical indicators for the use of a tracheostomy (**Table 26-1**).[12] A number of indications for tracheostomy are widely accepted (**Table 26-2**).[11–18] As mentioned previously, a tracheostomy is generally considered an elective procedure done under nonemergent conditions after the airway has been secured by other techniques.[19–23] Its use as an emergency procedure is controversial. Used by battlefield surgeons during wartime, its reputation as a procedure of last resort is not without reason. When performed under emergency circumstances, it is fraught with danger.

A tracheostomy is frequently considered in the treatment of upper airway obstructions including epiglottitis, deep space neck infections, angioedema, airway foreign bodies, multiple lacerations to the floor of the mouth, and complex facial fractures. Although these conditions can create serious and immediate airway compromise, the airway can be managed in most cases with orotracheal

TABLE 26-1 Clinical Indications for Performing a Tracheostomy, as Proposed by the American Academy of Otolaryngology–Head and Neck Surgery

Upper airway obstruction, including
Obstructive sleep apnea
Bilateral vocal cord paralysis
Need for prolonged mechanical ventilation
Inability of patient to manage his or her secretions
Facilitation of ventilation support
Adjunct to manage head and neck surgery
Adjunct to manage head and neck trauma
Difficulty with intubation and need for airway

Source: Adapted from Weissler.[12]

TABLE 26-2 Commonly Cited Indications for Performing a Tracheostomy

Airway obstruction[13–15,17]
Tumor, trauma, hemorrhage
Edema, foreign body, infection
Congenital airway anomalies
Trauma to face and neck with airway compromise[13,14,16]
Inability to open mouth
Maxillomandibular fixation, trismus[18]
Angioedema[15,17]
Need for prolonged ventilatory support[14]
Impaired clearance of secretions
Need for aggressive pulmonary toilet[15]
Laryngeal injury[7,10,15]
Unstable cervical spine[16]
Laryngospasm[17]
Surgical airway in an infant[7]
Inability to intubate by other measures[16]

intubation. **An emergency tracheostomy is not the treatment of choice but rather the choice of last resort**.

There are a few clinical settings in which an emergency tracheostomy should be considered: laryngotracheal injury with airway disruption;[11,28,29] severe maxillofacial trauma; complete subglottic obstruction; and the need for an airway when all other methods have failed. With the exception of these limited applications, an emergency tracheostomy is discouraged.[11,14,32,33]

LARYNGOTRACHEAL TRAUMA

Most head and neck trauma patients can be managed with nonsurgical airway techniques. There are a number of options available, including orotracheal intubation, nasotracheal intubation, intubation guided by a lighted stylet or "lightwand," retrograde guidewire intubation, and fiberoptic-assisted intubation. Nasotracheal intubation should be avoided in patients with a potential head injury. If a surgical airway is necessary, a cricothyroidotomy is usually the procedure of choice.

Laryngotracheal injuries are rare but potentially life threatening. When suspected, immediate efforts should focus on getting the patient to the operating room. These injuries can result from either blunt or penetrating injury to the neck. They are often accompanied by edema, hemorrhage, subcutaneous emphysema, and fracture of either the thyroid or cricoid cartilages. In their presence, rapid access to the cricothyroid membrane may be limited, making it difficult to perform a cricothyroidotomy, and tracheostomy should be considered.[11,34–36] Blunt injury has been described when the anterior neck forcefully strikes a fixed object such as a rope or a cable. A classic example of this type of injury is forcefully striking the anterior neck against the steering wheel during high-speed motor vehicle accidents.[11,35,36] Penetrating injuries to the airway are usually apparent; however, blunt injuries to the trachea require a high index of suspicion.[36,37] In a review of 51 patients with blunt injury to the trachea, the most common presenting signs and symptoms included subcutaneous emphysema, respiratory distress, hoarseness or dysphonia, and hemoptysis.[36] In this same review, a high rate of endotracheal intubation failure was reported with the conclusion that emergent tracheostomy was the best means of airway control.[36] In cases of penetrating trauma to the larynx, physicians may consider obtaining emergent airway control directly through the wound as a temporary measure prior to operative management.[9]

Laryngotracheal disruption, occurring when the larynx and trachea become separated, is an unusual injury. This is the one injury in which a tracheostomy is the undisputed method for establishing and securing the airway. Patients with laryngotracheal disruption may exhibit varying degrees of respiratory distress, visible bruising over the anterior neck, hoarseness or aphonia, subcutaneous emphysema or blood-streaked sputum. A defect may be palpable in the neck. Soft tissue radiographs of the neck may reveal an interrupted air column. If the airway is disrupted, a "low tracheostomy" between the fourth and fifth tracheal rings should be performed. The severed airway will tend to retract into the thorax, and a low tracheostomy will offer the best chance of securing the dismembered segment. Misguided attempts to visualize the airway, intubate orally, or perform a cricothyroidotomy may further damage the already precarious airway. This is fortunately a rare injury with only a few case reports in the literature.[28,29] A tracheostomy performed in this setting is more treacherous than usual. Although a tracheostomy may be the only way to secure the airway, this airway intervention has a better chance of success when performed in the operating room.

SURGICAL AIRWAYS IN THE PEDIATRIC PATIENT

Surgical approaches to the airway are more difficult and complicated in pediatric patients, especially newborns and infants. In the child, the larynx is positioned more cephalad than in the adult, allowing relative protection by the mandibular arch.[9] It is more anteriorly located and significantly smaller than in adults, as well as more floppy and mobile. The infant's cricothyroid membrane, unlike that of the adult, is extremely narrow and cannot easily be used for access to the airway. For this reason, a surgical cricothyroidotomy should be avoided until a child is greater than 12 years old.[9,11] Attempts at creating emergency surgical airways in children are typically acts of desperation. A calm, reasoned approach to the pediatric airway and common respiratory problems is essential. Efforts should first be made to suction the airway clear of secretions, followed by ventilation with a bag-valve-mask device. **Direct visualization by laryngoscopy and orotracheal intubation should be attempted before resorting to a surgical airway.** If an unstable patient cannot be ventilated, a needle cricothyroidotomy can serve as a temporizing measure until a surgical team can be assembled and better control achieved.[9,11]

In the pediatric population, laryngotracheal injury is rare.[11] Typically, children sustain blunt anterior neck injury as the result of high-speed accidents involving bicycles, falls, and motor vehicles. Additionally, this injury type may be the result of sports-related activity. Clinical signs and symptoms of laryngeal or tracheal trauma mirror that of adults. Airway management in these patients can be achieved with a tracheostomy. However, this may be quite difficult and is only advocated by some authors.[9] Attempts to obtain surgical assistance should be sought immediately.

CONTRAINDICATIONS

Simply stated, an emergency tracheostomy is contraindicated when other methods can be used to secure the airway. There are a few instances when an immediate surgical airway is necessary. **Cricothyroidotomy is the procedure of choice when a surgical approach to the airway is required**. Compared to a tracheostomy, a cricothyroidotomy is faster and more direct; it relies predominantly on external landmarks, requires only a single operator, can be done with ambient lighting, and requires a limited amount of equipment.[12,24] In contrast, a tracheostomy is a procedure requiring multiple steps. It involves direct visualization to dissect through vascular structures and requires better light than is commonly present at the bedside. It is easier and therefore faster to execute if one has an assistant, proper suctioning equipment, and electrocautery. Without these advantages, the technique is difficult and likely to be complicated. A "timely trach" can be performed within 5 to 10 minutes.[12] However, reported times to definitive airway during elective open tracheostomies have ranged from 13.5 to 105 minutes.[24–27] Although this time frame may be adequate for urgent situations, it is too slow for the true emergency in a patient who lacks an airway.

EQUIPMENT

A tracheostomy requires an extensive amount of equipment. Appropriate supplies should be sterilized and assembled in a prepackaged tray. A list of required equipment is given in **Table 26-3**. If such a tray is not available, supplies that are immediately on hand have to suffice. A thoracotomy or a major procedure tray will contain most of the required equipment.

PATIENT PREPARATION

Patient preparation will depend largely on the circumstances dictating the procedure. If the patient is uncooperative, hypoxic, or thrashing about, rapid control will have to be established with a sedative. The ideal agent is one that sedates with minimal hemodynamic consequences, preserves spontaneous respirations, and leaves an intact

TABLE 26-3 The Supplies Required to Perform a Tracheostomy

Patient preparation	Setup
Cardiac monitor	Povidone iodine or chlorhexidine solution
Pulse oximeter	Surgical drapes to enclose the field
Intravenous line with saline	Sterile gown, gloves, and mask
Oxygen	
Ambu bag for ventilating patient	
Procedure	
Local anesthesia	Two pairs of scissors, one straight and one curved
10 mL syringe	Two tissue forceps without teeth
1% lidocaine	Two Allis forceps, to grasp the trachea
18 gauge needle	Two small rakes, for exposure
25 gauge needle	Mastoid retractor
#10 scalpel blade and handle	Trousseau dilator
#11 scalpel blade and handle	Two tracheal hooks
Two skin forceps	10 mL syringe
Eight small curved hemostats	Umbilical tape
Sterile 4 × 4 gauze squares, two dozen	Needle holder
Two Kocher forceps (if needed, to clamp the thyroid)	
Frazier suction catheter with suction tubing	
Suture ligatures (3–0 chromic, 3–0 silk, and 3–0 nylon)	
Tracheostomy tube, appropriate size for patient	
Water-soluble lubricant or anesthetic jelly	
Suction source and tubing	

gag reflex. If the patient is awake and cooperative, calm reassurance may allow the procedure to be performed under local anesthesia. If the patient is unconscious, a local anesthetic is sufficient.

Place a rolled towel under the patient's shoulders and neck if no contraindications exist (Figure 26-7). This detail cannot be emphasized enough. Full neck extension brings the airway anterior and increases the length of the supraclavicular trachea by as much as 2.6 cm.[9] It enlarges the surgical field for improved access. Neck extension tends to fix the airway in position and pull it taut. When the neck is in a neutral or flexed position, the trachea lies more posteriorly and is more "floppy." In this situation, it is easier for the operator to stray off midline. When the neck is flexed, the surgical field may be reduced to a dark hole with poor visibility. In the pediatric patient, a certain degree of extension is helpful, but full extension may occlude the airway.



FIGURE 26-7. Optimal patient positioning for a tracheostomy with the neck extended.



FIGURE 26-8. Hand positioning to palpate the anatomic landmarks.

Prior to beginning the incision, the physician should check the equipment. A tracheostomy tube that is appropriate for the patient's size should be selected. An average male will accommodate a size 7 or 8 Shiley tracheal tube. An average-size female will accommodate a size 6 or 7 Shiley tracheal tube. The cuff of the tracheal tube should be tested prior to use. As an alternative, an endotracheal tube can be used.

Identify the anatomic landmarks required to perform this procedure. Using the nondominant hand, place the thumb on one side and the middle finger on the other side of the patient's trachea (**Figure 26-8**). Identify the laryngeal prominence (Adam's apple) with the index finger. Slide the index finger caudally to identify the cricothyroid membrane, cricoid cartilage, and tracheal rings.

Clean the neck of any dirt and debris. Even during the resuscitation of an unstable patient, there should be adequate time for the use of aseptic solution as well as sterile technique. Prepare yourself by applying a mask, eye protection, sterile gown, and sterile gloves. Apply a sterile drape to isolate a surgical field. Infiltrate local anesthetic solution along the planned incision line. It was once thought that injection of local anesthetic into the trachea blunts the cough reflex and provides a sense of depth of the airway. A recent review of 97 patients who underwent an awake tracheostomy noted that this could result in cough, agitation, and less beneficial outcomes.[38]

Once the patient is positioned, prepped, and anesthetized, establishment of the airway should be just 2 to 3 minutes away. **The last step in preparation should be the mental decision that no other technique will suffice and the commitment to proceed with confidence.**

TECHNIQUE

In the most critical situation, the simplest technique is likely to be the most successful.[39] The right-handed operator should stand to the patient's right and fix the airway with their left hand (**Figure 26-8**). Left-handed operators should adjust their technique based on their preference for handedness. Apply the thumb and third digit of the nondominant hand on the thyroid cartilage while the index finger palpates the cricoid and tracheal rings (**Figure 26-8**). An awake or lightly anesthetized patient may swallow or gulp during

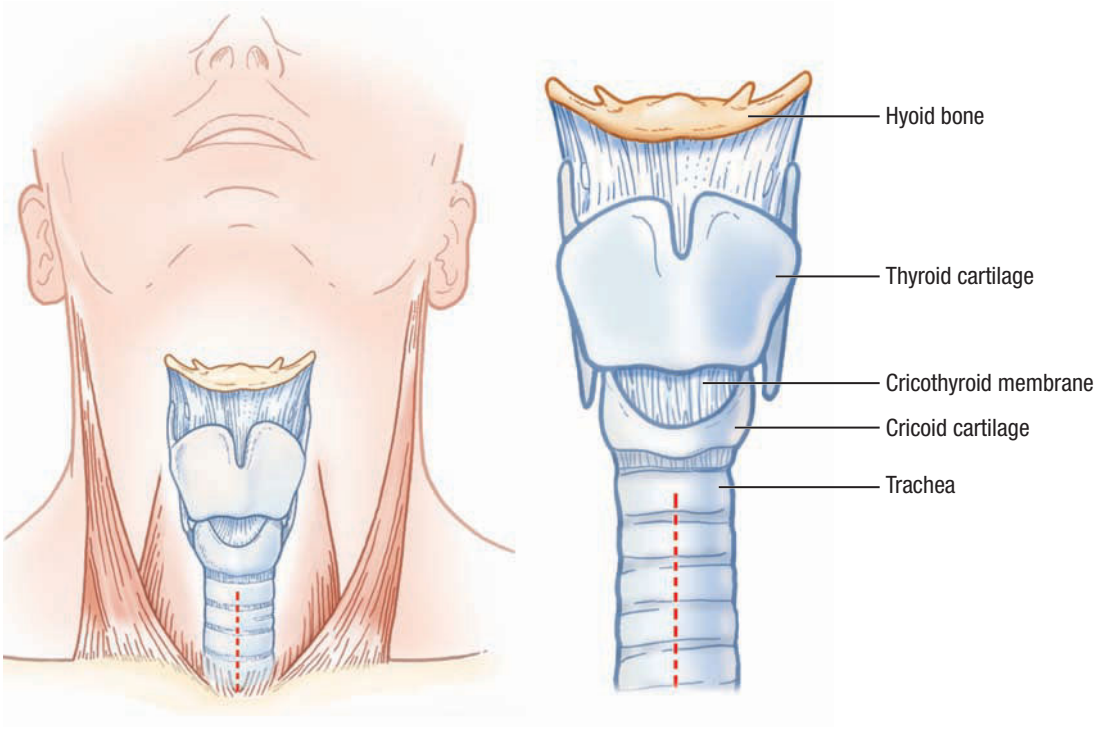


FIGURE 26-9. The skin incision is made in the midline, beginning below the cricoid cartilage and extending down toward the supraclavicular notch. An incision made with these landmarks will lie over the second through fourth tracheal rings.

the procedure, thereby moving the landmarks. Fixing the left hand firmly on the upper airway will minimize this distraction.

A vertical incision is preferred in the emergent setting because it allows greater exposure of the cricothyroid membrane and the trachea, and avoids traversing lateral structures.[11] Make a 3 or 4 cm vertical midline incision through the skin and subcutaneous tissues beginning just below the cricoid cartilage and extending inferiorly to the supraclavicular notch (**Figure 26-9**). A larger skin incision causes no harm as long as it remains superficial, to avoid damaging the cricoid cartilage. **Extreme care should be taken to ensure that the incision and further dissection remain in the midline.**[11]

Once the skin and subcutaneous tissue have been incised, attention should be directed toward clearing the pretracheal space and defining the tracheal rings. Divide the superficial and deep strap muscles in the midline and retract them away from the trachea (**Figure 26-10**). Bluntly dissect free and reflect away any blood vessels in front of the trachea. If they impede progress, they can be clamped with hemostats and divided. The thyroid gland lies above the trachea. Bluntly dissect between it and the trachea with a hemostat to mobilize the thyroid gland (**Figure 26-11**). An alternative option to consider in the emergent setting is to use the nondominant index finger to dissect the pretracheal space bluntly and reflect the thyroid isthmus either superiorly or inferiorly. This minimalist blunt approach lacks finesse but is effective and timely.[14]

Retract the thyroid gland upward (**Figure 26-12**). If this becomes difficult, it may be faster to divide the isthmus between two hemostats (**Figure 26-13**). The divided edges can be oversewn after the tracheostomy tube is in place. Once the thyroid has been divided, the operating field will be cluttered with hemostats and may be partially obstructed. Do not apply traction to the instruments, as this can avulse tissue, leading to bleeding and further obstruction of the surgical field.

When ready to make the tracheal incision, it may be helpful to have an assistant place a tracheal hook under the first tracheal ring and apply traction superiorly and anteriorly (**Figure 26-14**). Have the assistant hold the tracheal hook in position. This will elevate and immobilize the trachea. The assistant should direct their hands superior to the wound to keep the field unobstructed. If the neck is properly extended, this may be unnecessary. If at any time identification of the trachea becomes difficult, needle aspiration may be used to confirm the presence of an air-filled tube.

Make an incision in the trachea. The preferred tracheotomy is a midline vertical incision extending from the second through the

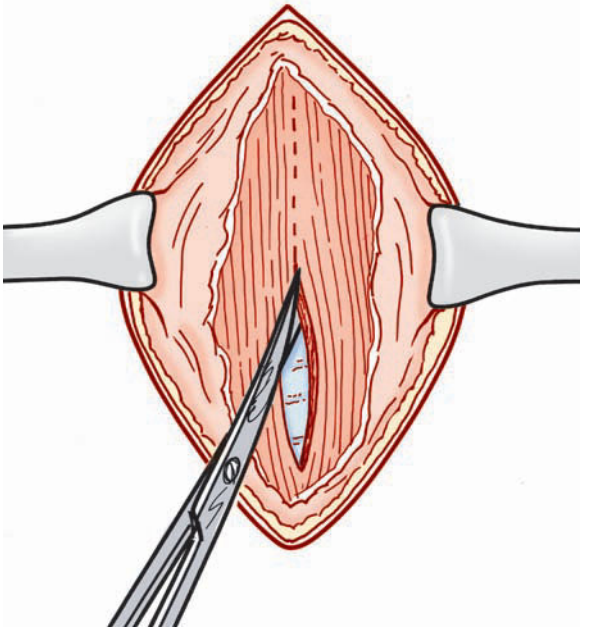


FIGURE 26-10. The skin and subcutaneous tissues have been retracted. The strap muscles are divided in the midline to expose the pretracheal space.

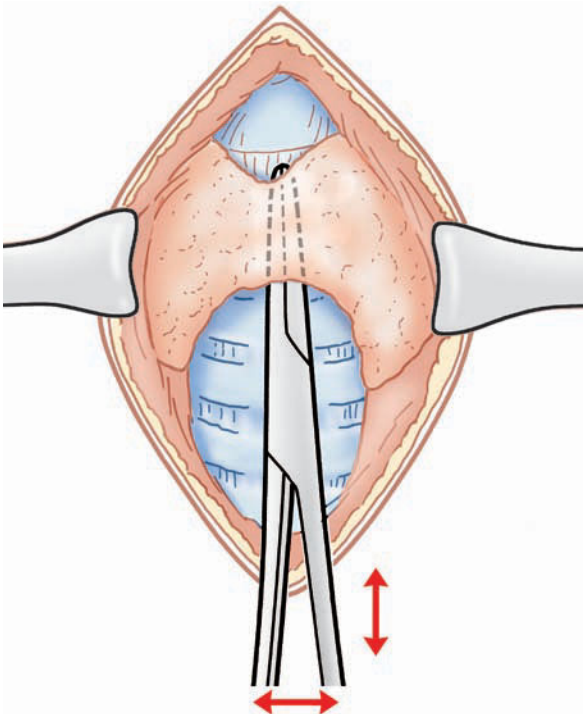


FIGURE 26-11. The thyroid gland is bluntly dissected from the trachea. Arrows represent movement of the hemostat.

fourth tracheal rings (**Figure 26-15A**). There are other options, but they are discouraged in the emergent setting because they stray from the midline (**Figures 26-15B** to **26-15D**). Insert a Trousseau dilator or hemostat into the incision. Use the dilator to open and widen the incision. Alternatively, the sides of the tracheal incision can be grasped and held open with Allis forceps (**Figure 26-16A**).

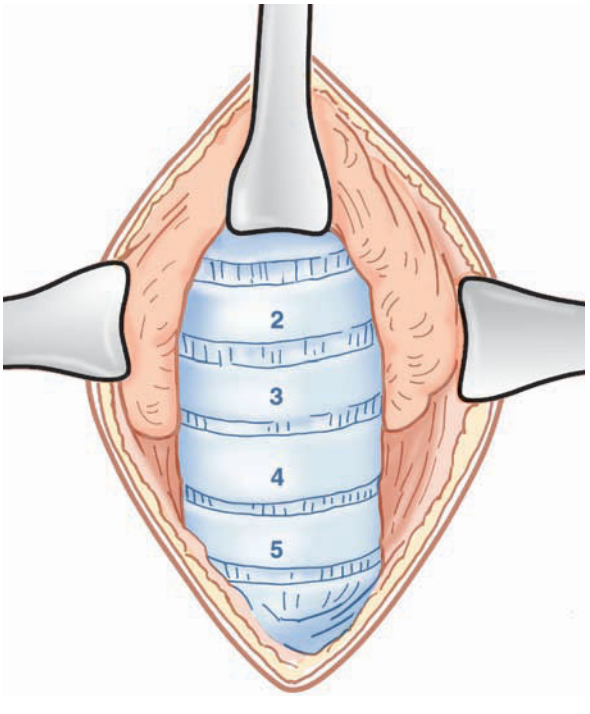


FIGURE 26-12. The thyroid gland is retracted upward and out of the surgical field.

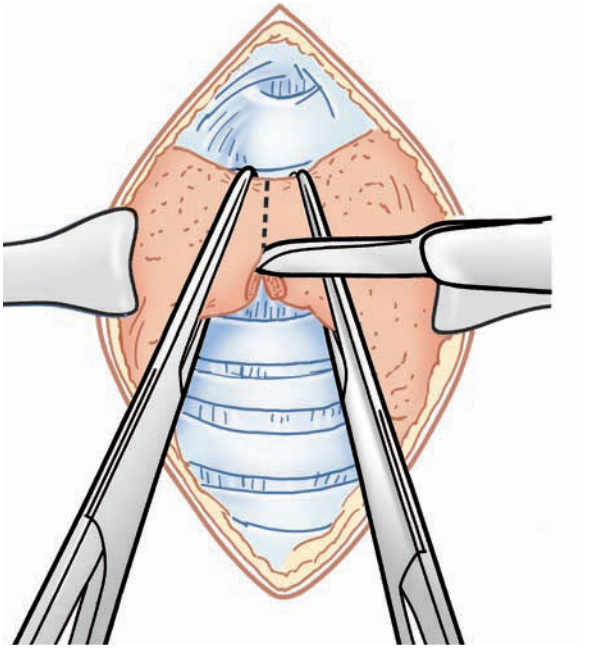


FIGURE 26-13. An alternative method of clearing the thyroid gland from the surgical field. The isthmus is clamped and transected.

Lubricate the appropriate size tracheostomy tube liberally. Insert the tracheostomy tube, with its obturator, through the tracheotomy while the incision is held open (**Figure 26-16A**). Advance the tracheostomy tube and inflate the cuff (**Figure 26-16B**). Hold the tracheostomy tube in place securely. Remove the obturator and insert the inner cannula. Attach a bag-valve device and begin ventilating the patient.

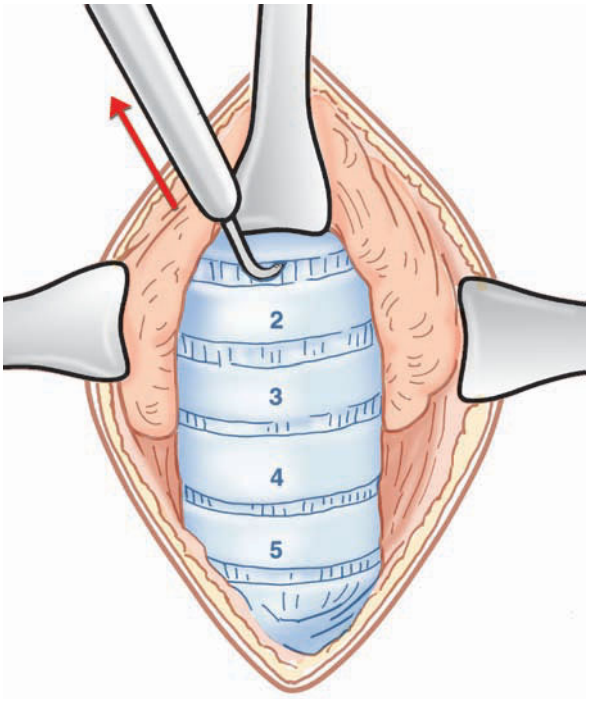


FIGURE 26-14. A tracheal hook is placed below the first tracheal ring to elevate and immobilize the trachea.

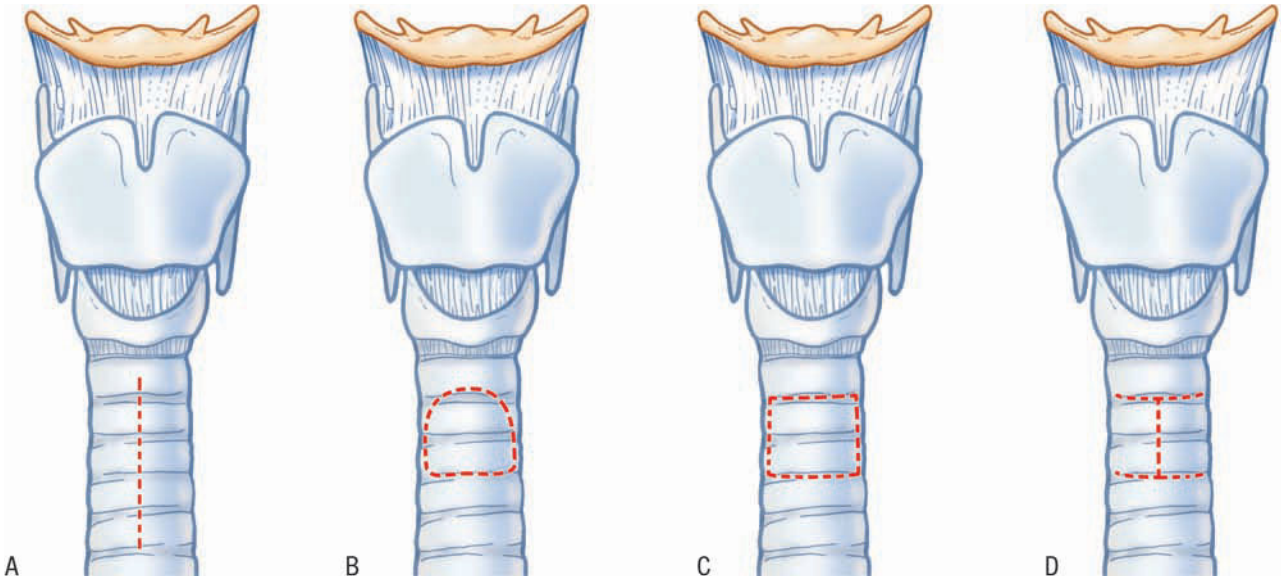


FIGURE 26-15. Types of tracheal incisions. **A.** A midline vertical incision through the second, third, and fourth tracheal rings. This is the preferred technique in an emergent procedure. **B.** A U-shaped inferiorly based window. **C.** A window has been created by excising the second and third tracheal rings. **D.** A T flap.

ALTERNATIVE TECHNIQUES

Since 1969, a number of authors have described a third invasive option for airway control, the percutaneous dilatational tracheostomy. Although techniques vary somewhat, they all rely on an initial puncture of the airway followed by progressive dilatation of a tract. Once a sufficiently large tract is formed, an airway tube is placed. There is now enough evidence to argue that percutaneous tracheostomies are competitive with, and perhaps preferable to, formal open tracheostomies done under elective conditions.[25,26,40–52] Several large series of percutaneous tracheostomies are now complete, but significant results are available only for elective tracheostomies done in patients who have already been intubated.[41,43,44,49] There are small case studies that have been published regarding the successful use of percutaneous dilatational tracheostomy in an emergency setting. These authors conclude that percutaneous dilatational tracheostomy is an effective airway, providing an alternative to endotracheal intubation. The resultant airway is stable and does not require conversion in the immediate postresuscitation period.[53] Furthermore, a recent case series of four patients undergoing percutaneous dilatational tracheostomy in the intensive care setting illustrated the possible benefits of performing the procedure in combination with ultrasound guidance.[54] The authors concluded that the use of ultrasound could identify patients unsuitable for the procedure, prevent puncture of aberrant vessels, estimate the distance from the surface of the skin to the trachea, and ensure accurate placement of the needle into the trachea.[54] While these studies are promising, larger studies are needed to determine the ultimate role of percutaneous dilatational tracheostomy in the emergency setting.[53] Cricothyroidotomy remains the procedure of choice for emergency surgical access to the airway.

ASSESSMENT

Once the airway is established, tracheostomy tube positioning should be confirmed by auscultation, ease of ventilation, and pulse oximetry. Obtain a chest and neck radiograph to confirm tracheostomy tube position and exclude a pneumothorax.

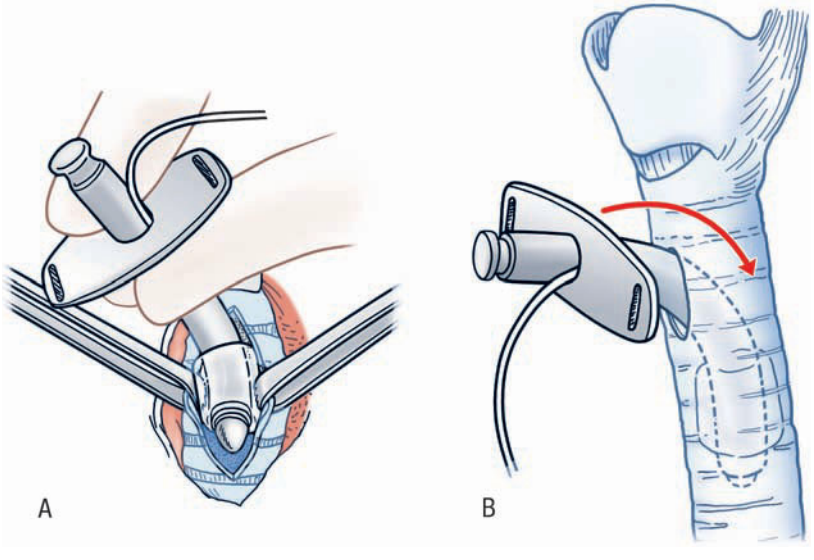


FIGURE 26-16. Insertion of the tracheal tube. **A.** The incision is held open with a Trousseau dilator, hemostat, or Allis forceps (shown here) as the tracheostomy tube is inserted. **B.** The tracheostomy tube is advanced and the cuff inflated.

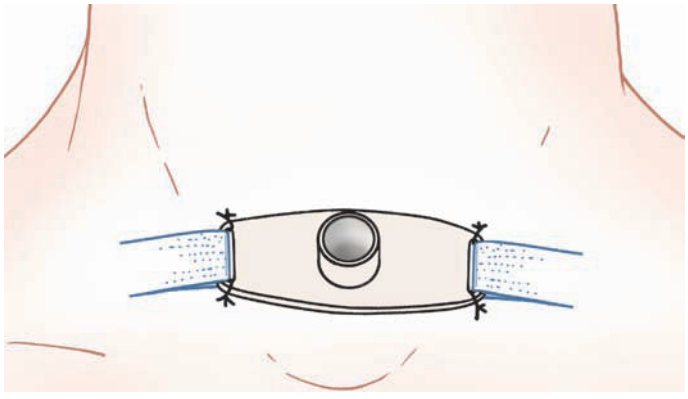


FIGURE 26-17. The tracheostomy tube is secured in place with umbilical tape ("tracheal tie"), then sutured.

TABLE 26-4 Complications of Tracheostomies

Immediate	Delayed	Postoperative
Hemorrhage	Hemorrhage	Disrupted tract
False passage	Tracheal stenosis	Displaced tube
Damage to surrounding structures	Subglottic stenosis	Obstructed tube, mucus plugging
Recurrent laryngeal nerve	Tracheoinnominate artery fistula	Delayed hemorrhage
Esophagus	Tracheoesophageal fistula	Subcutaneous emphysema
Posterior tracheal perforation	Fused vocal cords	Mediastinal emphysema
Common carotid artery	Delayed wound problems	Infection: wound, tracheitis, mediastinitis, and pneumonia
Internal jugular vein	Excess granulation tissue	Aspiration
Anterior jugular vein	Persistent stoma	
Pleura, pneumothorax		
Cricoid		
Air embolism		
Apnea		
Cardiac dysrhythmias		
Cardiac arrest		

Source: Adapted from references 12, 14, 17, 19–21, 27, 32, 33, and 56.

AFTERCARE

Once the airway has been established, inspect the wound to ensure hemostasis. Any clamped vessels or thyroid tissue should be tied. The skin edges do not need to be closed unless the skin incision was overly zealous. If the skin is reapproximated, close it loosely to avoid the development of subcutaneous emphysema. Secure the tracheostomy tube with umbilical tape wrapped around the neck. Suture the flange of the tracheostomy tube to the skin using 3-0 silk as an additional safeguard (**Figure 26-17**). If the wound is oozing, place a loose gauze pad between the skin and the tracheostomy.

Special care should be taken to protect the artificial airway. Suction the lumen frequently and as necessary to prevent obstruction from blood or secretions. Administer humidified oxygen through the tube to prevent dried and inspissated secretions from occluding it.

COMPLICATIONS

An elective tracheostomy is a relatively basic and common surgical procedure. Despite this, it has an unusually high complication rate. Authors report widely different morbidity rates, perhaps determined in part by the clinical settings if not their own biases. Reported morbidity ranges from 6% to 58%, with procedures done emergently having the highest rates.[20,21,23,24] However discomforting these numbers may be, the risk is certainly acceptable in the face of an unstable airway in a dying patient.

Complications from a tracheostomy can be divided into immediate operative complications, postoperative complications, and delayed complications. A summary of reported complications are listed in **Table 26-4**. **It cannot be stressed enough that the best way to avoid complications is to avert the need for a tracheostomy.** Under emergent circumstances, a variety of things can and do go wrong. It is best if one has thought about these possibilities, considered alternative strategies for airway management, and sought assistance from surgical colleagues. A more detailed discussion regarding chronic complications is found in Chapter 27 (Tracheostomy Care).

The most common problem with a hastily performed tracheostomy is hemorrhage. Most bleeding can be controlled with the application of direct pressure. An assistant may be invaluable in providing sufficient control until the airway is established. The search for a bleeding source during the procedure will waste valuable time and can usually wait until the airway is established. The best way to avoid this difficulty is strict hemostasis during the procedure and being careful to avoid the transection of any blood vessels. The next most likely problem is inadvertent injury to adjacent structures. This can be avoided by remaining strictly in the midline, positioning the patient properly, and using a tracheal hook. Additional problems that can be encountered include the creation of a false passage. This should not occur if the operator has visualized the trachea and remained in the midline. In pediatric patients, pneumomediastinum is one of the most frequent early complications of tracheostomy.[55]

The Emergency Physician should be cautious not to adopt methods for tracheostomies learned from elective procedures performed in the operating room under controlled circumstances. **The emergent tracheostomy must be carried out with the simplest, fastest, and most straightforward technique possible.** Tracheostomies done under elective conditions may use rescue stay sutures and more elaborate tracheal incisions. The added benefits of these features do not offset the additional time required to perform them.

Any physician who cares for patients under emergency circumstances should think through the clinical scenarios in which an emergent tracheostomy may be necessary. Expertise in surgical airway techniques should first be obtained in a laboratory setting. Unless one is poised to respond with a plan of action for the emergent airway and prepared with the necessary surgical skills, such situations create chaos and all too often end in disaster.

SUMMARY

A well-trained Emergency Physician must be prepared for any kind of airway emergency and should be skilled in a variety of approaches. Optimal airway management begins with optimal medical management of the patient, including the early identification of possible airway compromise and aggressive preventive treatment. Many airway problems can be averted with anticipatory action. In the armamentarium of airway procedures, a tracheostomy will be (and should be) a rare solution. The physician who is knowledgeable about and comfortable with alternative airway techniques, including surgical access, will be prepared to act decisively yet appropriately upon encountering a challenging airway crisis. While a cricothyroidotomy is the surgical airway procedure of choice, a tracheostomy should be considered for laryngeal injuries with airway disruption, or when all other methods have failed.

27 Tracheostomy Care

H. Gene Hern Jr.

INTRODUCTION

Tracheostomy care and management of tracheostomy complications are tremendously important to the Emergency Physician. Rapid assessment and understanding of tracheostomies and their potential complications can be lifesaving in the critically ill and tracheostomy dependent patient.

Tracheostomies have been performed since ancient times but have been perfected in the last few centuries. A Greek physician named Asclepiades of Bismuth was the first credited with performing a successful tracheostomy in 100 BC.[1] Two of the four physicians summoned to President George Washington's deathbed were said to have argued for tracheostomy as his only means of survival. In the 1800s, Trousseau reported successful tracheostomies in more than 2000 cases of upper airway obstruction secondary to diphtheria.[2] Chevalier Jackson, in the 20th century, perfected the tracheostomy technique and reduced the operative mortality from 25% to below 1%.[3] This is roughly what it remains today.

The important aspects of tracheostomy care include the assessment of respiratory distress in the tracheostomy patient, proper suctioning techniques, and assessment and evaluation of possible complications arising from the tracheostomy itself or its placement. For the purposes of this chapter, tracheostomy care will be divided into routine care and emergent care.

ANATOMY AND PATHOPHYSIOLOGY

The trachea is a fibromuscular tube with approximately 18 to 20 cartilaginous arches extending from the cricoid cartilage to the division into right and left mainstem bronchi (**Figure 26-4**). The surface of the tracheal mucosa is covered in respiratory epithelium. This epithelium is responsible for tracheal secretion, mucociliary "elevator" movement of secretions and debris, and humidification. The remaining part of the upper respiratory tract, which is bypassed by the tracheostomy, plays a major role in warming and humidifying inspired air.

The term tracheostomy and tracheotomy are widely interchanged in current parlance. Tracheotomy refers to the actual incision through the skin to the trachea, which is then kept open by a tracheotomy tube. A tracheostomy refers to the procedure in which the tracheal opening is sutured to the skin incision. This creates a more permanent orifice. The term tracheostomy will be used for the remaining sections of this chapter.

A tracheostomy is created by an incision at the level of the second or third tracheal rings. After the subcutaneous tissue is dissected and anatomic structures identified, an incision is made into the trachea. A hook is inserted into the incision and used to stabilize the trachea while a tube is placed into the trachea. The trachea is secured to the overlying skin and the tube is secured in place. Further details can be found in Chapter 26.

TRACHEOSTOMY TUBES

Tracheostomy tubes vary in their composition, angles, and types and the presence or absence of a cuff. The basic tube consists of an outer cannula and an inner cannula (**Figure 27-1**). The size of the tracheostomy tube is usually defined by its inner diameter. The outer cannula is the more permanent fixture in the tracheostomy. The inner cannula is a low-profile tube that inserts into the outer cannula. It can easily be removed and replaced. The inner and outer cannulas contain a locking mechanism by which the inner cannula is secured into the outer cannula. The proximal end of the inner cannula contains a standard 15 mm connector that allows direct connections to a ventilator or a bag-valve device.



FIGURE 27-1. The tracheostomy tube consists of an outer cannula (*left*) and an inner cannula (*middle*). The inner cannula inserts and locks into the outer cannula (*right*).

Pediatric tracheostomy tubes, it must be noted, have a much smaller inner diameter and do not accommodate inner cannulas (**Figure 27-2**). Since pediatric tracheostomy tubes are not made with an inner cannula, they require more frequent suctioning and changing.

Tracheostomy tubes are manufactured with and without cuffs (**Figure 27-3**). Older high-pressure, low-volume cuffs produced tracheal mucosal injury within hours. They have been replaced by high-volume, low-pressure cuffs that can be used for extended periods with minimal mucosal injury.

Obturators are solid devices that aid in the smooth insertion of the tracheostomy tube (**Figure 27-4**). When placed inside the outer cannula, an obturator will totally occlude the cannula and extend a few millimeters beyond the distal end. The smooth tip of the obturator allows the outer cannula to be inserted with minimal effort and prevents the edges of the cannula from getting caught and damaging tissue. Once the outer cannula has been inserted, the obturator is removed and replaced with a low-profile inner cannula.



FIGURE 27-2. The pediatric tracheostomy tube.



FIGURE 27-3. Tracheostomy tubes may be uncuffed (*left*) or cuffed (*middle*). The inflated cuff is a high-volume, low-pressure system (*right*).



FIGURE 27-4. The obturator is a solid device (*left*) that inserts into the proximal end of the outer cannula and projects from the distal end of the outer cannula (*right*).

ROUTINE CARE

The routine care of the patient with a tracheostomy includes humidification of air as well as cleaning and suctioning of the tracheostomy. Inspired air that bypasses the upper respiratory tract in patients with tracheostomies is not as warm or humidified as air inspired through the nose or mouth. When cold, dry air is inspired into the trachea, the mucociliary "elevator" becomes impaired, resulting in thicker secretions. It is important, especially in the postoperative period, to warm and humidify the inspired air for the patient with a tracheostomy.[4]

Care of the tracheostomy must include ensuring adequate cleanliness of the tube. Cleanse the skin site with diluted hydrogen peroxide, at a 50% concentration, applied to cotton-tipped swabs or other similar absorbent devices.[5] The skin surrounding the tracheostomy should be kept dry between cleanings with tracheal bandages or gauze sponges. It is important to note the underlying skin condition. Erythematous or macerated skin can become eroded or infected. Proper skin-care techniques should be used to ensure skin viability. Tracheal bandages or tape used to secure the tracheostomy in place should not be so tight as to compromise skin perfusion. A good rule of thumb is to have two finger breadths of laxity between the skin and the securing ties.[5]

SUCTIONING

Suctioning of the tracheostomy should be conducted when there are thick and tenacious secretions at the tracheostomy lumen or when the patient is having difficulty clearing secretions. Suctioning through the tracheostomy will eliminate debris and infectious agents, improve oxygenation, and prevent atelectasis. Other indications for suctioning include diminished or coarse breath sounds, unexplained decreases in oxygen saturation levels, or increased airway pressures.[6] Suctioning should not be done as part of "routine care" when there are few secretions or if the patient is adequately able to generate enough force to clear the secretions.[7] While the suctioning of tracheostomies is often essential to proper pulmonary toilet, it can also be hazardous. Known complications to tracheal suctioning include hypoxia, hypotension, atelectasis, infections, tracheal mucosal damage, vagus stimulation, arrhythmias, and even cardiac arrest.[6,8]

Suctioning can also be very frightening to the patient and must be done with some expediency and professionalism. These patients' anxiety levels are quite high, as their ability to breathe may be compromised by secretions, they may be hypoxic, and they have a decreased ability to communicate freely at baseline.[4]

EQUIPMENT

- Protective clothing (disposable gowns, gloves, face shields, goggles, and shoe covers)
- Bag-valve device
- Flexible multi-eyed suction catheter, less than half the diameter of the inner cannula
- Saline bullets
- Continuous wall suction
- Pressure regulator to maintain suction pressure

PATIENT PREPARATION

Place the patient in an upright or semirecumbent position. If possible, hyperextend the patient's neck. Preoxygenate the patient with 100% oxygen prior to suctioning. **Hypoxia is a common complication of suctioning and can be virtually eliminated with proper preoxygenation.** In addition, proper preoxygenation often prevents cardiac arrhythmias from occurring during suctioning.[8] Pretreatment with atropine in neonates and children has been suggested to minimize bradycardic episodes.[9]

It has been debated which technique of preoxygenation is best. Options include hand ventilation with a bag-valve device for five to eight breaths, hyperventilation with 100% O_2 via a nonrebreathing mask, or hyperventilation with 100% O_2 via a ventilator. The advantage of hand ventilation is that there is faster delivery of oxygen to the lungs rather than waiting for the higher percentage of oxygen to bleed down the ventilator tubing into the lungs. However, maintaining tidal volumes and positive end-expiratory pressure may be more important in particular settings. The bag-valve device may result in decreased cardiac output and hypotension secondary to increased intrathoracic pressures.[6] The method of preoxygenation is left up to the physician.

TECHNIQUE

Assemble and prepare the equipment. Set the pressure regulator to 60 to 80 mmHg for infants, 80 to 100 mmHg for children, and 100 to 120 mmHg for adolescents and adults. Higher pressures may cause injury to the tracheal mucosa. The suction catheter chosen should

be approximately one-half the diameter of the tracheostomy tube. The catheter has an open valve that must be covered to apply suction through the tip of the catheter. If available, apply cardiac monitoring and pulse oximetry to the patient prior to suctioning.

The procedure should be performed with aseptic technique. The physician should wash his or her hands and apply sterile gloves. The use of a face mask, eye protection, and a gown is highly recommended. The insertion of the suction catheter often induces the patient's cough reflex. Proper protective clothing will prevent the physician from being exposed to respiratory secretions.

Gently insert the suction catheter into the trachea (**Figure 27-5**). Advance it approximately 8 to 10 cm until the tip is at the level of the carina. **Suction pressure should never be applied during insertion of the suction catheter.** Withdraw the catheter approximately 2 to 3 cm and apply suction by placing a finger over the catheter's open valve.[10] **Continue to apply suction as the catheter is simultaneously rotated and withdrawn.** This technique will limit the amount of mucosal damage from the suction catheter. If the catheter is not being withdrawn when suction is applied, the mucosal surface will invaginate into the holes in the suction catheter tip. The resulting trauma may cause bleeding or erosion of the tracheal mucosal surface.[7]

Suction the airway for no more than 10 to 15 seconds.[7,11] This will ensure that the patient experiences a minimal amount of hypoxia. If the suctioning must be repeated, preoxygenation with 100% oxygen must precede each suctioning episode.

The standard use of saline to loosen secretions is somewhat controversial. Some authors have suggested that saline is used to break up thick and tenacious sputum and mucus.[9] There is little support for this assertion. It has been shown that saline instillation increases the cough reflex and stimulates a cough response, which may increase mucus clearance. Others have noted that little saline is actually recovered with suctioning and that saline itself may cause a gradual decrease in oxygen saturation.[6] The instillation of saline into the tracheostomy cannot be recommended at this time.

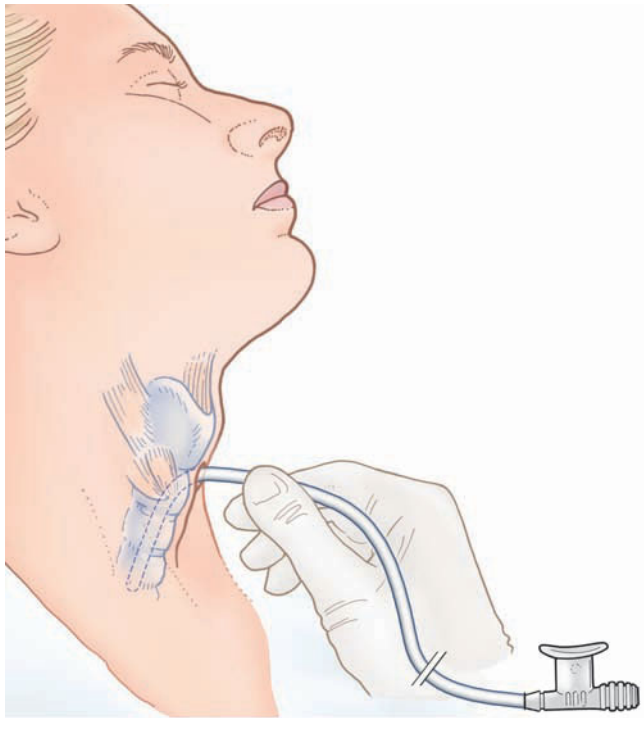


FIGURE 27-5. Insertion of a suction catheter. The vent is uncovered during insertion to prevent tracheal mucosal injury.

EMERGENT CARE

When a patient with a tracheostomy presents to the Emergency Department complaining of shortness of breath or respiratory distress, immediate attention must be given to them. Obstruction and hypoxia are frequent causes of morbidity in this patient population. What follows is a discussion of the algorithm for airway obstruction and respiratory distress in the patient with a tracheostomy.[9]

EQUIPMENT

- Protective clothing (disposable gowns, gloves, face shields, goggles, and shoe covers)
- Bag-valve-mask device
- Flexible multi-eyed suction catheter less than half the diameter of the inner cannula
- Saline bullets
- Continuous wall suction
- Suction pressure regulator
- Continuous ECG monitor
- Pulse oximetry
- Tracheal tubes of various sizes, at least the current size of the tube and one smaller
- Water-soluble lubricant
- Tracheal Airway kit (hook, dilator, and forceps)
- Endotracheal tubes
- Laryngoscope handle and blades
- Access to advanced airway equipment, including a fiberoptic scope

PATIENT PREPARATION

The evaluation of any patient with a tracheostomy who is in respiratory distress begins with placing the patient in a room capable of advanced airway management. Place the patient on 100% oxygen and obtain intravenous access, cardiac monitoring, and continuous pulse oximetry. Equipment should be readily available and accessible. This includes endotracheal and tracheostomy tubes of various sizes as well as a laryngoscope and laryngoscope blades.

The practitioner must evaluate the type of tracheostomy tube present.[12] Recognition of the type of tube will aid in the evaluation of possible complications and the management of the respiratory distress. For instance, if the tube has no inner cannula (pediatric tubes), the entire tracheostomy tube may have to be removed for further cleaning after suctioning is performed. If the tracheostomy tube has no cuff, the patient's respiratory distress may be due to aspiration of secretions or gastric contents.

TECHNIQUE

Inspect the tracheostomy tube for obvious signs of obstruction. The degree of obstruction will increase exponentially as the cross-sectional diameter of the tracheostomy tube decreases. As dried secretions, blood, or aspirated material gathers in the inner cannula, the amount of force required to create airflow through the tube increases dramatically. In addition, secretions may act as a ball-valve mechanism, allowing air to move inward but not outward.

An obvious obstruction or foreign body, if visible at the tracheostomy tube opening, must be removed. The practitioner must then suction the patient through the inner cannula using the technique described above. **Keep in mind the importance of preoxygenation.** If this does not adequately relieve the patient's respiratory

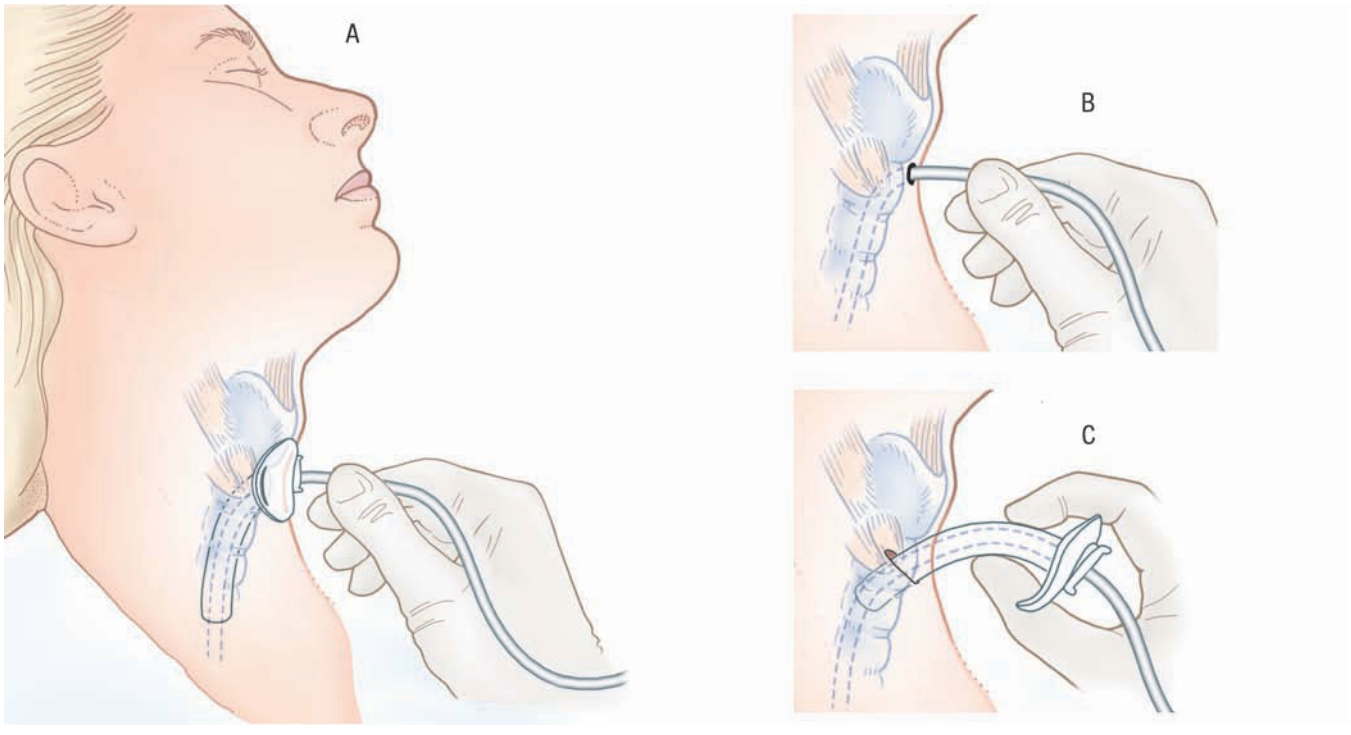


FIGURE 27-6. Removal of the outer cannula over a catheter. **A.** The catheter is inserted through the outer cannula to a depth of 8 to 9 cm. **B.** The outer cannula has been removed over the catheter. **C.** The new outer cannula is inserted over the catheter and into the trachea.

distress, remove the inner cannula. Inspect it for dried secretions and clean it later if necessary. The patient may again be suctioned, this time through the outer cannula. If no diminution of symptoms is noted, the outer cannula may need to be removed.

Before removing the outer cannula, it is important to have all the necessary equipment to replace it at the bedside. If the outer cannula has a cuff, deflate it. Remove the outer cannula with a smooth circular motion. Inspect it for a foreign body and dried secretions. The outer cannula may be cleaned then replaced or may be replaced with an entirely new tracheostomy tube. The practitioner may elect to use a fiberoptic scope or red rubber catheter to aid in tube placement. Each of these devices allows the tracheostomy tube to be placed over it and guided into the tracheal lumen.

If the tracheostomy is relatively new, less than 4 weeks old, it should be removed over a red rubber catheter (**Figure 27-6**). This will ensure that the tracheostomy tube is inserted into the trachea and not a false passage. Lubricate the red rubber catheter. Insert the catheter through the outer cannula and into the trachea (**Figure 27-6A**). Advance the catheter 8 or 9 cm. While holding the catheter securely, remove the outer cannula over the catheter (**Figure 27-6B**). Lubricate a new outer cannula. Insert the outer cannula over the catheter and gently advance it into the trachea (**Figure 27-6C**). Remove the catheter and insert the inner cannula into the outer cannula.

A suction catheter can be used as an alternative to a red rubber catheter. Attach the suction catheter to an oxygen source. Lubricate the end of the suction tubing. Advance an outer cannula over the distal end of the suction tubing. Insert the suction catheter into the tracheostomy to a depth of 8 or 9 cm. Place a finger over the open valve of the suction catheter to provide oxygen to the patient through the catheter. **This will prevent the patient from becoming hypoxemic during the procedure.** Advance the outer cannula over the catheter and into the trachea. Remove the suction catheter and insert the inner cannula into the outer cannula.

If no assist device is used, the tracheostomy tube can be replaced manually (**Figure 27-7**). Lubricate the obturator and insert it into the outer cannula. Inflate the cuff and check its integrity. Deflate the cuff. Lubricate the outer cannula liberally. Place the tip of the obturator perpendicular to the patient's neck and insert it with a semicircular motion (**Figure 27-7A**). Continue advancing the outer cannula with a semicircular motion as it curves into the trachea (**Figure 27-7B**). Remove the obturator and insert the inner cannula into the outer cannula. Begin ventilation of the patient if necessary.

If the new tracheostomy tube will not advance into the trachea, repeat the procedure with a tracheostomy tube one size smaller. **Do not force the tube, as this can create a false passage in the subcutaneous tissues of the neck.** If it still will not advance, attempt to insert an uncuffed tube. Alternatively, insert the tracheostomy tube over a catheter (**Figure 27-8**). Lubricate a red rubber catheter (or oxygen catheter) and insert it 8 or 9 cm through the tracheostomy (**Figure 27-8A**). Insert a lubricated outer cannula over the catheter and into the trachea (**Figure 27-8B**). Remove the catheter and insert the inner cannula. As a last resort, a tracheostomy hook and Trousseau dilator can be used to lift and open the tracheostomy site to allow the insertion of a tracheostomy tube.

ASSESSMENT

The adequacy of airway maneuvers in the patient with a tracheostomy resides in the patient's response to the interventions. If the patient's pulse oximetry and heart rate return to baseline and the patient appears more comfortable, secure the tracheostomy tube. Take care to ensure adequate skin care beneath the tracheostomy tube site.

If a patient remains in respiratory distress despite all appropriate actions, then further causes of respiratory distress must be evaluated. Obtain a chest radiograph. Consult a Pulmonologist for fiberoptic bronchoscopy to evaluate the patient for mucus plugging or foreign-body aspiration. Do not forget to consider other causes

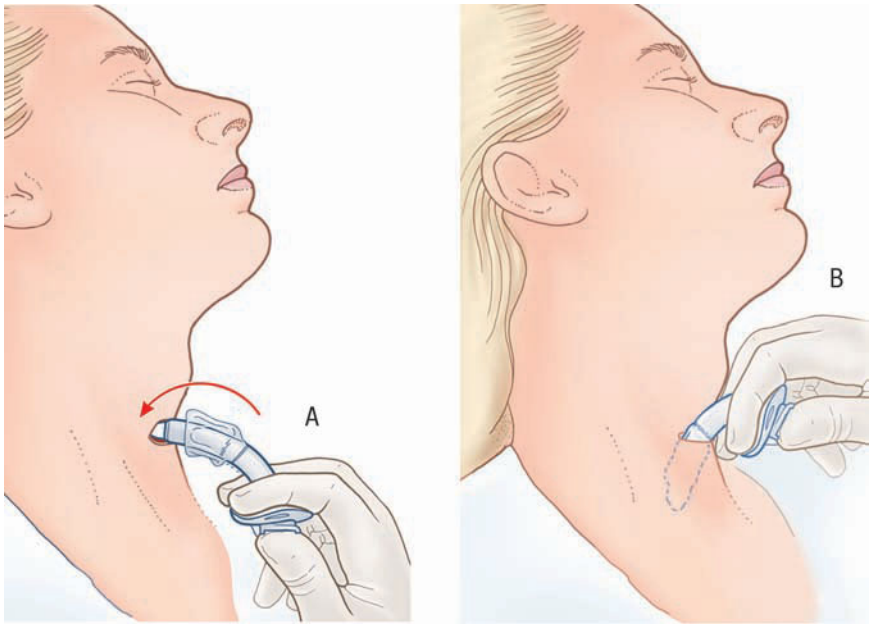


FIGURE 27-7. Manual insertion of a tracheostomy tube. **A.** It is positioned 90° to the tracheostomy site and advanced with a semicircular motion (*arrow*). **B.** The system continues to be advanced, following the curve of the tube, until the flange is against the skin.

of respiratory distress in the patient with a tracheostomy. This includes, but is not limited to, a pneumothorax, pneumonia, pulmonary embolus, congestive heart failure, and myocardial infarction.

AFTERCARE

The patient should be observed for a few hours to ensure the stability of the airway. During this time, further suctioning can be performed as required. Educate the patient and family about preventive measures regarding tracheostomy care.

Once the patient's respiratory distress has been addressed, the patient should be evaluated for further conditions that may preclude him or her from being discharged. Were there just some dried secretions in the inner cannula? Does the patient have a new source of secretions (bacterial pneumonia) that could not be managed at home? Are the caregivers at home knowledgeable about the tracheostomy and trained to deal with complications? If there is any question about the patient's ability to deal with further episodes of respiratory compromise, the patient should be admitted for further evaluation by an Otolaryngologist. The

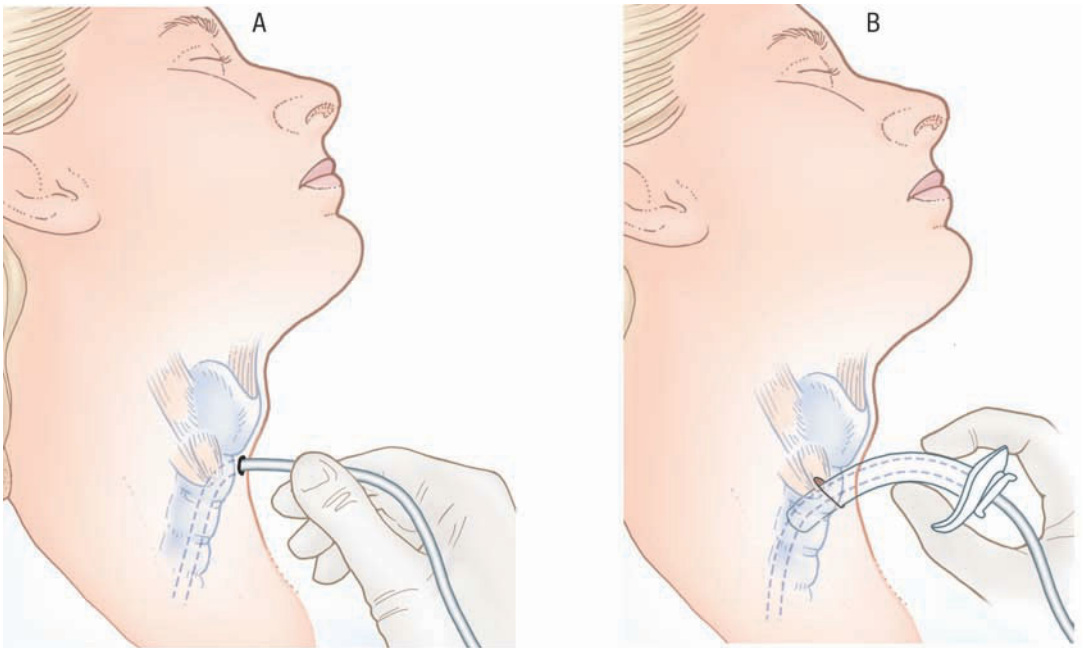


FIGURE 27-8. Insertion of the tracheostomy tube over a catheter. **A.** Insert the catheter through the tracheostomy to a depth of 8 to 9 cm. **B.** Advance the outer cannula over the catheter.

patient may require skilled home care or a skilled nursing facility in order to fully care for the tracheostomy.

COMPLICATIONS OF THE TRACHEOSTOMY

In addition to respiratory compromise from plugging of the tracheostomy with secretions, other complications may cause the patient to present to the Emergency Department. One retrospective review over a 7-year period showed that 33% of patients presented with dislodged tracheal tubes, 30% presented with infection (one-quarter of these had cellulitis around the tracheostomy, the rest had bronchitis or pneumonia), 18% had plugged tracheal tubes, 11% had bleeding, 5% had tracheal or stomal stenosis, and 3% had a pneumothorax.[2]

BLEEDING

Bleeding is a significant concern in the patient with a tracheostomy. While bleeding at the site of a recent tracheostomy may be a frequent complication, it may also be extremely serious. Bleeding can arise from granulation tissue, venous sources, or arterial sources including the great vessels. Tracheoinnominate fistulas are quite rare, occurring in less than 2% of cases, but they carry a mortality rate of 25% to 50%.[9] They may present as the classic "exsanguinating bleed" but often present with a less impressive sentinel bleed. **Any bleeding of more than a few milliliters of blood should raise concern for a possible fistula of the innominate artery. Prompt critical resuscitation measures and emergent consultation with a Vascular Surgeon and Otolaryngologic Surgeon is required.** Definitive management is surgical. Techniques for temporarily controlling bleeding from the innominate artery include local digital pressure, hyperinflation of the tracheostomy tube cuff, and traction on the tracheostomy tube. An alternative method is to deflate the tracheostomy tube cuff, reposition the cuff at the bleeding site, and then reinflate or hyperinflate the cuff. **When bleeding occurs, the tracheostomy tube should not be removed until the airway is secured by another means from above (orally or nasally).**

FREE AIR

Pneumothoraces, pneumomediastinum, and subcutaneous air occur in a small number of patients.[9] Pediatric patients are at a higher risk, as the dome of the pleura in a child is closer to the site of the operation. As patients "fight" a ventilator or attempt to inspire against an obstructed airway, they can generate tremendous negative inspiratory pressures. This can result in the dissection of air between the tissue planes and into the thoracic cavity, causing a pneumothorax. Small pneumothoraces and pneumomediastinum can be observed as they will most likely resorb with no further complications. A large pneumothorax will require drainage. **The possibility of a tension pneumothorax must always be considered in patients with tracheostomies and respiratory distress or hypotension.**

GRANULOMAS

Tracheal wall granulomas can develop at the tracheostomy site or near the tip of the tracheostomy tube. They are formed in response to mechanical trauma to the mucosa. Granulomas are sometimes a source of bleeding. Direct pressure or cautery may be required for hemostasis. Small granulomas are often observed, while large or symptomatic ones require excision.

INFECTIONS

Tracheostomy-related infections can present at any time. Stoma infections are considered to be local skin infections. Antibiotic treatment should be based on potential pathogens and local antibiotic resistance patterns. Tracheitis may be bacterial or viral in origin. Common bacterial etiologies include *Staphylococcus aureus*, group A streptococcus, and *Haemophilus influenzae*. The determination of a bacterial infection versus colonization should be based on clinical findings and culture results. Management of tracheitis includes broad-spectrum antibiotics for common pathogens, maintenance of a patent airway through suctioning, and possible bronchoscopy.

LARYNGOTRACHEAL STENOSIS

Laryngotracheal stenosis is a complication of long-term endotracheal intubation or direct tissue trauma from the tracheostomy. The tracheal tissues become irritated from the tracheostomy tube. This results in tissue edema that leads to erosions into the mucosa, ulcerations, and eventually scar tissue. Treatment involves surgery to remove the scar tissue and create an artificial airway to bypass the stenosis.

DEPRESSED SCAR FORMATION

The tracheostomy wound is left open to granulate and heal by secondary intention. This can result in skin and soft tissue atrophy and tissue adhesions to the anterior tracheal wall. As the tissue heals, scar contracture and a depress scar can result. This may result in patient discomfort with head movement or swallowing. Treatment requires surgical scar excision and revision.

SUPRASTOMAL COLLAPSE

Pressure placed on the tracheal cartilages by the tracheostomy tube results in cartilage inflammation, chondritis, and necrosis of the cartilaginous rings. Mild suprastomal collapse usually requires no treatment. Moderate and severe collapse may require a tracheal stent, suturing the anterior trachea to the skin and subcutaneous tissues, or pulling the anterior trachea anteriorly and securing it in place.

TRACHEOESOPHAGEAL FISTULA

A tracheoesophageal fistula is a rare complication of a tracheostomy. The tracheostomy tube can cause pressure necrosis on the posterior tracheal wall that continues to erode into the esophagus. The result is an open tract between the trachea and the esophagus. Patients often have difficulty eating, aspiration pneumonitis, or respiratory difficulty associated with eating and drinking. Treatment requires surgical management.

TRACHEOMALACIA

Tracheomalacia is the lack of support for the trachea by its cartilaginous rings. It can result from degradation of the cartilaginous tracheal rings from the tracheostomy tube or from a tracheoesophageal fistula. Bronchoscopy is required to assess the severity of the tracheal collapse prior to possible intratracheal stenting.

SUMMARY

Emergency Physicians should be familiar with tracheostomy equipment including the outer and inner cannulae, obturators, and cuff management. Patients presenting to an Emergency Department may require immediate and critical intervention to resuscitate them. Familiarity with various techniques to evaluate the patient with a tracheostomy should include tracheal suctioning, removal of the inner and outer cannulae, replacement of a tracheostomy tube, and evaluation for other emergent conditions relating to tracheostomies. This would include bleeding, infection, and pneumothorax at the very minimum. In addition, the Emergency Physician should be mindful of other conditions of the esophagus, trachea, or soft tissues that might complicate the care of the patient with a tracheostomy.

28 Transtracheal Aspiration

Joseph A. Salomone III

INTRODUCTION

Transtracheal aspiration is a technique for the collection of bronchial secretions for laboratory evaluation and culture. This technique is useful when standard sputum collection has not provided adequate material or determination of the infective agent(s). Specimens collected by this technique are free of contamination from nasal, oral, and pharyngeal secretions. This technique was first described in 1959.[1] Several modifications to the original technique have been made.[2–5] This technique may be more properly named transcricothyroid membrane aspiration.

ANATOMY AND PATHOPHYSIOLOGY

The most superficial portion of the cervical airway begins at the inferior thyroid cartilage and extends inferiorly to the thyroid isthmus (**Figure 28-1**). The inferior border of the thyroid cartilage is attached to the cricoid cartilage by the cricothyroid ligament. This is formed by a thicker central conus elasticus and laterally by thinner ligaments that are covered by the cricothyroid muscles (**Figure 28-1B**). The internal surface is covered by the mucous membrane of the larynx. Collectively, this is often referred to as the cricothyroid membrane or cricovocal membrane. The paired cricothyroid arteries cross from lateral to medial to form an arch that anteriorly crosses the upper one-third of the cricothyroid membrane. The pyramidal lobe of the thyroid occasionally extends superiorly to this level.

INDICATIONS

Transtracheal aspiration is indicated for the collection of tracheobronchial secretions for laboratory evaluation. Often, previous attempts to collect standard coughed and expectorated sputum samples have failed to yield adequate samples or reveal the etiology of a pulmonary infection. Patients who do not appear to be responding to the appropriate antibiotic regimen that was indicated by evaluation and culture of sputum samples may benefit from this technique to better determine the pathogen(s). This is particularly true in cases of atypical or mixed flora, as in suspected aspiration pneumonias, where this technique may yield superior culture results when compared to sputum samples.[6]

CONTRAINDICATIONS

Patients who are unable to cooperate with or tolerate the required positioning should not be selected for this technique.[7] Agitated patients requiring sedation that may affect respiratory effort should be avoided. Traumatically injured patients should have the cervical spine cleared for possible injury prior to performing the procedure. Patients with known or suspected blood dyscrasias (e.g., abnormal platelet counts, elevated prothrombin, or partial thromboplastin times) should not be subjected to this technique due to the increased risk of tracheal hemorrhage. The physician must be able to easily identify the patient's anatomic landmarks, including the thyroid and cricoid cartilages and the intervening cricothyroid membrane. Patients with abnormal or distorted anatomy should be excluded. Patients who are endotracheally intubated or have a tracheostomy do not require this procedure.

EQUIPMENT

- Sterile gown, gloves, and mask
- Pillow or padding for shoulders
- Povidone iodine solution or chlorhexidine solution
- Sterile gauze squares
- Normal saline solution, sterile and preservative-free
- Local anesthetic solution, 3 mL (1% lidocaine HCl)
- 3 mL syringes
- 30 mL syringe
- 25 to 27 gauge needles, ½ in
- 18 to 22 gauge catheter-through-the-needle
- 18 to 22 gauge catheter-over-the-needle, 3 in long
- 18 to 19 gauge needles, 1½ in
- Pulse oximeter
- Cardiac monitor
- Sterile specimen container
- Bandage, 1 in wide
- Sterile drapes or towels
- Resuscitation equipment including emergent airway management supplies

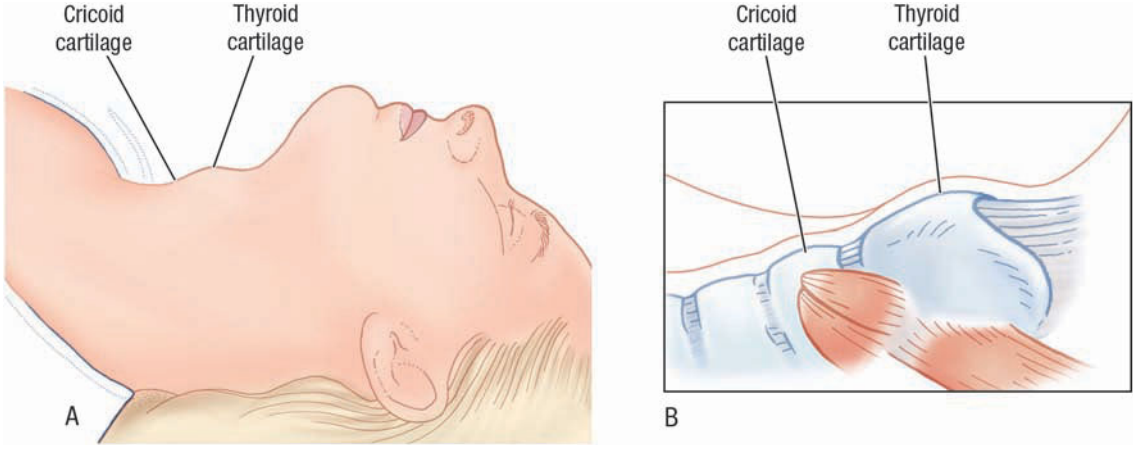


FIGURE 28-1. Anatomy of the airway structures of the neck. **A.** Topographic anatomy. **B.** The cartilaginous structures.

PATIENT PREPARATION

Explain the procedure, its risks, and its benefits to the patient and/or their representative. Obtain an informed consent. Place the patient on cardiac monitoring and continuous pulse oximetry. Administer supplemental oxygen and establish intravenous access.

Sedation is not generally required. A small dose of midazolam (1 to 5 mg IV) may be used, if appropriate, for light sedation. Deep sedation should be avoided, as it may compromise respiratory efforts and increase the risk of aspiration of gastric contents.

Place the patient supine in bed. Place a pillow or appropriate padding under the patient's shoulders and upper back to allow for comfortable hyperextension of the neck. Identify by palpation the thyroid cartilage, laryngeal prominence (Adam's apple), cricoid cartilage, and cricothyroid membrane. These are the anatomic landmarks that will be used to identify the proper site for performing the procedure.

TECHNIQUE

CATHETER-THROUGH-THE-NEEDLE TECHNIQUE

The operator should follow universal precautions with the use of a mask, eye protection, a sterile gown, and sterile gloves. Using sterile technique, prepare the equipment. Draw 3 to 5 mL of sterile and preservative-free normal saline solution into a 30 mL syringe with a sterile needle. Attach an appropriately sized needle from a catheter-through-the-needle set (18 to 20 gauge for an adult, 20 to 22 gauge for a child) to a 3 mL syringe. An alternative technique is to draw up 1 to 2 mL of sterile saline into the syringe before attaching the catheter-through-the-needle. Draw up 1 to 3 mL of local anesthetic solution into a 3 mL syringe armed with a 25 to 27 gauge needle.

Position the patient as noted above. Using sterile technique, prepare the neck. Clean the anterior neck of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Place sterile towels or a sterile drape to isolate the anterior neck. Palpate the anterior neck and reidentify the thyroid cartilage, laryngeal prominence, cricoid cartilage, and cricothyroid membrane. Leave the nondominant index finger over the cricothyroid membrane for reference.

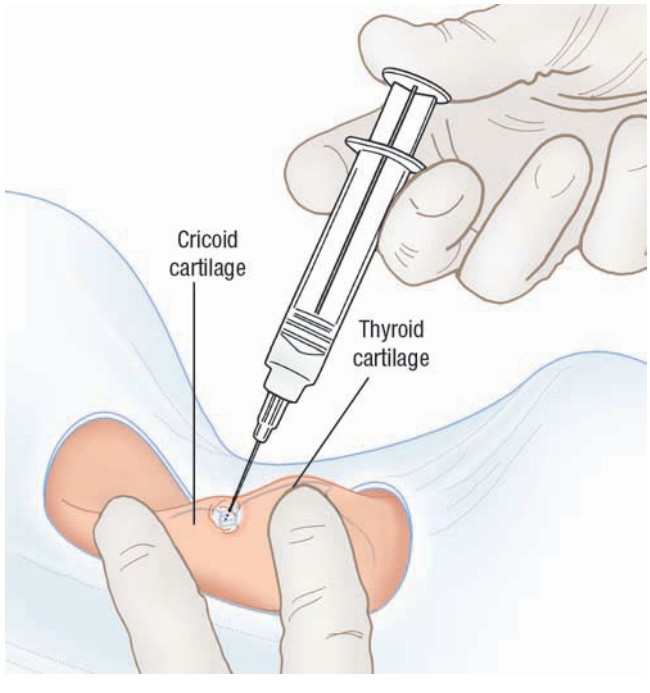


FIGURE 28-2. A subcutaneous wheal of local anesthetic solution is placed over the middle of the cricothyroid membrane.

Apply a small subcutaneous wheal of local anesthetic solution below the skin at the anterior midpoint of the cricothyroid membrane (**Figure 28-2**). Inject 0.5 to 1.0 mL of local anesthetic solution into the subcutaneous tissues down to the level of the cricothyroid membrane, taking care not to distort the anatomy. Reidentify the cricothyroid membrane by palpation. Insert the needle on the syringe, directed caudally and at a 30° to 45° angle to the skin (**Figure 28-3**). Continue to advance the needle while applying negative pressure to the syringe (**Figure 28-3A**). Stop advancing the needle when air is aspirated into the syringe. This signifies that the needle is inside the trachea. If using a saline filled syringe, air bubbles will be clearly visible within the saline. Hold the needle securely and remove the syringe. Insert the catheter through the needle (**Figure 28-3B**). While holding the catheter securely, withdraw the needle until the tip has exited the skin of the neck (**Figure 28-3C**). **Place the needle guard over the needle.** This will prevent shearing off of the catheter. Apply the 30 mL syringe containing saline to the catheter (**Figure 28-3C**).

Ask the patient to cough if they are not already doing so. Aspirate with the 30 mL syringe as the patient coughs. If no specimen is obtained, instill the sterile saline. Once again, ask the patient to cough if not stimulated by the saline. Aspirate until a specimen is acquired. An alternative to using a large syringe for aspiration is the use of low wall suction and a Lukens tube or a similar trap device to collect the specimen.

Remove the catheter, needle, and syringe as one unit. Hold direct pressure on the puncture site for 3 to 5 minutes. Apply a bandage or sterile dressing to the puncture site. Place the specimen in a sterile container and have it transported to the laboratory.

Many physicians are reluctant to use the catheter-through-the-needle system as there is the possibility of shearing off the catheter within the trachea. **This can be prevented by applying the needle guard over the needle immediately after it is withdrawn from the skin.**

CATHETER-OVER-THE-NEEDLE TECHNIQUE

The more commonly used technique is to use a catheter-over-the-needle (angiocatheter) system (**Figure 28-4**). The operator should follow universal precautions. Cleanse, prepare, and anesthetize the patient as above.

Using sterile technique, prepare the equipment. Draw 3 to 5 mL of sterile and preservative-free normal saline solution into a 30 mL syringe with a sterile needle. Attach an appropriately sized catheter-over-the-needle (18 to 20 gauge for an adult, 20 to 22 gauge for a child) to a 3 mL syringe. An alternative technique is to draw up 1 to 2 mL of sterile saline into the syringe before attaching the catheter-over-the-needle. Draw up 1 to 3 mL of local anesthetic solution into a 3 mL syringe armed with a 25 to 27 gauge needle.

Reidentify the cricothyroid membrane by palpation. Insert the catheter-over-the needle on the syringe, directed caudally and at a 30° to 45° angle to the skin (**Figure 28-4A**). Continue to advance the catheter-over-the-needle while applying negative pressure to the syringe. Stop advancing the catheter-over-the-needle as soon as air is aspirated into the syringe. This signifies that the needle is inside the trachea. If using a saline filled syringe, air bubbles will be clearly visible within the saline (**Figure 28-4B**). Hold the syringe securely and advance the catheter until its hub is against the skin (**Figure 28-4C**). Remove the needle and syringe. Apply the 30 mL syringe containing saline to the catheter (**Figure 28-4D**).

Ask the patient to cough if they are not already doing so. Aspirate with the 30 mL syringe as the patient coughs. If no specimen is obtained, instill the sterile saline. Once again, ask the patient to cough if not stimulated by the saline. Aspirate until a specimen is

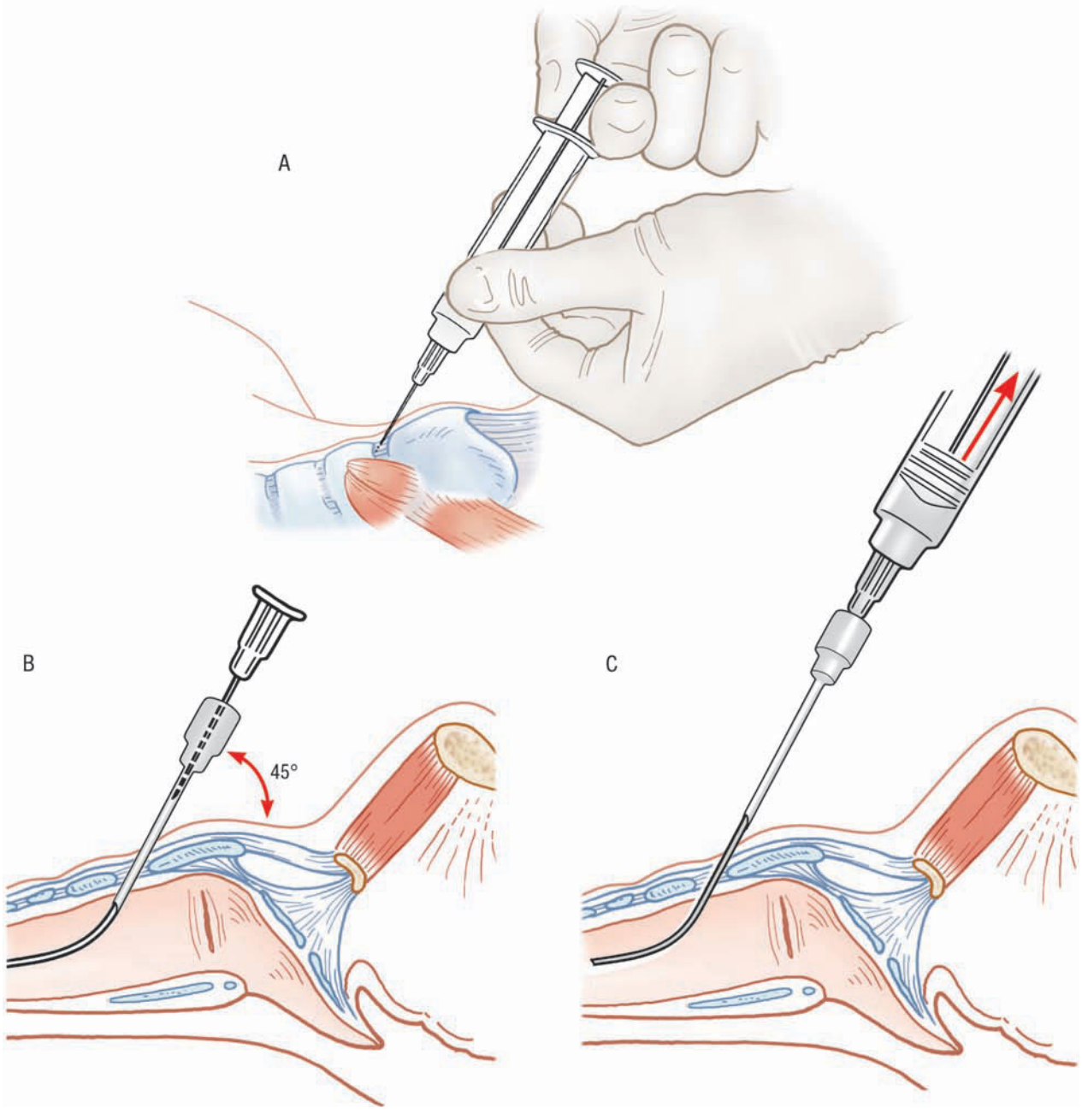


FIGURE 28-3. The transtracheal aspiration technique with a catheter-through-the-needle system. **A.** The needle is inserted through the cricothyroid membrane while negative pressure is applied to the syringe. **B.** The syringe has been removed and the catheter advanced through the needle. **C.** The needle has been withdrawn until its tip exits the skin. A syringe containing saline is attached to the hub of the catheter.

acquired. An alternative to using a large syringe for aspiration is the use of low wall suction and a Lukens tube or a similar trap device to collect the specimen.

Remove the catheter. Hold direct pressure on the puncture site for 3 to 5 minutes. Apply a bandage or sterile dressing to the puncture site. Place the specimen in a sterile container and have it transported to the laboratory.

ASSESSMENT

The patient should be observed for bleeding at the puncture site, the development of subcutaneous emphysema, any changes in sputum production, or hemoptysis. Obtain a chest radiograph immediately after the procedure to look for subcutaneous air and/or a pneumothorax.

AFTERCARE

The patient should remain on continuous pulse oximetry to monitor possible deterioration in respiratory status. Obtain a chest radiograph in 24 hours to look for subcutaneous air and/or a pneumothorax. Any procedure that might stimulate coughing should be avoided for at least 24 hours.

COMPLICATIONS

The complications range from minimal hemoptysis and localized subcutaneous emphysema to massive pulmonary hemorrhage and death.[8–13] Minimal hemoptysis was seen in 15% of pediatric patients in one study and commonly in several adult studies. Localized subcutaneous emphysema in the anterior neck occurred in 5% to 18%

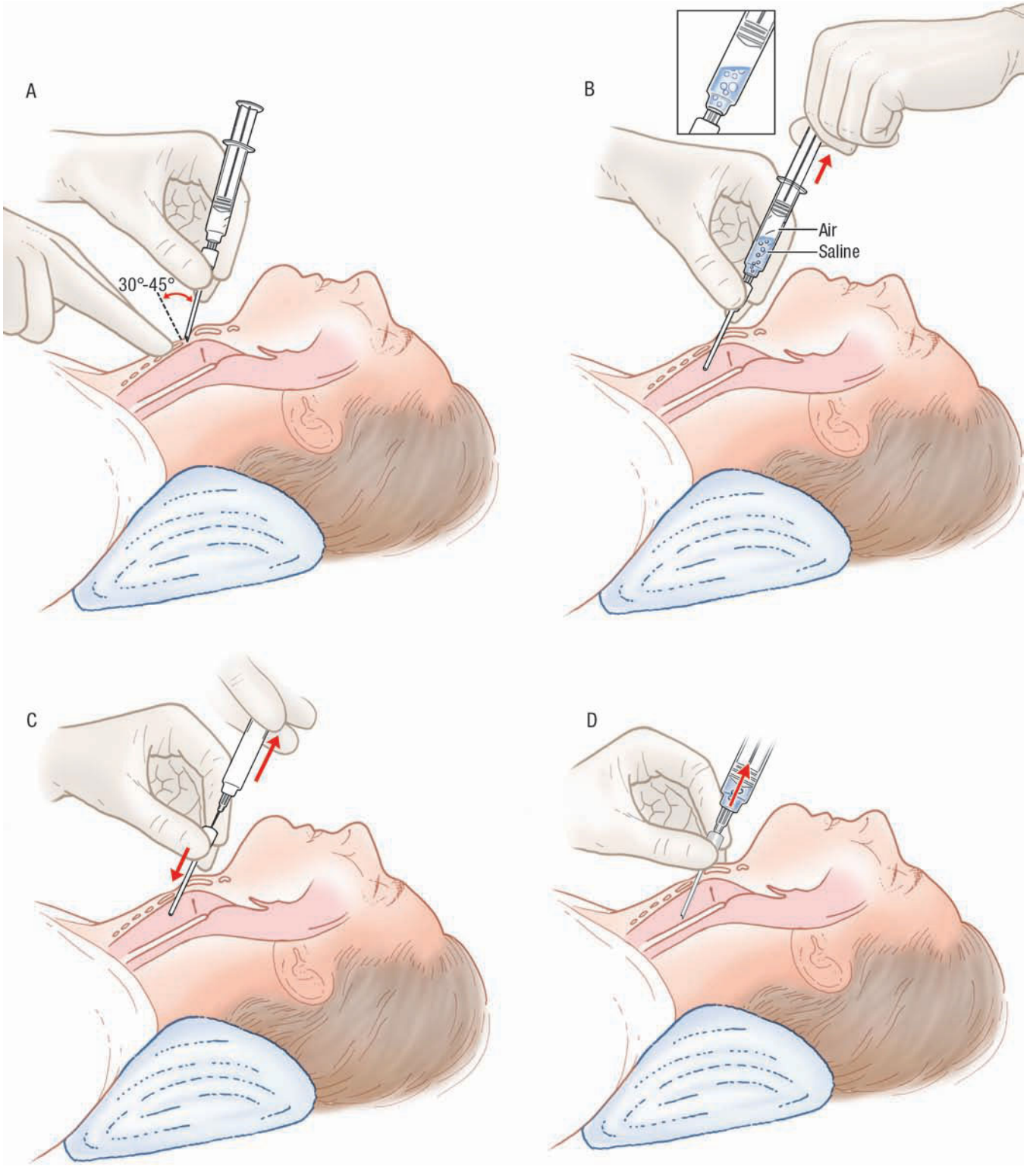


FIGURE 28-4. The transtracheal aspiration technique with a catheter-over-the-needle system. **A.** The catheter-over-the-needle is inserted through the cricothyroid membrane. **B.** Negative pressure is applied to the syringe. **C.** The catheter is advanced until its hub is against the skin. **D.** The needle and syringe have been withdrawn. A syringe containing saline is attached to the hub of the catheter.

of patients. There are rare reports of fatal endotracheal hemorrhage, profound coughing with development of massive subcutaneous and mediastinal emphysema, vomiting and aspiration of gastric contents, cardiac dysrhythmias, and sudden cardiac death. There is at least one case of fatal gastrointestinal hemorrhage from ruptured esophageal varices and Mallory–Weiss tears following "unrestrainable" coughing.

SUMMARY

Transtracheal aspiration is a useful technique for obtaining uncontaminated specimens for analysis and culture. The procedure is best used in those patients who have complicated courses or are failing to respond to appropriate treatment or when there is a high index of suspicion for aspiration pneumonia and more atypical infectious agents.

SECTION 3

Cardiothoracic Procedures

29 Cardiac Ultrasound

Gregory M. Press and Amy Rasmussen

INTRODUCTION

Pericardial tamponade is arguably the most dramatic ultrasound (US) finding for the Emergency Physician (EP). The diagnosis is difficult to make without cardiac US, and acute intervention can be lifesaving. Cardiac US has proven to be an invaluable tool for identifying critical pathology and directing decision making in the Emergency Department (ED).[1] A quick bedside US can assess a patient's cardiac activity, global cardiac function, presence or absence of effusion, and volume status. Cardiac US is an essential part of the evaluation of the trauma patient,[2] the cardiac arrest patient,[3,4] and the patient with undifferentiated hypotension.[5,6]

Cardiac ultrasonography can be one of the most challenging areas of emergency US. The EP must have a keen grasp of the spatial anatomy of the heart to properly perform and interpret the US examination. An EP can become competent in basic cardiac ultrasonography with practice. This tool can be utilized to gain great insight into the body's most vital organ. This chapter will cover basic cardiac anatomy, the indications for emergency echocardiography, techniques, and image interpretation.

ANATOMY AND PATHOPHYSIOLOGY

GENERAL ANATOMY AND PHYSIOLOGY

It is essential to know the anatomy of the heart before performing any US examination (**Figure 29-1**). The heart lies obliquely in the middle of the chest. It consists of four chambers: the left atrium, the right atrium, the left ventricle, and the right ventricle. The atria

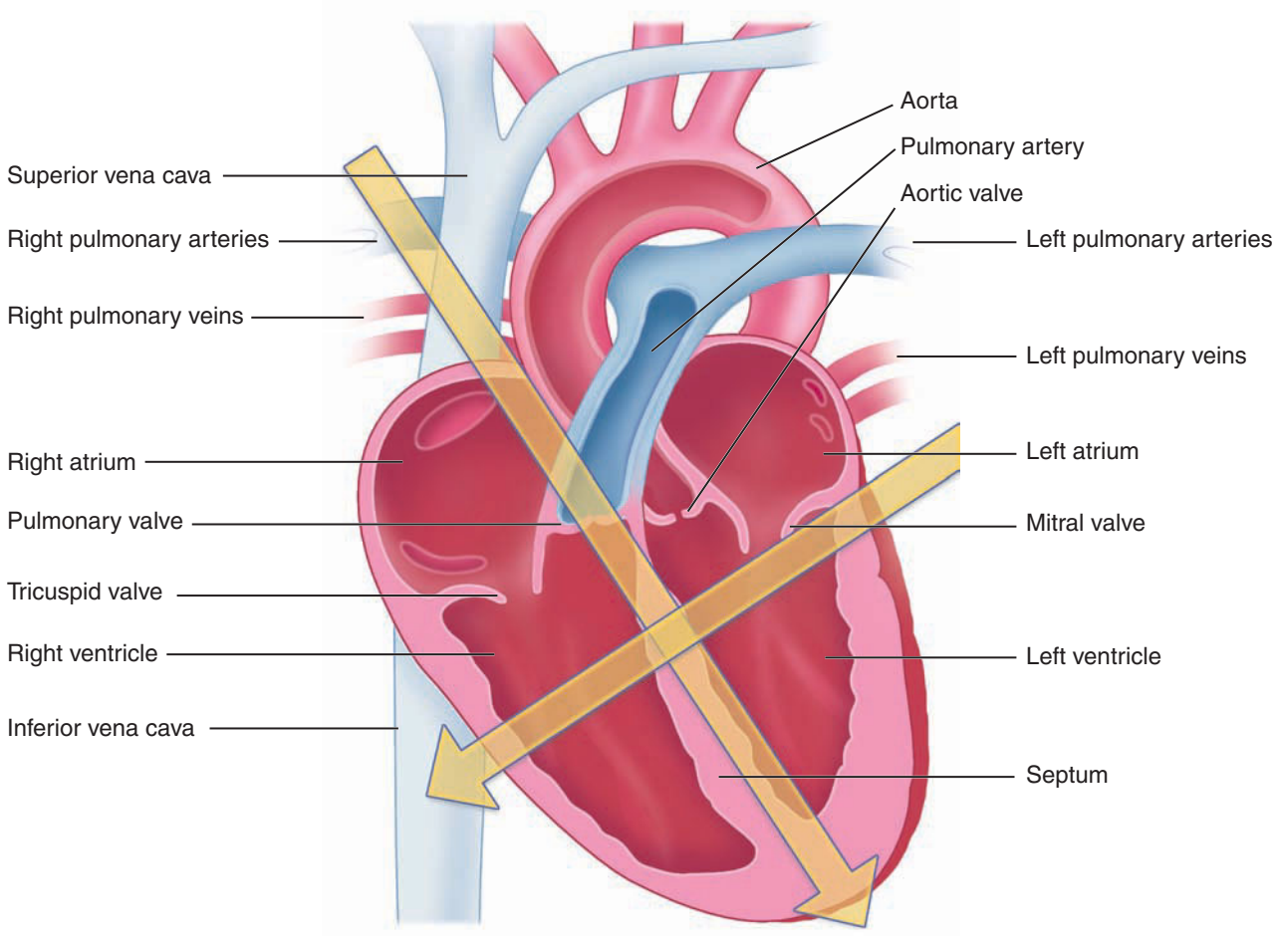


FIGURE 29-1. The cardiac anatomy. The long axis of the heart (*long arrow*) extends from the base to the apex. The short axis (*short arrow*) is a transverse slice perpendicular to the long axis.

are thin-walled muscular structures. The ventricles are more voluminous and muscular, with the left ventricle having the thickest wall. The base of the heart is the superior portion. It is formed by the left atrium, and to a lesser extent the right atrium. The apex of the heart consists of the inferolateral portion of the left ventricle. The anterior surface of the heart abuts the chest wall and is mainly formed by the right ventricle. The left ventricle forms the majority of the inferior surface, with the inferior portion of the right ventricle making a minor contribution. The heart has two axes; both are used extensively in ultrasonography. The long axis extends from the base to the apex, roughly along a line from the right shoulder to the left hip. The short axis slices the heart transversely and perpendicular to the long axis, roughly along a line from the left shoulder to the right hip.

The right heart delivers blood to the lungs to be oxygenated, and the left heart distributes it to the rest of the body. The right atrium receives deoxygenated blood from the body via the superior and inferior vena cava. Blood flows from the right atrium through the tricuspid valve and into the right ventricle during diastole. Blood is pumped from the right ventricle through the pulmonary valve and into the pulmonary artery during systole. The blood is oxygenated by the lungs then flows into the left atrium via the pulmonary veins. Blood flows across the mitral valve into the left ventricle during diastole. It is then pumped by the left ventricle for distribution to the body via the aorta during systole.

The heart is contained within the two-layered pericardial sac. The visceral pericardium is a single layer of cells in direct approximation with the epicardium. The tougher outer fibrous parietal pericardium surrounds the visceral pericardium. The two layers form a potential space that contains a small volume of fluid of approximately 20 to 50 mL.[7] This pericardial fluid allows the heart to freely move within the fibrous pericardium. Larger volumes of fluid can collect in this potential space in pathologic states.

PERICARDIAL EFFUSION

A pericardial effusion is a collection of fluid in the space between the visceral and parietal pericardium. Effusions can be due to trauma, uremia, infection, neoplasm, connective tissue disorders, iatrogenic complications, idiopathic conditions, chyle, and numerous other rare causes.[8] Cardiac tamponade occurs when the fluid collects rapidly, such as in the setting of trauma, where it can cause collapse of the ventricles and decreased cardiac output.[8,9] Fluid that collects more slowly will allow the parietal pericardium to expand accordingly and usually does not lead to cardiovascular collapse.[9]

CARDIAC ARREST

Cardiac arrest is the end result of numerous different pathologic states. Asystole is the complete absence of cardiac activity, or akinesis of the heart.[10] While atrial twitching may be visualized on US, the lack of ventricular activity is uniformly seen in asystole. Pulseless electrical activity (PEA) describes the state in which no pulses are palpable, but cardiac electrical activity is visible on ECG monitoring. Cardiac activity may or may not be present upon US of a heart in PEA. Cardiac arrest can occur from nonperfusing tachyarrhythmias and bradycardias. Cardiac motion is present in the case of ventricular fibrillation but is unorganized, preventing adequate cardiac filling and ejection of blood. Severe bradycardia causes the heart to beat at a rate too slow to provide adequate perfusion of the heart and other tissues.

CONGESTIVE HEART FAILURE

Congestive heart failure (CHF) is an increasingly common condition that distorts normal cardiac anatomy.[11] Dilation of the left ventricle, decreased ejection fraction, and decreased cardiac output are seen in systolic heart failure.[12] With a loss of healthy contractility and enlargement of the left ventricle, dilation of the other cardiac chambers generally ensues. Diastolic failure is due to prolonged exposure to high cardiac afterload as seen with aortic stenosis and uncontrolled hypertension.[13] This results in hypertrophy of the left ventricular myocardium. The thickened myocardium cannot relax appropriately to allow ventricular filling during diastole. Diastolic and systolic heart failure both result in a heart that appears globally enlarged. The point of maximal impulse (PMI) is lateralized due to enlargement of the left ventricle from either dilatation or hypertrophy. Both disease states can be visualized on US.

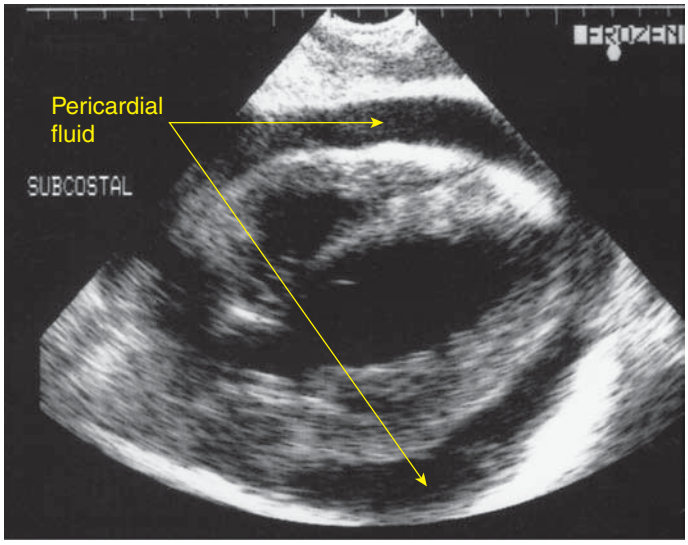


FIGURE 29-2. Free pericardial fluid is visualized as an anechoic stripe surrounding the heart. (Modified with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

US FOR SUSPECTED PERICARDIAL FLUID

Pericardial fluid appears as an anechoic collection between pericardium and myocardium (**Figure 29-2**). Small effusions may layer posteriorly or appear as thin black stripes under the pericardium. Larger effusions extend anteriorly to surround the heart entirely. Epicardial fat may be confused for pericardial fluid but can usually be differentiated because it appears as an isolated thin hypoechoic layer along the anterior aspect of the heart (**Figure 29-3**).[18] Fluid generally appears anechoic and not hypoechoic like the epicardial fat. Loculated effusions are usually spherical or lenticular collections with echogenic borders and septae.

US FOR TRAUMATIC HEMOPERICARDIUM

Cardiac US has been used to diagnose hemopericardium in the setting of trauma, particularly penetrating injuries.[2,19] US is a rapid and noninvasive means of determining the need for operative intervention. The physical exam is generally unreliable in diagnosing a hemopericardium.[20] A subxiphoid pericardial window is invasive and unwarranted in low-risk patients.[2] Rozycki et al. evaluated the use of US performed by Surgeons, Cardiologists, and technologists for diagnosing a hemopericardium due to penetrating torso trauma. This study revealed a sensitivity of 100%, specificity of 96.9%, and an accuracy of 97.3%.[2] Plummer et al. demonstrated that a rapid sonographic evaluation of the heart performed by EPs expedites lifesaving management for victims of penetrating trauma.[19] Both length of time to operative intervention and mortality were significantly improved by ED cardiac US.

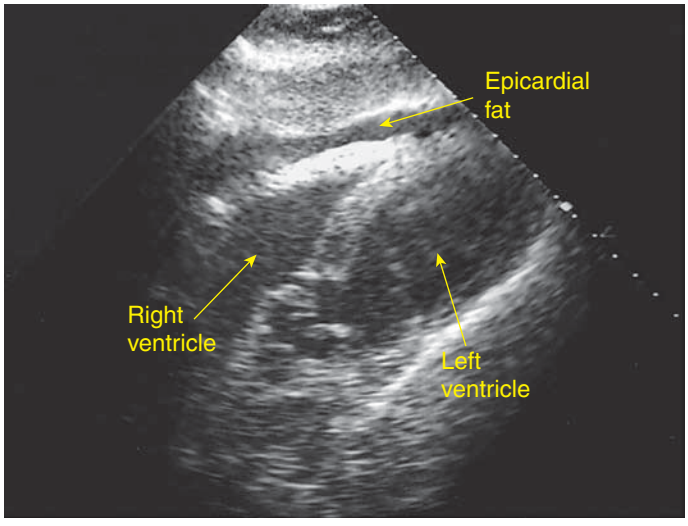


FIGURE 29-3. Subcostal long axis view of the heart demonstrating the epicardial fat pad anterior to the right ventricle. The epicardial fat pad is hypoechoic and not anechoic as usually seen with fluid. (Modified with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

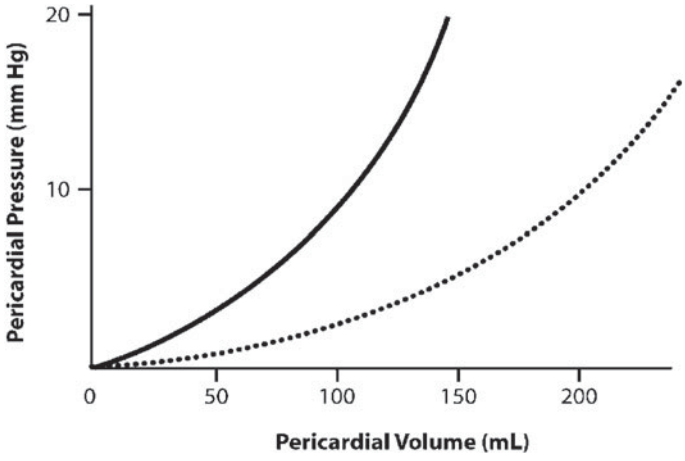


FIGURE 29-4. Pressure–volume relationship of the pericardial space. An acute effusion is represented by the solid line. A chronic effusion is represented by the dotted line. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

The Focused Assessment with Sonography for Trauma (FAST) exam is the cornerstone of trauma ultrasonography.[17] This study consists of four views: three abdominal views and a single cardiac view. The incidence of hemopericardium is significantly lower for blunt trauma than for penetrating injuries. Substantial blunt force to the chest or deceleration injuries may result in myocardial or aortic tears and a hemopericardium.[21] Refer to Chapter 5 for the complete details of the FAST exam.

US FOR NONTRAUMATIC EFFUSIONS

The clinical suspicion for a pericardial effusion should prompt the EP to perform bedside ultrasonography. The diagnosis of pericardial effusion should be considered in any patient presenting with shortness of breath, chest pain, and decreased exercise tolerance. Hypotension, distended neck veins, pulsus paradoxus, a pericardial rub on physical examination, and low voltage or electrical alternans on ECG are all consistent with a pericardial effusion. Unfortunately, most of these findings are neither sensitive nor specific for a pericardial effusion or cardiac tamponade.[20] Hence, cardiac US is critical in making the diagnosis. It is important to note that chronic pericardial effusions are generally better tolerated than acute effusions. Pericardial compliance over time allows for a greater volume that exerts less pressure upon the cardiac chambers (**Figure 29-4**).[9]

Mandavia et al. investigated the ability of EPs to diagnose a pericardial effusion with US.[1] Of the 515 patients enrolled, 103 had pericardial effusion identified by the EPs for a sensitivity of 96% and a specificity of 98% according to the comparative standard.

US IN CARDIAC ARREST

US is useful for guiding the management of patients in cardiac arrest. Confirmation of asystole helps the EP in deciding to terminate resuscitation efforts. The sonographic findings of an arrested heart include still ventricular walls, sporadic nonperfusing twitches of the valves or myocardium, and at times a "smoky" appearance to the intracardiac blood without forward motion. Blaivas and Fox evaluated the predictive value of cardiac US in cardiac arrest.[4] Of 136 patients with cardiac standstill on US, 71 had an identifiable rhythm on the monitor. No patient with PEA and cardiac standstill survived to leave the ED.

PEA refers to a state in which the heart generates electrical activity on the ECG monitor but is unable to perfuse a palpable pulse. The spectrum of etiologies for this condition can be visualized with US, from "subpalpable hypotension" with contracting ventricles to terminal erratic cardiac twitches. In an observational study performed by Tayal and Kline, PEA patients without sonographic cardiac activity all died.[3] Several patients with sonographic motion of the myocardium had reversible causes such as a pericardial effusion survived. US has value in diagnosing several other etiologies of PEA including: cardiac tamponade,[1] myocardial infarction,[22] cardiogenic shock,[5,6] pulmonary embolism (PE),[23] aortic rupture,[24] hypovolemia, and hemorrhagic shock states.[14]

Circumstance may arise when ventricular fibrillation is not appreciated on the ECG monitor but is diagnosed by US. Fine ventricular fibrillation can look like asystole on the ECG monitor. Ultrasonography of fine ventricular fibrillation appears as rapid trembling of the ventricular myocardium versus the lack of any motion for asystole.

US FOR LEFT VENTRICULAR FAILURE

The high prevalence of CHF makes the assessment of left ventricular (LV) function particularly valuable in the ED. New-onset CHF is generally a clinical diagnosis for the EP. However, cardiac US allows for direct evaluation of LV function. Cardiac US may aid in distinguishing CHF from other causes of dyspnea such as chronic obstructive pulmonary disease, pneumonia, pericardial effusion, and PE.[25,26] US can help differentiate cardiogenic shock from other types of shock in a patient with unexplained hypotension.[6]

Moore and Agur investigated the use of bedside US for estimations of LV function in hypotensive patients.[27] They concluded that EPs can make accurate determinations. Randazzo et al. conducted a study in which EPs performed bedside cardiac US examinations on 115 patients.[28] Overall agreement between EP categorization of LV ejection fraction and formal Cardiologist echocardiogram was 86.1%.

Complex statistical calculation packages exist in echocardiography for determining the function of the left ventricle. However, the echocardiographer's estimation of LV ejection fraction has been shown to be quite accurate.[29] Rapid general assessment of LV function is suited for the EP. LV function can be categorized as hyperdynamic, normal, moderately impaired, and severely impaired for practical purposes in the ED. The more cardiac US's one performs,

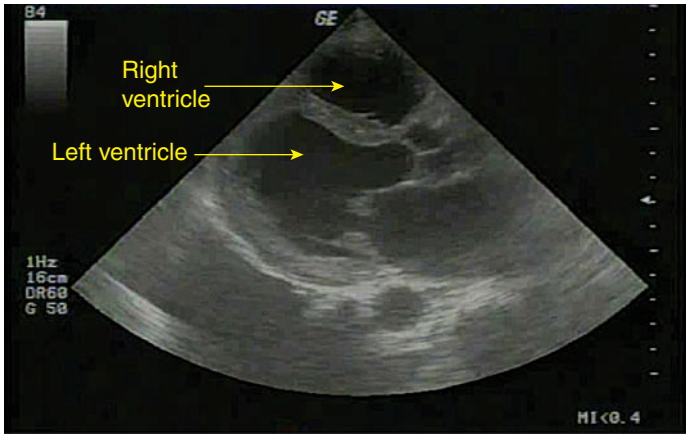


FIGURE 29-5. Parasternal long axis view of the heart in a patient with CHF. The enlarged left ventricle has limited contractility and a poor ejection fraction.

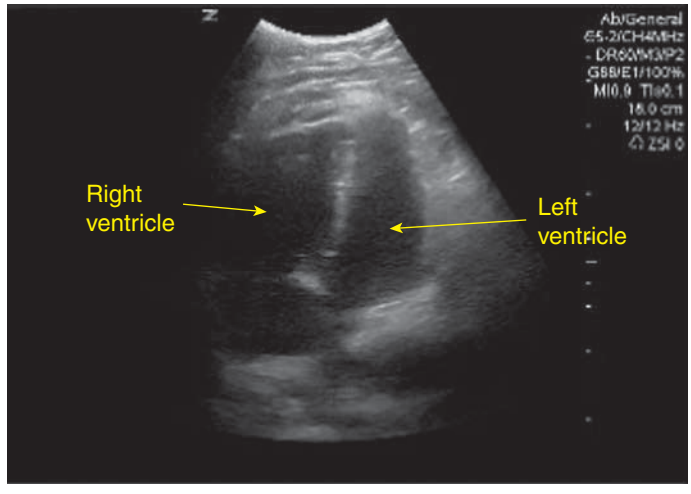


FIGURE 29-7. Right ventricular dilatation and bulging of the septum into the left ventricle are seen in the presence of a large PE.

the more comfortable one becomes categorizing a patient's LV function. A hyperdynamic heart is seen in the setting of hypovolemia or distributive shock. The tachycardic contractions cause the ventricular walls to nearly approximate or "kiss" each other. Hypokinetic contractions appear stiff. Patients with impaired LV function generally have dilated cardiac chambers, limited contractility, and limited inward movement of the ventricular walls during systole (**Figure 29-5**).

US FOR PULMONARY EMBOLISM

Patients with a large PE and hemodynamic compromise are often too unstable for conventional diagnostic imaging such as computed tomography and ventilation–perfusion scans. US can provide clues at the bedside for the diagnosis of a PE. The deep veins of the extremities can be assessed for clot.[30] A large obstructive PE will produce signs of right heart strain on cardiac US.[31,32] Dilation of the right ventricle should raise concern for a PE (**Figure 29-6**). Paradoxical bulging of the septum toward the left ventricle during diastolic filling is a sign of right heart strain (**Figure 29-7**).[32] Numerous other conditions such as emphysema, pulmonary hypertension, and right ventricular infarction cause right heart strain.[25,26] Konstantinides et al. showed that in hemodynamically stable patients with a PE and cardiac US findings of right heart dysfunction, administration of thrombolytic therapy reduced the need for escalation of treatment but did not affect mortality.[33]

US TO ASSESS SHOCK STATES

Bedside US is a valuable tool in the management of patients with undifferentiated shock. US provides a direct view into the cardiovascular system and allows the EP to make determinations about the hemodynamic status of a patient. Shock due to heart failure, cardiac tamponade, and PE was described previously. Hypovolemic and distributive shock generally presents with a tachycardic hyperdynamic heart. Rose et al. presented a protocol for the sonographic evaluation of the heart, peritoneal space, and aorta for undifferentiated hypotension.[5] Jones et al. concluded that implementing a similar protocol resulted in a more focused differential diagnosis and a more accurate ultimate diagnosis for patients in shock.[6]

Central venous pressures (CVP) and right atrial pressures can be estimated by US evaluation of the inferior vena cava (IVC) and the internal jugular veins, respectively.[16,34] An IVC diameter of 1.5 to 2 cm is considered normal (**Figure 29-8**).[16] A larger diameter

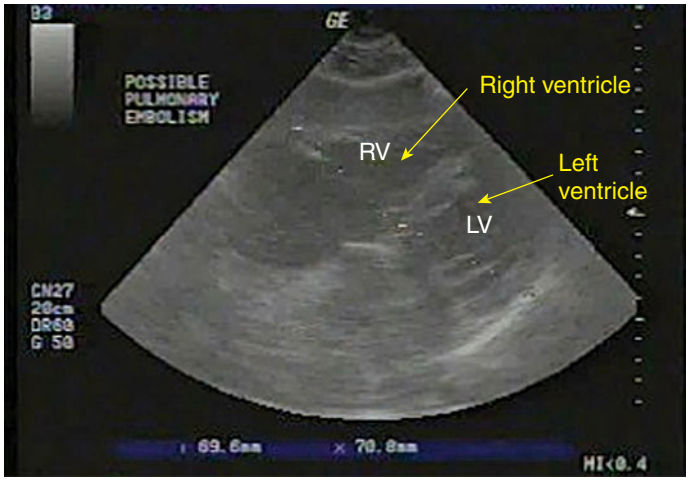


FIGURE 29-6. Concern for a PE is raised by the dilatation of the right ventricle. The diameter of the right ventricle is essentially equal to the diameter of the left ventricle.

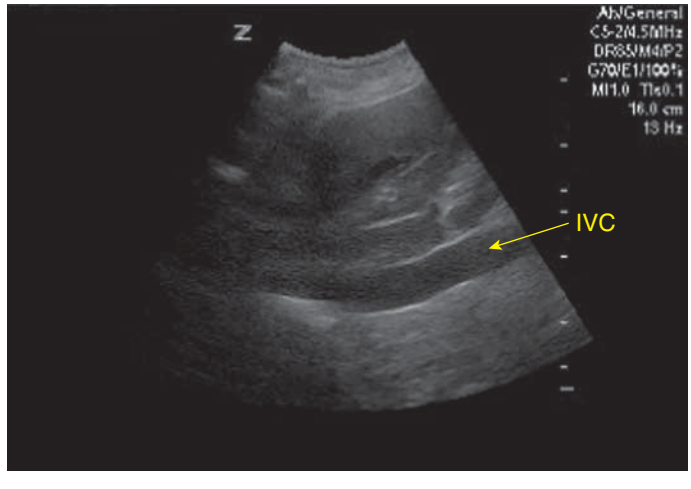


FIGURE 29-8. The normal caliber of the IVC as it passes beneath the liver in the caudal-cephalad direction.

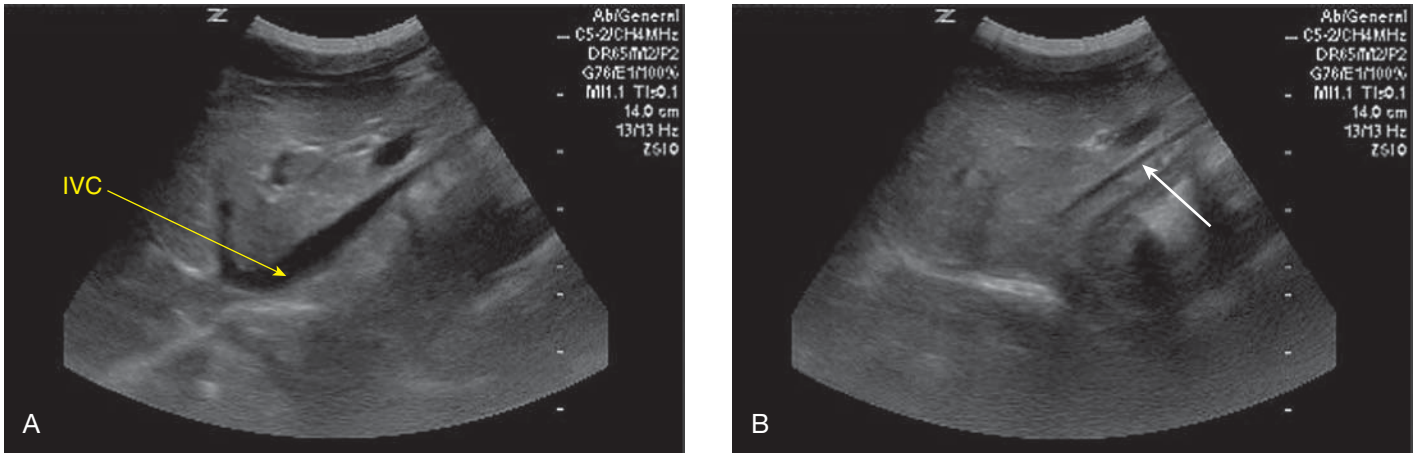


FIGURE 29-9. Longitudinal view of the IVC. **A.** The diameter of the IVC is narrow in this septic patient. **B.** Upon inspiration, the IVC collapses nearly completely (*white arrow*).

indicates elevated CVP while a smaller diameter is indicative of depressed CVP. The diameter of the IVC varies with respiration. Negative intrathoracic pressure produced by inspiration causes the IVC to collapse (**Figure 29-9**). A collapse of 50% is considered normal, with greater collapse indicative of low CVP and negligible collapse indicative of high CVP.[14–16] Simply stated, "fat" great veins are consistent with an elevated CVP and "flat" great veins are consistent with a low CVP.

INDICATIONS

The list of indications for cardiac US in the ED is continually expanding (**Table 29-1**). The two indications first described for ED US were for the identification of pericardial fluid (traumatic and nontraumatic) and the evaluation of cardiac activity.[17] These are still the primary examinations the EP must gain comfort in performing. Additional echocardiographic studies can be undertaken once these two have been mastered. This includes, but is not limited to, evaluation for left ventricular failure, chamber dilatation, myocardial wall motion defects, PE, evaluation of shock states, cardiac valve thrombus or vegetations, valvular dysfunction, procedural guidance (i.e., pericardiocentesis and transvenous pacer placement), and estimation of CVP by great vein measurements.

Numerous other indications exist for emergency US. EPs have begun to use cardiac US to evaluate wall motion defects in the setting of myocardial infarction.[22] Valvular abnormalities such as stenosis, regurgitation, thrombus, and vegetations (**Figure 29-10**) can also be assessed by emergency cardiac US.[35] The evaluation for cardiac myxomas, cardiac tumors, septal defects, dynamic function, and pediatric echocardiography are other cardiac US considerations in the future for the EP.

TABLE 29-1 Indications for Emergency Cardiac Ultrasonography

Primary indications	Advanced indications
Pericardial effusion	Cardiac chamber dilation
Cardiac arrest	Central venous pressure estimates
Traumatic hemopericardium	Intracardiac thrombus identification
	Left ventricular function
	Myocardial wall motion defects
	Procedural guidance
	Valvular dysfunction
	Valvular vegetations

CONTRAINDICATIONS

US is a noninvasive diagnostic modality. It is contraindicated only if it would delay and negatively impact a clinically obvious need for emergent operative intervention. The cardiac US exam should not be performed unsupervised by providers who have not been adequately trained.

EQUIPMENT

- US machine
- US gel
- Phased array low frequency US probe
- US probe cover or glove

A complete discussion of US equipment is beyond the scope of this chapter. Decisions regarding machines and probes depend on the user, cost, and intended applications. The cardiac US exam can be performed with a good quality low frequency probe. Probes with smaller footprints allow for easier viewing between the ribs.

The vast majority of cardiac US examinations performed by EPs are performed via the transthoracic approach. The preferred probe for transthoracic imaging is a small footprint, low frequency, phased

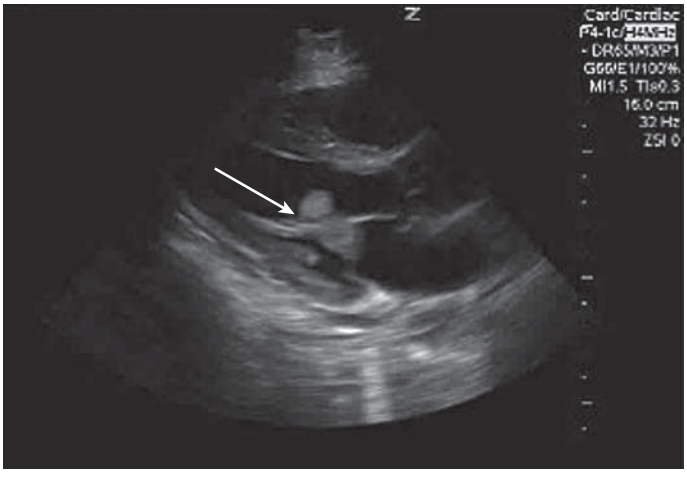


FIGURE 29-10. An infectious thrombus (*white arrow*) is located on the anterior leaflet of the mitral valve in this parasternal long axis view.

array, or microconvex probe (**Table 3-2**). Curved sequential probes can be used and may produce superior images. The large footprint of these probes can be cumbersome when trying to image between ribs or in a small subxiphoid space.

The US probe is generally used directly against the patient's skin, with gel between them. Place the probe in a probe cover or glove to prevent contamination of the probe if the patient's skin is covered with blood, urine, feces, or other substances. Place US gel in the probe cover or glove before inserting the probe. Squeeze out any air in the space between the tip of the probe and the probe cover or glove.

PATIENT PREPARATION

Little to no preparation is required to perform the cardiac US exam. Wipe any debris and liquids from the patient's skin in the areas to be scanned. Place the US probe in a probe cover or glove, as described above, if the patient's skin is contaminated with blood, vomit, other body fluids, or other substances that may contaminate or damage the probe.

TECHNIQUES

Echocardiography is a complex field. US is a dynamic tool that is well suited to imaging an organ in motion such as the heart. Much information about cardiac function and flow can be gained from complicated statistical calculation packages, advanced Doppler, and M-Mode measurements. This section focuses on the primary views most relevant to the EP with the hope of providing a foundation for more in-depth study of advanced cardiac US techniques in the future.

ORIENTATION INDICATOR

The probe orientation indicator in echocardiography is conventionally set to the right side of the screen. In Radiology, the probe indicator is set to the left side of the screen. Some controversy exists in EM as to which side of the screen to have the probe indicator for cardiac US. The approach preferred by the present authors is to set the orientation indicator on the left side of the screen, consistent with its location for other emergency US indications. It is impractical to switch the location of the indicator in the middle of a FAST exam or when performing multiple studies in a hypotensive patient. To obtain the conventional echocardiographic views, the probe must be rotated 180° from the conventional emergency US position. The left–right reversal of the indicator and the rotation of the probe result in the same image displayed on the screen. Most modern machines have a cardiac preset that automatically adjusts a number of factors to maximize cardiac imaging. It is important for the sonographer to be aware that this preset places the orientation indicator on the right side of the image. Left–right inversion is easily achieved on most machines.

SUBXIPHOID VIEW

The subxiphoid view is probably the most commonly used view by EPs. It provides visualization of the four heart chambers and allows for a superior evaluation for pericardial fluid. It can be performed without interruption of cardiopulmonary resuscitation or the insertion of chest tubes and subclavian central venous lines. The subxiphoid view is often the easiest view to incorporate into the FAST exam. This view can be limited in patients with a protuberant abdomen, abdominal pain, abdominal injuries, free air below the diaphragm, and/or nausea.

Place the probe in the subxiphoid space. Angle the probe cephalad into the patient's chest with the marker aimed to the patient's right (**Figure 29-11A**). Hold the probe with your fingers out from the underside or topside to allow for a shallow angle (approximately 20°) between the probe and the patient. The shallow angling of the transducer risks breaking contact between the footprint and skin.

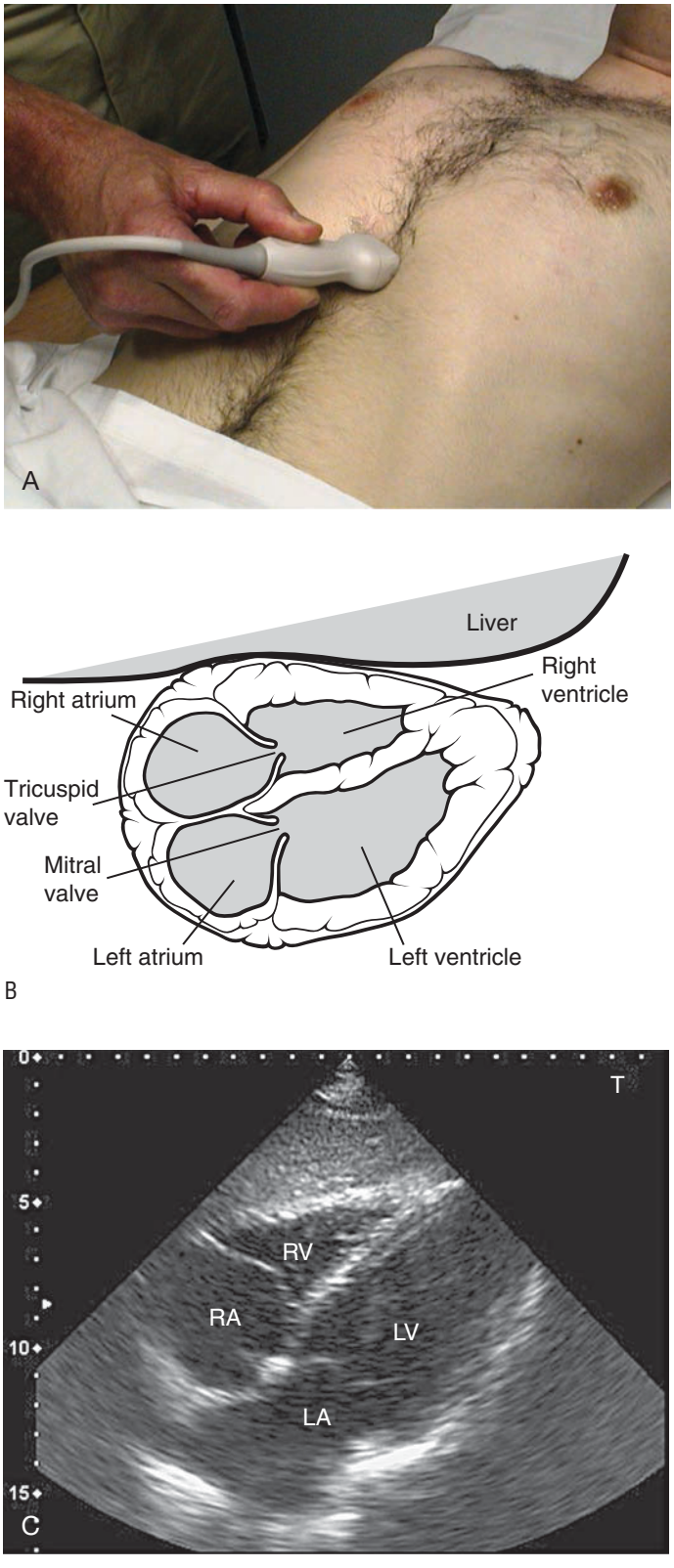


FIGURE 29-11. The subxiphoid view. **A.** Patient and probe positioning. **B.** Diagram of the US image. **C.** The US image. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

Apply an adequate amount of gel and firm pressure into the subxiphoid space to maintain contact.

To obtain a complete view of the heart, the US beam depth must be increased beyond that typically used for most other cardiac and abdominal imaging. To grasp the spatial orientation of this view, bear in mind that the probe is aimed from the inferior aspect of the heart. The US beam first traverses the left lobe of the liver, and hence, liver tissue is seen at the top of the image (**Figures 29-11B & C**). The plane of the beam then slices through the right-sided chambers, the septum, and then the left-sided chambers (**Figures 29-11B & C**). The echogenic pericardium is seen surrounding the myocardium.

Adjustments in a number of planes may improve the quality of the image. First, try to increase or decrease the steepness of the angle of the probe. While the heart lies more to the patient's left, so does the stomach, which contains air that scatters the US beam. The liver, on the other hand, serves as a good "acoustic window" or a transmitter of the beam allowing for better image acquisition. Taking advantage of imaging through the liver often involves veering from just right of midline, a slight counter clockwise rotation of the probe, and angling toward the patient's left shoulder. Ask the patient to take a deep breath to bring their heart inferiorly and into the scanning plane to improve the image.

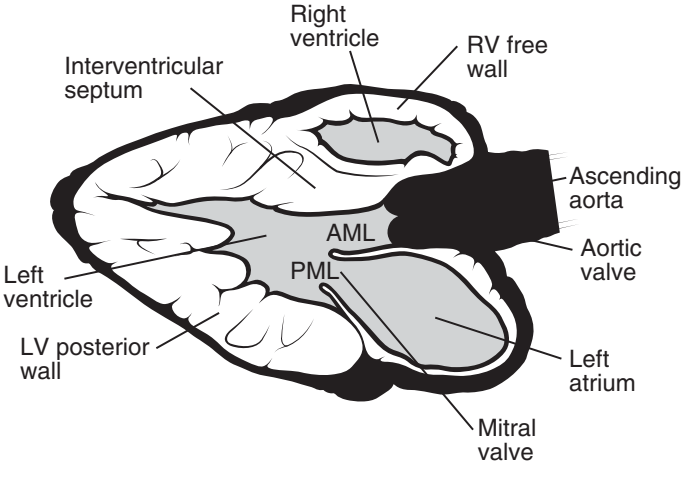
PARASTERNAL LONG AXIS VIEW

The parasternal long axis view may not be familiar to most EPs. It often is easier to obtain, provides clearer images, and is better tolerated by the patient. Place the probe to the left of the sternum, along the long axis of the heart (**Figure 29-12A**). Hold the probe perpendicular to the chest wall with the marker aimed toward the apex of the heart or the PMI. This is roughly toward the patient's left hip. Unfortunately, shadowing from bone and scattering from air in the lung surrounds the heart. Place the probe between two ribs and just lateral to the sternum, but not over lung tissue. The third or fourth intercostal space affords the best view.

The right ventricle sits underneath the probe and is visualized in the near field of the screen (**Figures 29-12B & C**). This view also provides an excellent glimpse into the left side of the heart. The left ventricle lies beneath the right ventricle. The interventricular septum is well visualized and extends to the apex of the heart on the left side of the screen. The base of the heart can be visualized on the right side of the screen (**Figure 29-12C**). The left ventricle empties into the aortic outflow tract, with the aortic valve and root usually visible. The left atrium lies deep, and the mitral valve can be seen opening into the left ventricle (**Figures 29-12B & C**). To visualize the apex of the heart in the center of the screen, slide the probe in the direction of the marker (toward the PMI) and in the opposite direction to the center of the base of the heart. The descending aorta may be visualized in a transverse slice along the underside of the heart and is an important landmark in distinguishing pericardial from pleural fluid. Pericardial fluid collects posteriorly and will appear as a black stripe separating the myocardium from the pericardium and descending aorta (**Figure 29-13**). Pleural fluid, on the other hand, will reside outside of the bright pericardium and tapers to a stop at the descending aorta.

Adjustments on the tilt of the probe may optimize the view. Place the patient in the left lateral decubitus position to bring the heart closer to the chest wall and improve the image. Slide the probe laterally, to a more cephalad intercostal space, or open its rotation with a counter-clockwise turn to better optimize the view for patients with CHF. Move the probe to a more caudal intercostal space, close the angle of the probe with a clockwise rotation, or use the subxiphoid view to better optimize the view for patients with emphysema and an inferiorly displaced heart.





B

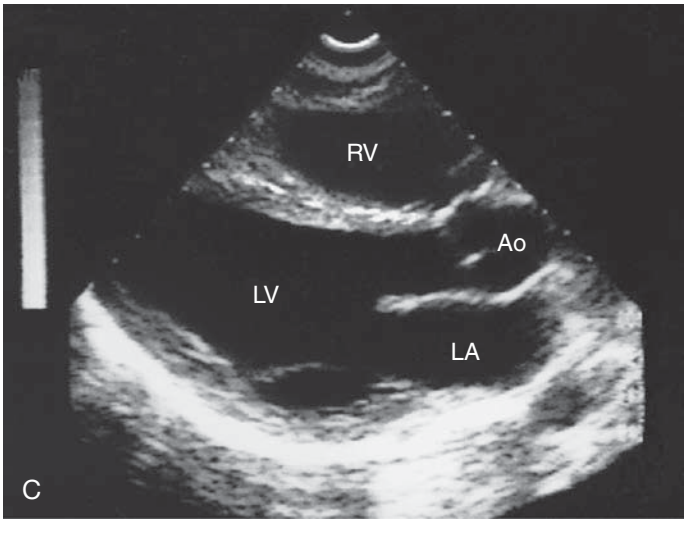


FIGURE 29-12. The parasternal long axis view. **A.** Patient and probe positioning. **B.** Diagram of the US image. **C.** The US image. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

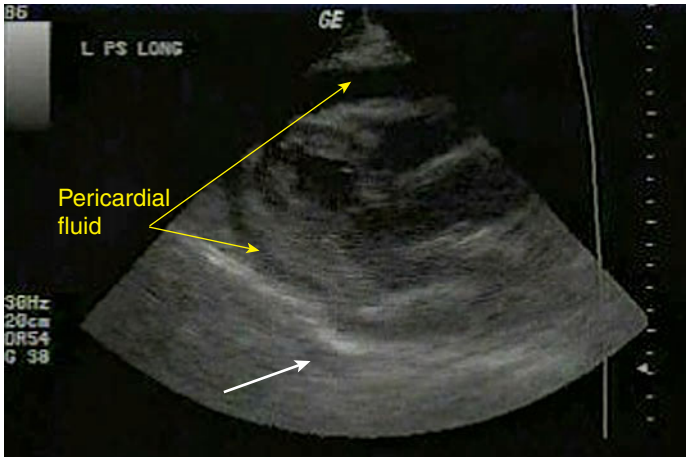


FIGURE 29-13. The parasternal long axis view of a pericardial effusion. Pericardial fluid separates the myocardium from the pericardium and the poorly visualized descending aorta (*white arrow*).

PARASTERNAL SHORT AXIS VIEW

The parasternal short axis view slices through the heart transversely. Place the probe similar to the parasternal long axis view, but with the probe rotated 90° to rest along the heart's short axis (**Figure 29-14**). Aim the marker toward the patient's right hip. The left ventricle appears as a prominent circle in the center of the screen, with the right ventricle resting atop it as a flatter or a crescent-shaped chamber (**Figures 29-14B & 29-15**). Tilting or sliding the probe along the heart's long axis toward the patient's left hip allows visualization of the apex of the heart. Tilting or sliding the probe toward the patient's right shoulder allows visualization of the base of the heart. The ventricles should cone down to a tip at the apex. When tilting back up from the apex through the heart, the papillary muscles (**Figure 29-15**) and mitral valve with its "fish-mouth" appearance (**Figure 29-16**) will come into view. Continue tilting the probe upward toward the base of the heart. The three leaflets of the aortic valve will be seen centrally (**Figure 29-17**). At this point, the scan is beyond the left ventricle, allowing the atria to be visualized as well as the right ventricle emptying into the pulmonary artery.

APICAL FOUR-CHAMBER VIEW

The apical four-chamber view is obtained by placing the probe at the PMI, just inferior to the left nipple and angling up through the heart (**Figure 29-18**). Aim the marker toward the patient's right. This study is relatively simple to perform by transitioning from the parasternal short axis view. Slide the probe down to the apex of the heart and then tilt it upward toward the base of the heart (**Figure 29-18A**). The image reveals a side-by-side view of the ventricles in the near field and the atria in the far field (**Figures 29-18B & C**). The lung adjacent to the heart impedes imaging. Place the patient in the left lateral decubitus position to alleviate scattering. The left ventricle appears larger and has thicker walls than the right ventricle. The mitral valve sits slightly lower than the tricuspid valve. Ventricular function, flow across the valves, and septal defects can be assessed with this view. This view allows for comparing chamber size and evaluating for right ventricular dilatation if there is concern for an obstructive PE.

SUBCOSTAL INFERIOR VENA CAVA VIEW

Sonographic evaluation of the IVC can provide valuable hemodynamic information to the EP.[14,15] This view is also referred to as the subxiphoid long axis view. Place the probe in the subxiphoid



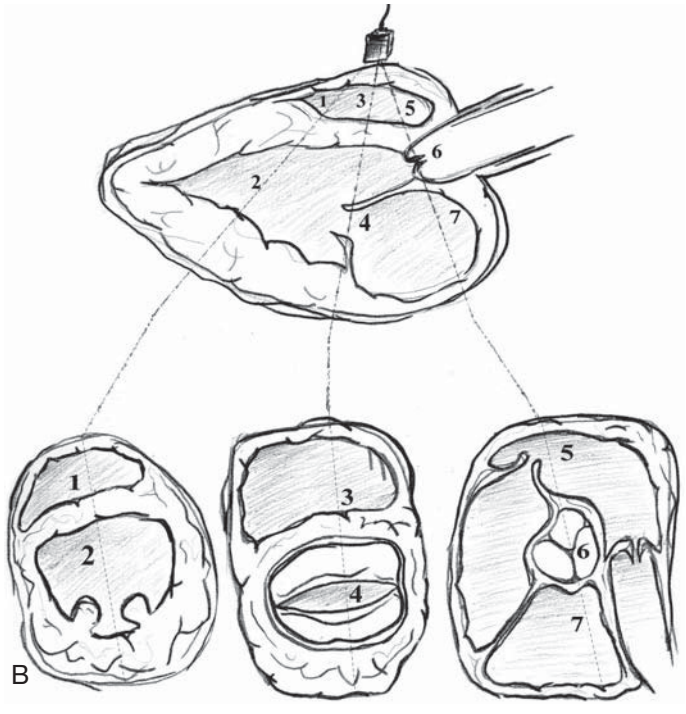
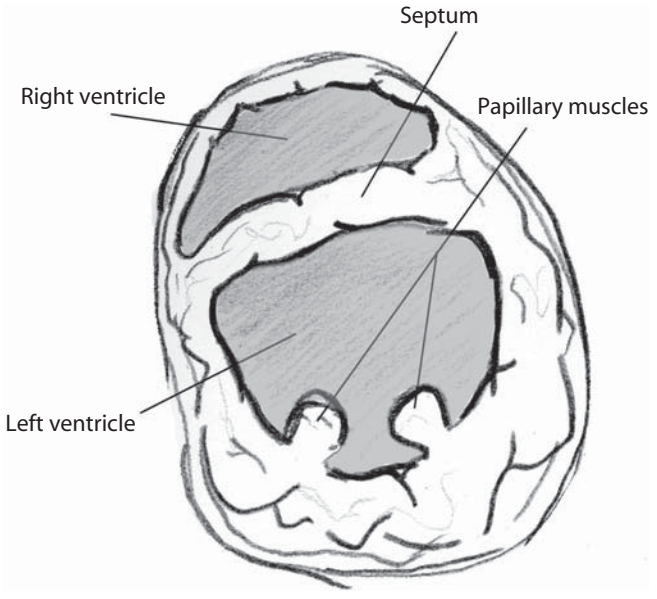


FIGURE 29-14. The parasternal short axis view. **A.** Patient and probe positioning. **B.** Diagram of the three US views depending on probe angulation. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

space, perpendicular to the patient's abdominal wall and with the marker aimed toward the patient's head (**Figure 29-19A**). The longitudinal IVC will appear posteriorly, beneath the liver and the bowel, as a long black cylinder. It is important to distinguish the IVC from the aorta. The aorta lies on the patient's left side, is more "pipe-like" in appearance, is noncompressible when pressure is applied by the US probe, and has a recognizable pulsatility. The IVC is compressible when pressure is applied by the US probe and varies in diameter with respiration (**Figures 29-19C & D**). It may be beneficial to start in the transverse plane in which both the IVC and the aorta are visualized (**Figure 29-20**). Starting with the transverse view, rotate the US probe 90°, maintaining the IVC in the center of the screen to obtain the longitudinal view



A

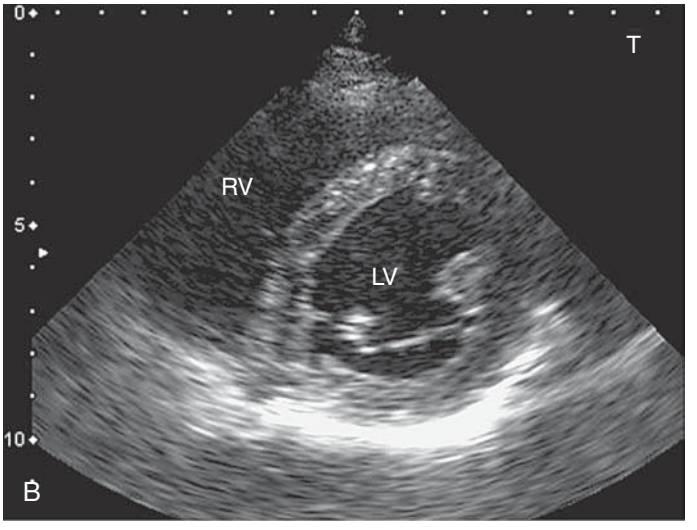


FIGURE 29-15. The parasternal short axis view at the level of the papillary muscles. **A.** Diagram of the US image. **B.** The US image. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

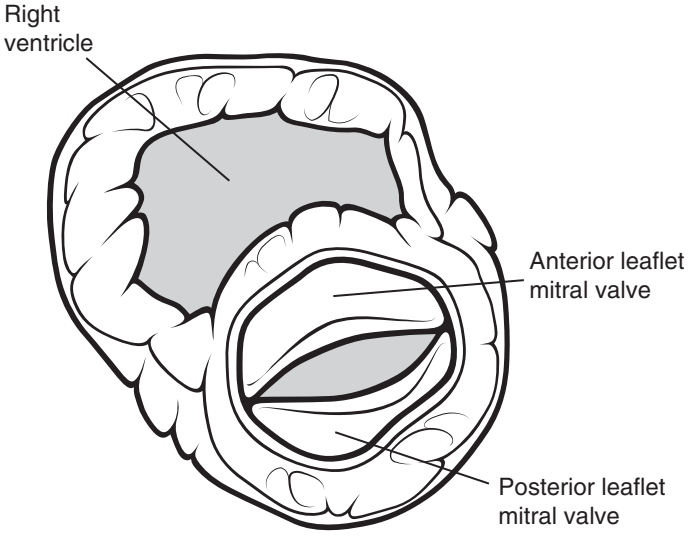
(**Figure 29-19**). Tilt the probe cephalad to visualize the IVC entering the right atrium (**Figures 29-19C & D**).

Measurements of the IVC proximal to its entrance into the right atrium allows for a noninvasive estimate of CVP. The negative pressure generated in the chest by inspiration draws blood cephalad and decreases the diameter of the IVC (**Figures 29-19C & D**). Normal dimensions for the IVC include a diameter of 1.5 to 2.0 cm and an inspiratory collapse of 50%.[14,15] A smaller diameter and greater inspiratory collapse are indicative of a low CVP.[14–16] A larger diameter and lesser inspiratory collapse reflect a high CVP.[14–16] Obtain estimates by having the patient sniff deeply and freeze the image postinspiration. Use the cine-rewind feature on the US machine to identify images or frames that allow for the measurement of the maximal and minimal IVC diameters through the respiratory cycle (**Figure 29-19**). M-Mode tracing of the respiratory cycle allows for precise measures of the inspiratory and expiratory IVC diameters (**Figure 29-21**).

US GUIDANCE FOR PERICARDIOCENTESIS

US-guided pericardiocentesis has proven to be safe and is the method of choice for most institutions.[36] A brief description of the procedure is provided in this section. Please refer to Chapter 36 for the complete details regarding pericardiocentesis.

Emergent pericardiocentesis can be guided by US using either a static or a dynamic approach. For the static approach, visualize the effusion by US and determine the best approach for needle placement. Remove the probe from the patient and proceed with the



A

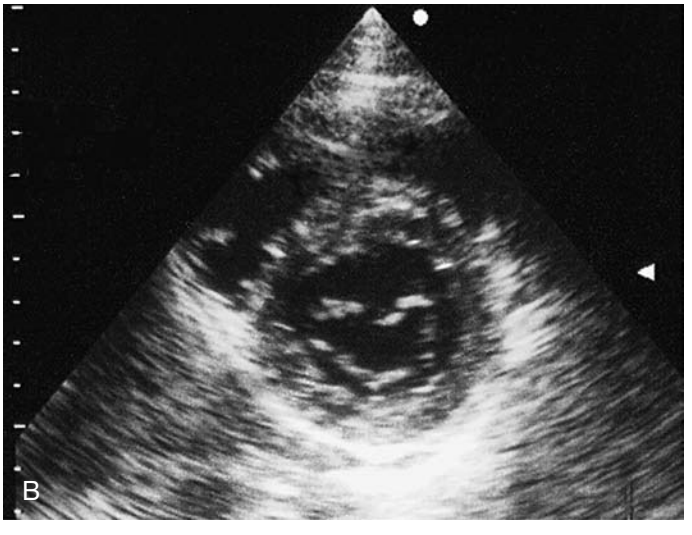
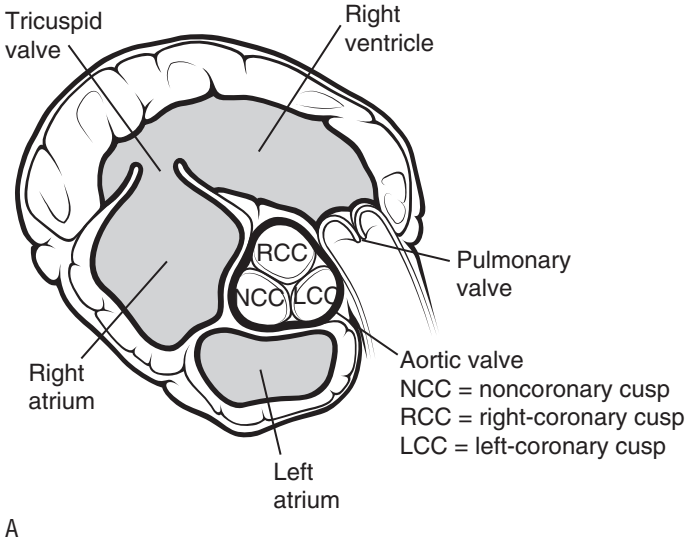


FIGURE 29-16. The parasternal short axis view at the level of the mitral valve. **A.** Diagram of the US image. **B.** The US image. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)



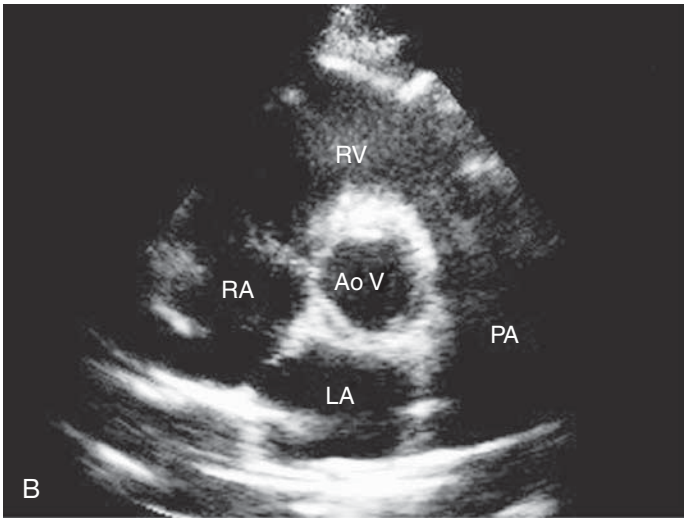
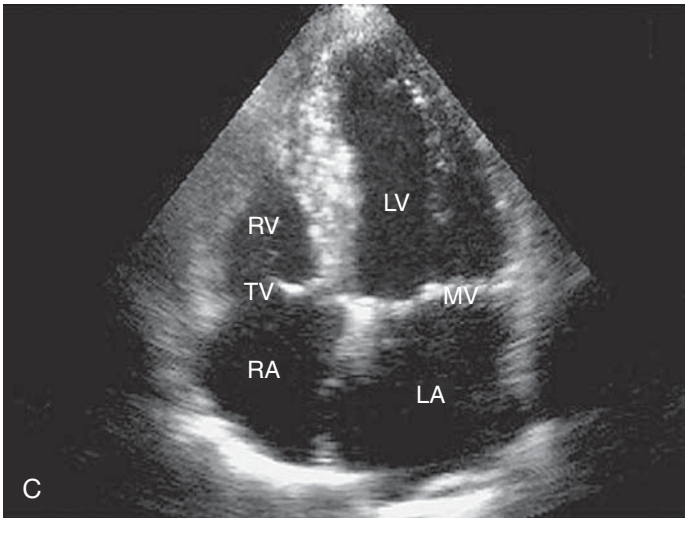


FIGURE 29-17. The parasternal short axis view at the level of the base of the heart. **A.** Diagram of the US image. **B.** The US image. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)





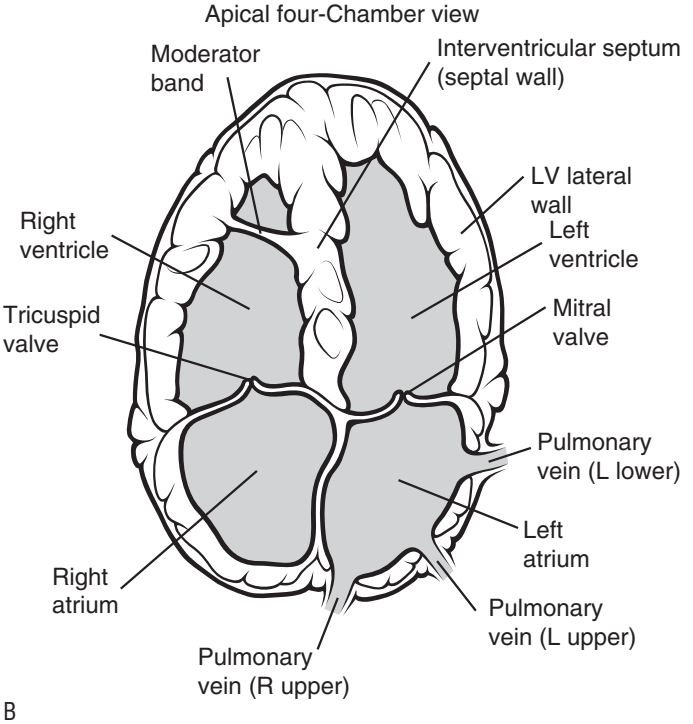
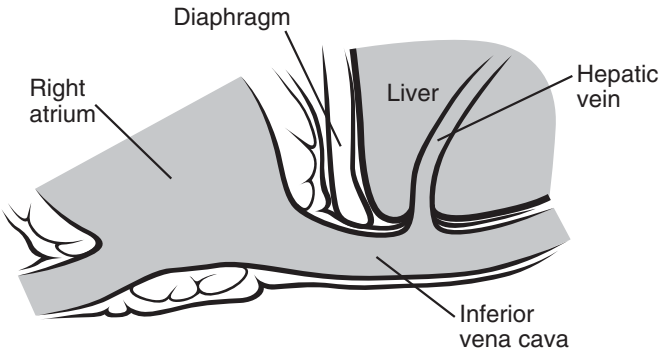
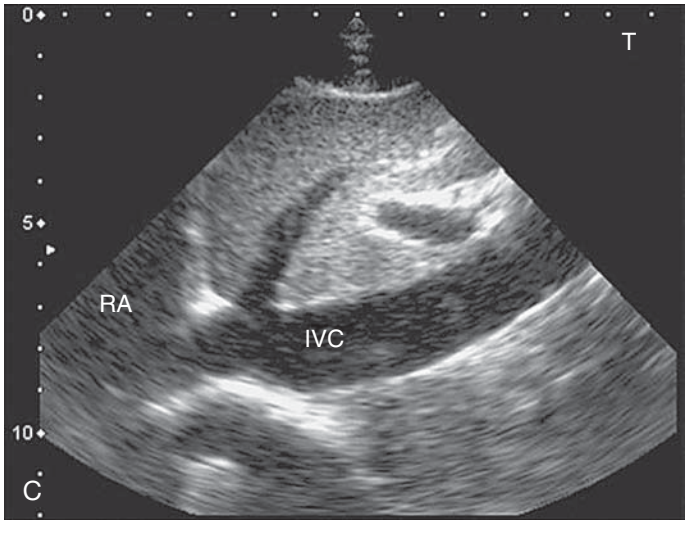


FIGURE 29-18. The apical four-chamber view of the heart. **A.** Patient and probe positioning. **B.** Diagram of the US image. **C.** The US image. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)







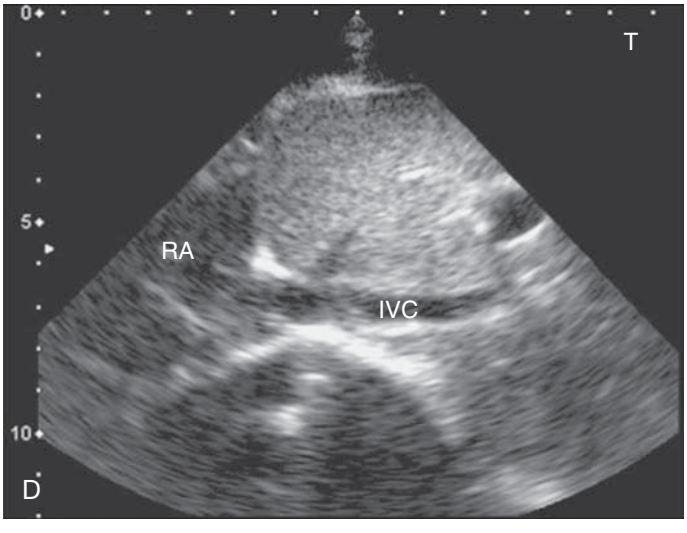


FIGURE 29-19. The subcostal IVC view. **A.** Patient and probe positioning. **B.** Diagram of the US image. **C.** US of the IVC during expiration. **D.** Diagram of the IVC during inspiration. (Used with permission from: Ma OJ, Mateer JM, Blaivas M: *Emergency Ultrasound*, 2nd ed. New York: McGraw-Hill, 2008.)

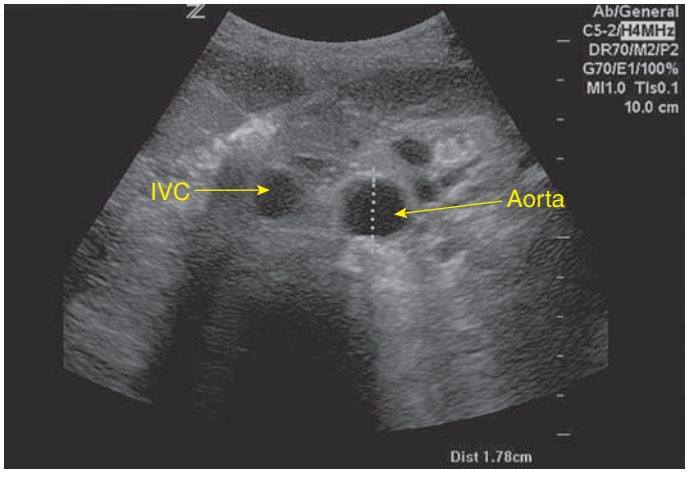


FIGURE 29-20. The transverse IVC view. The IVC is located to the right of the patient's aorta.

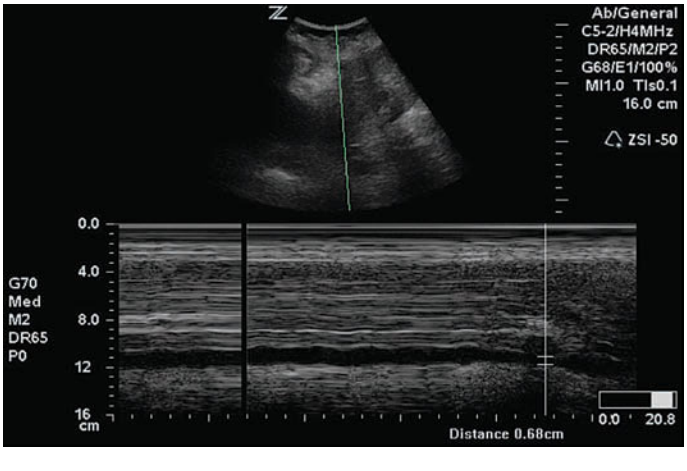


FIGURE 29-21. M-Mode tracing of the IVC. Respiratory variation is seen. The dark stripe represents the diameter of the IVC over time. Measurements are taken at the point of inspiratory collapse (*white lines*).

pericardiocentesis procedure. For the dynamic approach, the heart is visualized throughout the procedure to guide needle placement. Sterile technique is required for the US probe and cord. The availability of a second ultrasonographer or an assistant for dynamic guidance is helpful, particularly if an agitated-saline injection is attempted.

The pericardiocentesis site depends on the patient's body habitus, the location of the maximal visualized effusion, and the US views obtainable. The two most common sites for needle insertion are the subxiphoid space and left anterior parasternal chest wall.

For the static approach, visualize the path of needle penetration with the corresponding US image. Measure the distance from the top of the image to the pericardial space to determine the depth of needle insertion. It is important to note that the liver is often visualized in the anticipated needle trajectory with the subxiphoid US view. Use the parasternal long axis view because the pericardium is more superficial in this view. This author prefers the parasternal long axis approach for these reasons. Proceed with the pericardiocentesis procedure.

For the dynamic approach, insert the needle directly adjacent to the transducer. Angle the probe to interface with the plane of needle insertion (**Figure 29-22**). Aim the US probe marker cephalad and between the ribs to provide good visualization of the intercostal space. Insert the needle over the superior edge of the rib and along the plane of the US beam. It is optional to use color Doppler in the near field to ensure the intercostal and internal mammary arteries are not punctured. Advance the needle while aspirating with the syringe as the needle is advanced. The pericardium may "tent" as the echogenic needle presses upon it (**Figure 29-23A**) and then enters the pericardial space (**Figure 29-23B**).

Injection of agitated saline may be attempted to confirm needle placement in the pericardial space. Agitate the saline by rapidly injecting saline back and forth from one syringe into another through two ports of a three-way stopcock: with the third port connected by sterile tubing to the pericardiocentesis needle. Once microbubbles have formed, inject the agitated saline into the pericardial space. The fluid will appear on US as a bright white scattering within the pericardial sac.

US GUIDANCE FOR CARDIAC PACING

US can be used to confirm capture of transcutaneous (Chapter 31) or transvenous (Chapter 33) cardiac pacing.[37,38] It is difficult to appreciate mechanical capture by simply looking for electrical changes on the ECG monitor. Transcutaneous cardiac pacing discharges often cause simultaneous jerking of the patient that masks a palpable pulse. Cardiac US evaluation during cardiac pacing allows visualization of mechanical contractions of the heart. During placement of the transvenous cardiac pacing wire, it can be visualized passing through the right atrium and tricuspid valve into the right ventricle. A subcostal view of the IVC can confirm errant passage of the wire down the IVC.



FIGURE 29-22. US probe and pericardiocentesis needle positioning.

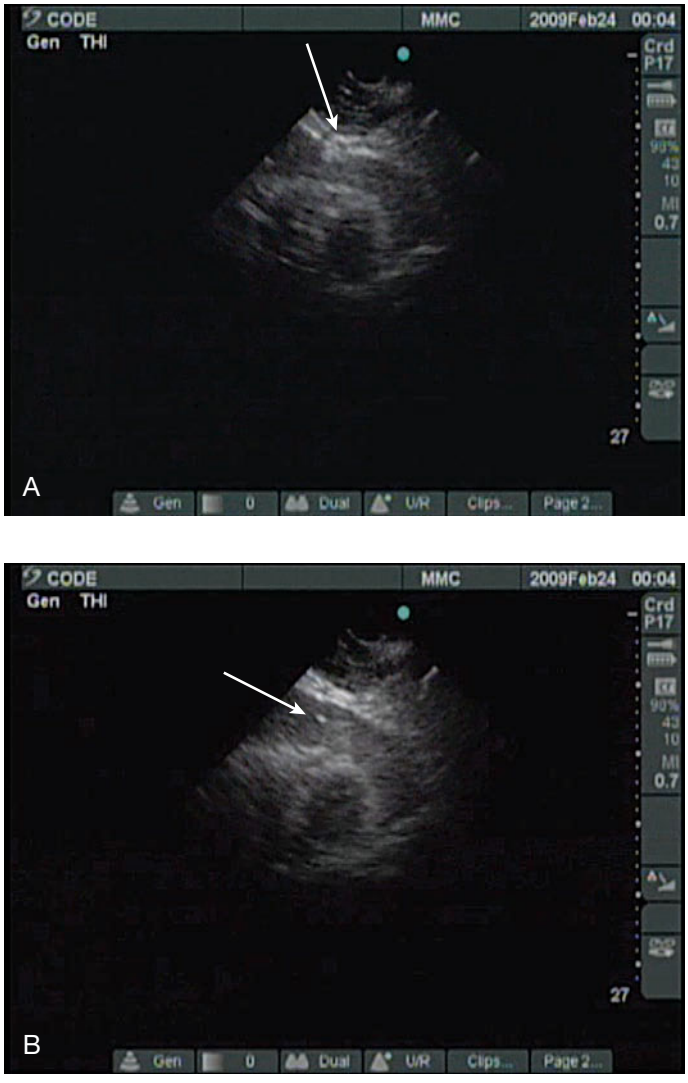


FIGURE 29-23. Pericardiocentesis. **A.** The needle is visualized tenting (*white arrow*) the anterior pericardium. A hazy pericardial effusion is present. **B.** The needle is visualized within the pericardial fluid as a bright white point (*white arrow*). (Image courtesy of Jason Gookhul, MD.)

SUMMARY

Limited ED cardiac ultrasonography provides real-time information to answer specific questions. It is not intended to replace formal cardiac echocardiography. There is a body of evidence that shows non-Cardiologists can accurately and safely perform limited cardiac US exams. The use of cardiac US in the ED has risen from a few basic examinations into a sophisticated series of exams in a very short time. This chapter provides an introduction to ED cardiac ultrasonography. The EP can become very comfortable with cardiac US as a supplement to the evaluation and management of patients. ED cardiac ultrasonography is a very valuable tool that can easily be incorporated into the daily clinical practice of Emergency Medicine.

30 Cardioversion and Defibrillation

Payman Sattar

INTRODUCTION

The application of electricity to the heart induces depolarization of the myocardial cells in a uniform fashion. This may interrupt reentry circuits that are inducing an arrhythmia. Once depolarization of the myocardium has been achieved, the sinus node may then resume its normal pacing function. This is accomplished with the transthoracic application of a direct-current electrical shock.

The techniques of cardioversion and defibrillation are relatively straightforward and practically identical. The main differences are the indications and use of synchronization with cardioversion. **The purpose of cardioversion is to deliver a precisely timed electrical current to the heart to convert an organized rhythm to a more hemodynamically stable rhythm. The purpose of defibrillation is to deliver a randomly timed high-energy electrical current to the heart to restore a normal sinus rhythm.** These techniques are currently performed by emergency medical technicians, nurses, paramedics, physicians, and a variety of other healthcare workers on a daily basis. This chapter discusses the techniques of manual cardioversion and defibrillation. A discussion of Advanced Cardiac Life Support (ACLS), cardiac rhythms, chemical cardioversion, and Pediatric Advanced Life Support is beyond the scope of this work. The technique of automatic external defibrillation is not discussed.

INDICATIONS

CARDIOVERSION

In general, electrical cardioversion is performed either electively or emergently. In the Emergency Department, the role of electrical cardioversion is usually limited to urgent or emergent situations or when medical therapy has failed.[1,2] This includes symptomatic reentry tachycardias (e.g., supraventricular tachycardia, atrial fibrillation, atrial flutter, and Wolff–Parkinson–White syndrome) and hemodynamically stable ventricular tachycardia associated with acute myocardial infarctions, altered levels of consciousness, chest pain, congestive heart failure, dizziness, dyspnea, hypotension, presyncope, pulmonary edema, shock, or syncope.

In the Emergency Department, electrical cardioversion is often preferred to chemical cardioversion for many reasons. Electrical cardioversion is simple and quick to perform. It is effective—in most cases almost immediately. It may be more successful than chemical cardioversion. The complications are usually minimal. Potential allergic reactions and toxic effects are nonexistent with electrical cardioversion.

DEFIBRILLATION

Defibrillation is indicated when ventricular fibrillation or ventricular tachycardia has not spontaneously converted to an organized rhythm. Ventricular fibrillation and ventricular tachycardia are rarely spontaneously reversible and are not compatible with life. Defibrillation must be performed immediately if the patient is found pulseless, unconscious and apneic, or during the ACLS protocol. "Fine" ventricular fibrillation can be present and may be confused with asystole. It may be secondary to low gain amplitude or improper lead positioning. If "quick-look" paddles are being used, they may be rotated 90°. If a monitor is being used, select a different lead and/or increase the gain to determine if the cardiac rhythm is fine ventricular fibrillation or asystole. Ventricular fibrillation or ventricular tachycardia secondary to myocardial ischemia or infarct, electrolyte abnormalities, long-QT syndromes, hypothermia, or drug toxicity (e.g., digoxin, tricyclic antidepressants, antiarrhythmics, antihistamine, and macrolide antibiotic combinations) may convert to a more stable rhythm with defibrillation.

CONTRAINDICATIONS

CARDIOVERSION

Cardioversion is contraindicated for several cardiac rhythms or conditions. Do not cardiovert a patient with a rhythm of ectopic atrial tachycardia, junctional tachycardia, multifocal atrial tachycardia, sick sinus syndrome, or sinus tachycardia. Cardioversion is not effective for these rhythms and may result in a worse (i.e., ventricular fibrillation or ventricular tachycardia) postshock rhythm. **Cardioversion of atrial fibrillation should not be attempted unless it is known with certainty that the rhythm initiated within the last 48 hours.** Cardioversion of chronic atrial fibrillation, or atrial fibrillation having lasted longer than 48 hours, may dislodge atrial thrombi, resulting in thrombus embolization and end organ injury (e.g., stroke). There is some controversy in the literature regarding the cardioversion of atrial flutter greater than 48 hours old without anticoagulation.[3,4] In general, elective cardioversion of atrial flutter should not be performed if the rhythm has lasted for longer than 48 hours. Often times, atrial fibrillation and flutter can coexist. **Do not cardiovert a patient with a known thrombus in the atria, atrial appendage, or ventricle without first consulting a Cardiologist. Cardioversion in patients with digoxin toxicity should be avoided.** Cardioversion in digoxin toxicity is usually ineffective and has been associated with postshock ventricular tachycardia and ventricular fibrillation.[5] Cardioversion is also contraindicated when the patient is without a pulse or has an underlying cardiac rhythm of asystole.

Alterations in the chemical or metabolic milieu of the myocardium may cause subsidiary pacemakers to become more dominant and overtake the sinus mode. This is referred to as enhanced automaticity and can be due to drugs (e.g., digoxin), hypoxia, or electrolyte abnormalities (e.g., hypokalemia or hypomagnesemia). Uniform depolarization with electricity does not terminate this abnormality, as uniform depolarization already exists. The rhythms that may occur are sinus tachycardia, ectopic atrial tachycardia, multifocal atrial tachycardia, and the digoxin toxic rhythms. Treatment of the underlying etiology is the treatment of choice.

DEFIBRILLATION

There are few contraindications to defibrillation. The main contraindication is in a patient who has made it clear that they does not wish to be resuscitated. Defibrillation should not be used for arrhythmias other than ventricular tachycardia or ventricular fibrillation.

EQUIPMENT

- Cardioverter-defibrillator unit
- Conductive jelly or pads
- Suction source, tubing, and catheter
- Airway management supplies
- Advanced Cardiac Life Support (ACLS) medications
- Intravenous sedative agents



FIGURE 30-1. Two examples of cardioverter-defibrillator units.

- Cardiac monitor
- Noninvasive blood pressure monitor
- Pulse oximeter
- Oxygen source and tubing
- Nasal cannula or face mask to deliver oxygen

THE CARDIOVERTER-DEFIBRILLATOR UNIT

The typical cardioverter-defibrillator unit performs both cardioversion and defibrillation (**Figure 30-1**). A list of available features on a typical unit is listed in **Table 30-1**. Newer models feature lower power outputs to accommodate their use in children, pediatric and adult paddles, biphasic waveforms, and cardiac pacing capabilities. Each Emergency Physician should be familiar with the specific unit at their facility. The general features of the unit are discussed below.

The unit is self-contained. It plugs into a standard electrical outlet. The unit also contains rechargeable batteries, which allow it to be portable. An oscilloscope provides real-time monitoring of the patient's cardiac rhythm. A continuous electrocardiographic (ECG) rhythm strip providing documentation on paper is standard with each unit, producing a hard copy to attach to the patient's medical record. Numerous dials or electronic touchpads with digital displays allow the operator to set the working mode, energy level, pacemaker settings, and oscilloscope input (e.g., ECG leads or "quick-look" paddles). The depolarizer within the machine provides direct electric current for cardioversion and defibrillation.

The synchronizer permits the discharge of electric current based on the patient's ECG waveform. It searches for the R and S waves of the ECG tracing to determine the proper time to discharge the current. It avoids delivering the current during the repolarization phase of the myocardial action potential, when the heart may convert to ventricular fibrillation or ventricular tachycardia. When the operator pushes the button to discharge the unit, a brief delay is noted while the synchronizer searches for an appropriate time to discharge the current.

TABLE 30-1 Characteristics of a Typical Cardioverter-Defibrillator Unit

Adult and pediatric paddles
Cardioversion capability
Continuous ECG rhythm-strip documentation on paper
Defibrillator capability
Depolarizer
On/off switch
Oscilloscope to monitor cardiac rhythms
Pacing capabilities
Portability
"Quick-look" paddles
Safety mechanism to prevent accidental electrical discharge
Synchronizer
Standard ECG leads (three) to attach to the shoulders and lower extremity
Wide range of energy selection

TABLE 30-2 Recommended Initial and Subsequent Monophasic Energy Levels for Cardioversion or Defibrillation

Cardiac rhythm	Initial energy setting	Subsequent energy settings*
Adults		
Atrial fibrillation	100 J	200, 300, 360 J
Atrial flutter	50 J	100, 200, 300, 360 J
Supraventricular tachycardia	50 J	100, 200, 300, 360 J
Ventricular tachycardia	200 J	300, 360 J
Ventricular fibrillation	200 J	300, 360 J
Children		
Supraventricular tachycardia	0.5 J/kg	1.0 J/kg
Ventricular tachycardia	2.0 J/kg	4.0 J/kg
Ventricular fibrillation	2.0 J/kg	4.0 J/kg

*To be performed sequentially in this order.

MONOPHASIC VERSUS BIPHASIC UNITS

In the past, all cardioverter-defibrillator units generated monophasic waveform current to deliver the shock. Biphasic waveform current generating units were developed in the late 1990s. The biphasic units deliver more current at a lower energy level to cardiovert or defibrillate (**Tables 30-2 & 30-3**). They have also been shown to be more effective in cardioverting and defibrillating a patient. Unfortunately, biphasic units are significantly more expensive than monophasic units. Determine which type of unit is available at your facility to determine the proper energy levels to administer.

TYPES OF ELECTRODES

The electrodes are referred to as either paddles or patches depending on their configuration. The paddles or patches must be firmly applied to the patient's torso. They allow a "quick look" and transmit

TABLE 30-3 Recommended Initial and Subsequent Zoll® Biphasic Energy Levels for Cardioversion or Defibrillation

Situation	Initial energy setting	Subsequent energy settings*
Adults		
Defibrillation	120 J	150, 200, 200 J
Synchronized cardioversion	70 J†	120, 150, 150 J
	75 J‡	
Children		
Defibrillation	2.0 J/kg	2.0, 2.0, 2.0 J/kg

*To be performed sequentially in this order.
†E Series.
‡M Series, CCT, R Series.

the patient's cardiac rhythm to the oscilloscope, letting the operator make medical decisions before the ECG leads are attached to the patient. Each paddle has a button on which a thumb is to be placed. This serves as a safety mechanism. Both buttons must be depressed simultaneously to discharge the current. This prevents accidental and premature discharge of current, which may injure the patient, the operator, or bystanders. Most newer units use self-adhesive, single patient use, disposable patches as an alternative to paddles. The patches apply to the torso similar to ECG leads. They connect by cables to the cardioverter-defibrillator unit.

Paddles or patches come in various shapes and sizes. Adult paddles or patches are round, oval, or rectangular in shape. They measure 8 to 10 cm in greatest diameter. They can be used on children weighing more than 10 kg or over 1 year of age, adolescents, and adults. Pediatric paddles or patches also come in a variety of shapes and measure 4 to 6 cm in greatest diameter. The pediatric paddles are to be used in children weighing less than 10 kg or less than 1 year of age. Some units contain both adult and pediatric paddles or the ability to use both adult and pediatric patches. In these units, the adult electrode slides off the paddle handle to reveal the pediatric-size electrode.

In choosing the proper paddle or patch for a small child, the cutoff of 10 kg and 1 year of age is relative. Choose the largest paddle or patch that will achieve complete and full contact with the child's chest wall. Larger paddles and patches will allow a greater amount of myocardium to be depolarized while decreasing the current density applied, so as to minimize myocardial injury. The paddles or patches must be at least 2 to 3 cm apart to prevent electrical bridging and burn injury to the child. Using paddles or patches that are too large will deliver the electric current over too great an area and decrease its effectiveness. The opposite is true in adults (using paddles or patches that are too small will deliver the electric current over a small area, which makes it too intense and increases the potential damage to the myocardium).

ELECTRODE POSITIONING

The paddles or patches may be positioned in several different patterns.[6,7,13] The most commonly used positions are anterolateral for paddles (**Figure 30-2**) and either anterolateral or anteroposterior (**Figure 30-3**) for patches. Anterolateral paddles or patches are positioned with the anterior paddle at the right upper sternal border

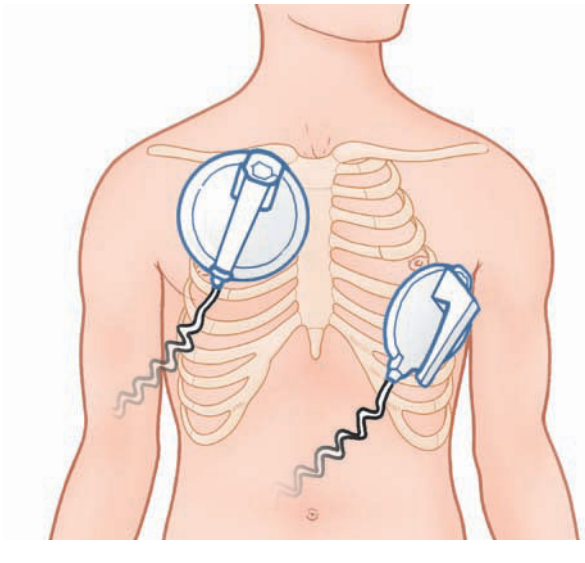


FIGURE 30-2. Anterolateral pad and paddle positioning.

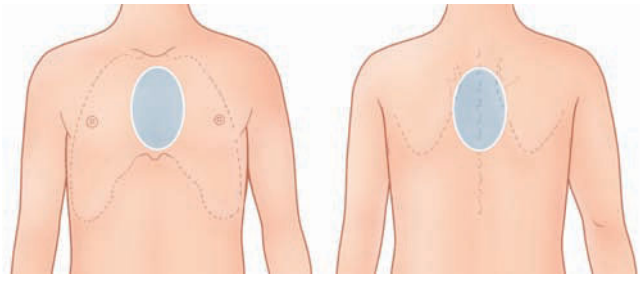


FIGURE 30-3. Anteroposterior pad and paddle positioning.

over the second and third intercostal spaces. The lateral paddle or patch is placed in the left midaxillary line centered over the fourth and fifth intercostal spaces. Anteroposterior placement is often used with disposable patches rather than paddles (**Figure 30-3**). The anterior patch is centered over the sternum, and the posterior patch is placed between the scapulae. A randomized and prospective trial evaluated the anteroposterior versus anterolateral patch position in converting atrial fibrillation.[13] The anteroposterior patch position was more effective in converting the rhythm. If pediatric paddles are required but not available, adult paddles can be substituted.[6] Roll the child onto their right side and place the paddles in the anteroposterior position. Other paddle positions include the laterolateral (axilla-to-axilla) position and the parasternal-infraclavicular (oblique, left anterior chest to right posterior infrascapular) position.[7]

CONDUCTIVE CONTACT MEDIUM

Electrically conductive contact medium should always be applied between the electrode and the patient's chest wall. Conductive gel pads are commercially available and primarily used. The contact material helps to maximize current flow, minimize resistance, reduce transthoracic impedance, and prevent thermal or electrical burns to the chest wall. The self-adhesive disposable patches are prelubricated with contact medium and need no additional contact medium.

Contact medium is required with the older units that use paddles. Self-adhesive, disposable conductive gel pads can be used. An alternative is the gel or paste form of contact medium. The contact medium should be applied to the paddles generously. It should not connect the paddles, because then it would divert the electric current along the chest wall, away from the heart, and cause burns to the chest wall. If contact medium is not available, saline-soaked gauze squares can be used in an emergency. The saline must be squeezed out of the gauze squares to prevent the accumulation of liquid on the chest wall, which could bridge the two paddles.

PATIENT PREPARATION

Place the patient supine on a bed. Attach the cardiac monitor, noninvasive blood pressure monitor, pulse oximetry, and oxygen to the patient. Obtain intravenous access. Suction and resuscitation equipment should be readily available in case it is needed. Cardioversion is scary and extremely uncomfortable for patients. Briefly explain the procedure to the patient, including the risks, benefits, and complications. Premedicate the patient prior to cardioversion if no contraindications exist, the patient is hemodynamically stable, and they can tolerate a delay to cardioversion. The choice of the appropriate sedative agent is physician-dependent. Commonly used agents include etomidate, ketamine, midazolam, methohexital, propofol, and thiopental. Diazepam and lorazepam are not often used because of the long delay to onset of action.

TECHNIQUES

Stand at the patient's left side. Turn on the cardioverter-defibrillator unit. Set the display to the "quick-look" paddles. Instruct the nurses to apply the ECG leads to the patient. Grasp the left paddle (sternum) with the left hand and the right paddle (apex) with the right hand. This is the anterolateral paddle position. Apply the paddles and observe the patient's cardiac rhythm. Set the mode as asynchronous (defibrillation) or synchronous (cardioversion) based on the patient's cardiac rhythm. Set the energy level (**Tables 30-2 & 30-3**). **Older defibrillator units deliver monophasic waveform energy. Newer units deliver biphasic energy, which has been shown to be more effective, and deliver more current at lower energy settings.**

Apply conductive pads to the patient's torso in the anterolateral position. Alternatively, apply conductive jelly to the paddles liberally and rub them together to coat the electrode surface completely. Apply the paddles firmly to the torso in the anterolateral position. **The paddles should be separated from each other by at least 2 to 3 cm to prevent arcing of the current and injury to the patient.**

Prepare to deliver the electric current to the patient. Charge the paddles. This must be done on the unit or the paddles before the initial and each subsequent discharge. It takes approximately 2 to 5 seconds to charge the paddles following activation of the charge button. **Ensure that nurses and other assistants are not touching the patient or the stretcher by saying "clear."** The assistant ventilating through a bag-valve device attached to an endotracheal tube does not need to drop the bag, as plastic is nonconductive. Turn off any open oxygen sources during shock delivery. **The person who will deliver the charge to the patient should ensure that their body is not in direct contact with the patient or the stretcher.**

Reevaluate the patient's cardiac rhythm. If still required, deliver the charge by simultaneously pressing the discharge buttons on each paddle. Observe the monitor and reevaluate the patient's cardiac rhythm. The unit can be recharged to deliver another electric charge to the patient if indicated.

The technique using self-adhesive disposable patches on newer units is similar with a few exceptions. Apply the patches in the anteroposterior position. No supplemental contact medium is required. The desired energy level is selected (**Tables 30-2 & 30-3**). Charge the cardioverter-defibrillator unit by pressing the charge button on the unit. Press the discharge button on the cardioverter-defibrillator unit to deliver the charge to the patient. Again reevaluate the need for further therapies as above.

Occasionally, the cardioverter-defibrillator unit may not deliver a shock. Check that the unit is plugged in, no touching or bridging of the pads or gel has occurred on the patient's chest, and that the paddles are charged. The cardioverter-defibrillator unit may not be able to properly sense the R-wave in synchronization mode with a rapid supraventricular rhythm. Reattempt to deliver the shock by holding down the discharge button for 15 seconds. This will give the cardioverter-defibrillator unit more time to determine and find a proper time to deliver the shock. Switching to asynchronous mode will allow the delivery of the shock, but risks shocking at the inappropriate time and converting the rhythm to ventricular tachycardia or ventricular fibrillation. Consider intravenous medication to slow the heart rate or chemically convert the rhythm rather than applying an asynchronous shock.

AFTERCARE

No specific aftercare is required related to the procedure of cardioversion or defibrillation. If using a cardioverter-defibrillator unit with paddles and conductive gel or paste, it is possible to cause a thermal burn to the skin. This should be treated as any other skin burn. Continuously monitor the patient after they are cardioverted or defibrillated. Almost all patients receiving cardioversion or defibrillation will be admitted to the hospital. Occasionally, a successfully cardioverted patient may be discharged home. The decision to discharge the patient should be made in consultation with the patients' Primary Care Physician and a Cardiologist.

COMPLICATIONS

Complications of cardioversion and defibrillation can range from none to death. Thermal and electrical burns are potential injuries. Skin burns may result, the severity of which increases depending on the energy level utilized and the number of shocks delivered. Care must be taken to avoid contact between the ECG monitor leads and the paddles, or of the paddles with each other, as sparks or fire may result. Burns can be minimized by utilizing electrically conductive contact media and firmly applying the paddles to the patient. Remove any fluid materials on the chest wall (i.e., conductive jelly, saline, sweat, urine, and water), as they can form a bridge between the paddles or pads and result in arcing and thermal burns to the thorax. Also, remove any nitroglycerin patches or ointments from the patient's torso. Ensure that there are no open oxygen sources that could ignite when the unit is discharged. If performed properly, repeated shocks will produce only a mild erythema to the chest wall. Systemic emboli may occur from clots in the left atrium becoming dislodged if the underlying rhythm prior to the cardioversion or defibrillation is atrial fibrillation.

Occasionally hypertension, other arrhythmias, or heart block may develop. If a synchronized or nonsynchronized shock is delivered on the T wave, ventricular fibrillation may result.[9–11] This usually occurs immediately and can be corrected with an nonsynchronized countershock. Ensure that the unit is in synchronous mode, not asynchronous mode, when cardioverting an organized cardiac rhythm. Always observe the monitor before delivering a countershock to ensure that it is required. If the T wave is large, change the monitor lead so that the T wave is smaller than the R wave and the unit will not cardiovert during a vulnerable period. Ventricular fibrillation that occurs within 30 to 60 seconds after the delivery of a synchronous shock is often due to digoxin toxicity and is difficult or impossible to correct. Transient ST-segment elevation may occur.[12]

Creatine kinase enzyme elevations may occur, most being skeletal muscle in origin.[10] Cardiac enzymes can also become elevated. The higher the energy level used and the more countershocks given, the greater the muscle damage that may result. Usually, no significant permanent myocardial damage occurs.

Do not apply the paddles or patches directly over an implanted defibrillator or pacemaker. The electric discharge can permanently damage these devices. Adjust the paddle or patch position so they are not directly over these devices.

Avoid injury to yourself or others by ensuring that no one is in contact with the bed or the patient when the shock is administered. Such injuries can range from mild shocks and burns to cardiac dysrhythmias. An improperly functioning unit can cause injury despite being used properly. Periodic maintenance and calibration of the unit is necessary.

SUMMARY

Cardioversion and defibrillation are the processes of applying electric current to a patient's chest to terminate a dysrhythmia. Cardioversion is a safe and effective method of converting reentry arrhythmias. If the patient is stable, a trial of medical therapy is warranted. If the patient is "unstable," cardioversion should be initiated as soon as possible. Consider administering parenteral

sedation, as cardioversion is anxiety-provoking and painful for the patient. Cardioversion should be performed in the synchronized mode. Always be prepared for ventricular fibrillation or ventricular tachycardia as a result of cardioversion of an organized rhythm. ACLS medications and airway support must be readily available. Defibrillation is essentially cardioversion of unstable ventricular tachycardia or ventricular fibrillation. It is performed like cardioversion except that synchronization and sedation are not required.

31 Transcutaneous Cardiac Pacing

Todd M. Larabee

INTRODUCTION

First documented as a technique in 1872, transcutaneous cardiac pacing (TCP) was successfully demonstrated in two patients with underlying cardiac disease and symptomatic bradycardia by Paul Zoll in 1952.[1] Studies involving open-chest and transvenous pacing, as well as open-chest cardiac massage, were occurring simultaneously by other groups. Zoll recognized the clinical difficulty of these approaches for the treatment of "ventricular standstill" in an emergent setting.[1,2] Zoll and colleagues performed animal experiments using electrodes placed in various positions prior to the use of subcutaneous needle electrodes at points "in a line transversing the ventricles" as described in the initial case report.[1] In 1956, they described the use of their procedure during eight surgical cases in which cardiac arrest occurred, with five patients successfully surviving to discharge.[2] At this time, cardiac monitoring during surgery was not routinely performed, thus the underlying rhythm being paced was not specifically determined in all reported cases.

Further work related to TCP seems to have lapsed until the 1980s, when several groups studied the technique for treatment of symptomatic bradycardias, asystolic cardiac arrest, and bradyasystolic cardiac arrest both in-hospital and in the Emergency Department. The results of these investigations were summarized by Hedges et al.[3] They concluded that TCP is as successful as transvenous cardiac pacing in obtaining electrical and mechanical capture in bradyasystolic arrests. TCP was easier to initiate than transvenous cardiac pacing. However, TCP did not improve the overall survival rates for these patients.[3]

TCP was recommended for cardiac emergencies by the International Liaison Committee on Resuscitation (ILCOR) guidelines beginning in 1980, and is currently recommended for treatment of symptomatic bradycardias, especially when the conduction block is at or below the His-Purkinje level.[4,5] TCP is no longer indicated for the treatment of asystolic cardiac arrest as there are no improvements in the rate of hospital admission or survival to hospital discharge in this setting.[5–7]

With current technology and equipment, TCP offers several advantages when compared to the placement of a transvenous cardiac pacemaker in the Emergency Department. The procedure requires minimal training and can be performed quickly. TCP is a noninvasive procedure and is not associated with the major complications of placing a transvenous cardiac pacemaker. This includes inadvertent arterial puncture, hemorrhage, pneumothorax, or cardiac tamponade from cardiac rupture. **TCP is an ideal early and temporary intervention for patients requiring stabilizing cardiac pacing support until more invasive procedures can be arranged in the proper clinical setting.**

ANATOMY AND PATHOPHYSIOLOGY

In the normal heart, electrical impulses originating in the sinoatrial (SA) node create an action potential that is conducted along the intrinsic cardiac nerve pathways to the atrioventricular (AV) node and disseminated through the His-Purkinje system. This action potential stimulates electrolyte flux, myocardial muscle depolarization, and subsequent cardiac muscle contraction. Electrical propagation and myocardial contraction occur separately in the atria and ventricles, with the atria contracting slightly ahead of the ventricles during ventricular diastole. This timing delay assists in filling the ventricles prior to their next ventricular systolic phase. The intrinsic heart rate is controlled by a balance of input from the sympathetic nervous system acting directly on the cardiac muscle and the parasympathetic nervous system acting most prominently at the SA and AV nodes.

The intrinsic heart rate can be disrupted due to a wide variety of disease processes. The usual blood supply for the SA node is from an early branch of the right coronary artery. Coronary artery disease can disrupt blood flow and oxygen supply to the myocardium, creating areas of cardiac ischemia that affects the conduction system, the impulse production, or conduction at the SA and AV nodes. Cardiac ischemia can result in action potential conduction delays and heart blocks, with resultant symptoms in the patient of bradycardia and hypotension. Electrolyte disturbances (e.g., hyperkalemia), structural heart disease, drug toxicity (e.g., calcium channel blockers and β-blockers), systemic toxins (e.g., cyanide), or systemic hypothermia are other causes of intrinsic conduction delays and heart blocks that can be considered in the differential diagnosis.

TCP delivers an extrinsic electrical impulse that overrides the intrinsic cardiac action potential. Initial pulse durations used were short at 1 to 2 milliseconds (ms). They have now been extended to 20 to 40 ms to decrease the threshold current or the current needed for cardiac muscle stimulation. The longer pulse duration also decreases patient comfort, as it is the degree of skeletal muscle contraction generated by the TCP pulse that determines patient discomfort.[8] Most TCP devices can generate up to 200 milliamps (mA) of current, while mean pacing currents needed to obtain capture have been shown to range from 40 to 100 mA.[8–11]

INDICATIONS

Transcutaneous cardiac pacing is technically the fastest and easiest method of emergency cardiac pacing. It is a temporary intervention prior to implementation of transvenous cardiac pacing or placement of a permanent cardiac pacemaker for primary cardiac dysfunction or until the underlying etiology of the bradycardia can be reversed. It is indicated for patients with symptomatic bradycardia from any etiology in whom pharmacologic interventions such as atropine have been unsuccessful. It can be effectively applied in the prehospital setting by EMS personnel, in a clinic, in the Emergency Department, or in the hospital. In patients with bradyarrhythmias that are expected to be transient (e.g., digoxin toxicity or AV block in the setting of an inferior wall myocardial infarction), TCP is quick, simple, and not associated with the morbidity or mortality of transvenous cardiac pacing.

It is indicated in patients with AV conduction blocks and sinus node dysfunction. It should be performed in symptomatic patients (e.g., syncope, presyncope, dizziness, fatigue, etc.) with complete or third-degree AV block, asystolic pauses exceeding 3 seconds, or an escape pacemaker rate less than 40 beats per minute. Patients with type I or type II second-degree AV block who are symptomatic should be transcutaneously paced. Symptomatic bifascicular block is also an indication for temporary TCP. Patients with sinus node dysfunction are candidates for pacing. Sinus node dysfunction

includes sinus pause with symptoms of cerebral hypoperfusion (e.g., syncope, presyncope, and dizziness), chronic sinus node dysfunction with or without symptoms but with escape rates of less than 40 beats per minute, or symptomatic sinus bradycardia.

TCP electrodes should be placed on patients in anticipation of potential clinical deterioration and bradyarrhythmias in the appropriate setting.[10] For example, a patient with a β-blocker overdose may present with a slow or normal heart rate but are otherwise asymptomatic. In this clinical scenario, hemodynamic deterioration is possible. Preparation for TCP (i.e., electrodes applied and connected to a generator unit, unit in standby mode, etc.) can be easily accomplished while further efforts related to the diagnosis and treatment are undertaken. If the patient develops bradyarrhythmias, the transcutaneous pacer can be immediately activated without the delays associated with obtaining the equipment and setting up the system.

TCP can also be used for overdrive cardiac pacing in event of a supraventricular or ventricular tachydysrhythmia such as ventricular tachycardia, torsade de pointes, or paroxysmal supraventricular tachycardia in the patient who is clinically stable.[12–15] A major limitation to overdrive cardiac pacing would be the maximum rate that the pulse generating unit can achieve. The technique requires pacing the patient at a rate of 20 to 60 beats per minute faster than the tachydysrhythmia.[14] Patients do not usually tolerate transcutaneous overdrive pacing due to the accompanying chest wall contractions and discomfort. The transvenous or transthoracic routes are preferred for overdrive pacing of the myocardium.

CONTRAINDICATIONS

There are no absolute contraindications to TCP. Hypothermia has been considered a relative contraindication to TCP. The associated bradycardia seen during hypothermia is thought to be a result of direct myocardial depression and decreased metabolic rate.[16,17] Concerns related to ventricular irritability, dysrhythmias, and resistance to defibrillation have led to the idea that electrical manipulation of the hypothermic myocardium should be avoided.[18] There are, however, case reports of successful TCP use during rewarming for severe hypothermia.[19] TCP is also relatively contraindicated for prolonged bradyasystolic cardiac arrest due to the overall poor resuscitation rates and outcomes of these patients.[6,7,10] TCP is no longer indicated for the treatment of asystolic cardiac arrest as there are no improvements in the rates of hospital admission or survival to hospital discharge in this setting.[10]

EQUIPMENT

- Pulse generator and monitor unit
- Pacing cable attached to the monitor
- Pacemaker patches or electrodes:
  - 6×7 cm^2 for infants and young children
  - 13×15 cm^2 for older children and adult
- ECG patches or electrodes (if pacemaker patches and unit do not monitor patient)
- ECG cable attached to cardiac monitor (if pacemaker patches and unit do not monitor the patient)
- Intravenous access supplies
- Sedative and analgesic medications
- Povidone iodine or chlorhexidine solution
- Skin razor

Most commercially available cardiac defibrillators used in the Emergency Department are a combination cardioverter, defibrillator, and cardiac pacer with an associated ECG monitor. (**Figure 31-1**) The unit is usually available on all code carts in the Emergency Department and throughout the hospital. The Emergency Physician should become familiar with their specific institutional equipment prior to an emergent situation requiring its use.

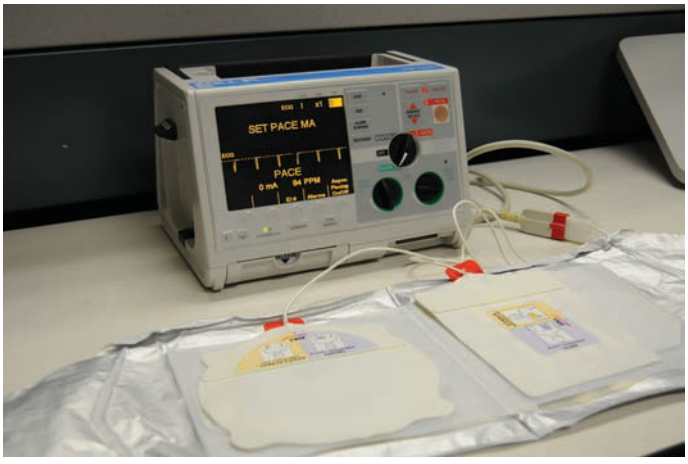


FIGURE 31-1. The cardiac monitor/defibrillator with TCP capabilities and attached surface patches.

The pacing patches are either round or rectangular, and come packaged as pairs with illustrations to demonstrate proper placement of the electrode (**Figure 31-2**). The negative electrode will be labeled "front" or "apex." The positive electrode may be labeled "back" or "posterior." Most modern TCP electrodes are disposable, single patient use, and multipurpose. The one electrode can be used to perform cardioversion, defibrillation, ECG monitoring, and TCP. Some older units may not have this flexibility and require separate ECG leads.

PATIENT PREPARATION

If time allows, discuss the procedure with the patient and/or their representative. This should include the reason for performing the procedure, the risks of the procedure including pain-related issues and how pain will be addressed, and the benefits of the procedure including expected symptom improvement. There is a small risk of developing a ventricular tachydysrhythmia during TCP.[20]

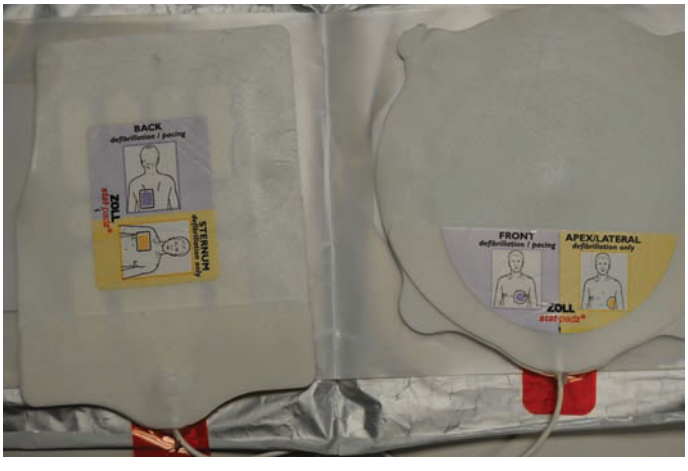


FIGURE 31-2. TCP electrodes with diagrams demonstrating placement on the electrode.

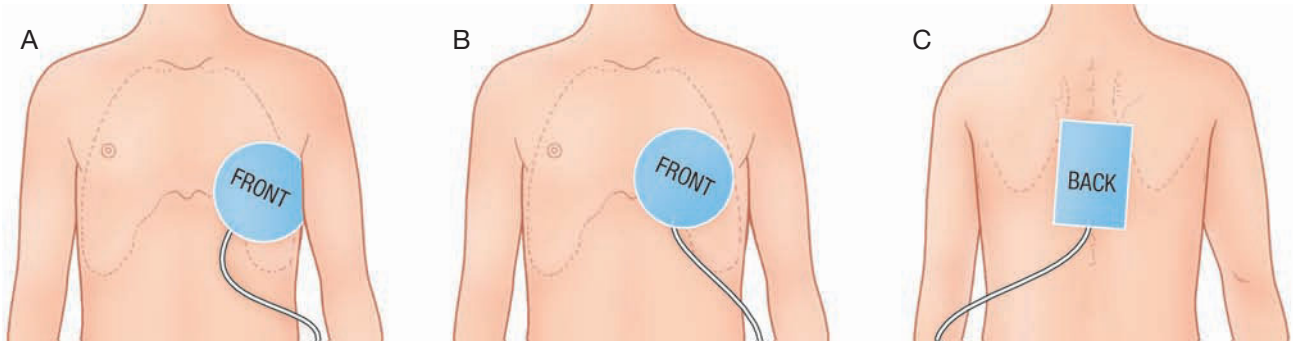


FIGURE 31-3. Placement of TCP electrodes. **A.** Anterior (negative) electrode placed over the cardiac apex. **B.** Anterior (negative) electrode position centered over the V_3 lead position. **C.** Posterior (positive) electrode position.

A written and signed consent documenting this conversation is always preferred. However, it is not required in an emergent situation. Documentation of the conversation in the medical record should be adequate in an emergent situation. Preparation for transvenous cardiac pacing (Chapter 33) can be simultaneously undertaken in the event that TCP is unsuccessful.

The patient's skin should be relatively clean and free of debris. Warm, soapy water can be used as a cleansing agent. Avoid potentially flammable cleansing solvents such as alcohol-based solutions. The skin should be dry. Trim the patients back and chest hair if the patient is hirsute and the pacing patches are poorly adherent. Trimming is preferred to shaving to avoid skin disruption or abrasions that may cause increased pain, skin irritation, and bacteremia during the procedure. If shaving is required, and pacing is not emergently required, first apply povidone iodine or chlorhexidine to the area and allow it to dry. This will decontaminate the skin prior to shaving.

Administer sedative and analgesic medications to manage the discomfort related to the chest wall skeletal muscle contractions associated with TCP.[20] Pain levels associated with TCP were found to be moderate to moderately severe (mean of 3.2 on a five-point scale) in 30 healthy volunteers.[11] One volunteer quit the study due to the severity of the pain.

TECHNIQUES

PAD PLACEMENT

Two pacing electrodes must be applied to the thorax (**Figure 31-2**). Place the front, anterior, or negative labelled electrode on the anterior chest wall, and centered over the apex of the heart (**Figure 31-3A**) or over the V_3 lead position (**Figure 31-3B**). In females, the anterior electrode should be positioned by lifting the breast and placing it under the fold of the breast and against the chest wall. Place the back, posterior, or positive labelled electrode directly behind the anterior electrode and to the left of the thoracic spine, between the spine and the scapula (**Figure 31-3C**). Avoid trapping air or debris under the pad during placement. As an alternative, the positive electrode may be placed on the right upper chest and the negative electrode over the apex of the heart (**Figure 31-4**).

PACING

Once the pacing electrodes are positioned, connect the cable from the electrodes to the pacer/monitor unit. Turn the output current (mA) dial as low as possible (**Figure 31-5**). Set the pacing rate between 80 and 90 beats per minute. Select the pacer function of the pacer/monitor unit. Turn the unit on. Gradually increase the current output by 5 to 10 mA at a time until capture is achieved (**Figure 31-6**). Note the mA output value that is required to initiate TCP. This is known as the threshold current. Increase the output current approximately 10%, or 5 to 10 mA, above the threshold current. Maintain the output current at this level.

In the near-arrest or unconscious patient, start with the output current set at maximum. Turn the unit on. Dial the output current down until capture is lost. This is the threshold current. Raise the output to restore capture. Increase the output current approximately 10%, or 5 to 10 mA, above the threshold current. Maintain the output current at this level.

Some pacer/monitor units can operate in a "standby mode." This mode can be used for patients who are at risk of developing symptomatic bradycardia, but who are currently clinically stable. Set the unit to "pacing mode." Attach the pacer electrodes to the patient and the unit. Initiate a brief period of TCP at a rate slightly faster than the patient's intrinsic rate to determine the threshold current and if capture is possible. Turn the unit off. Set a reduced rate on the pacer dial. This rate should be below the patient's current heart rate but also be the minimal heart rate acceptable to the Emergency Physician for the patient. Switch the unit to "standby mode" and turn it on. If the patient's heart rate falls below the value set on the unit, the pacer function will automatically engage.

OVERDRIVE PACING

When performing overdrive TCP, full cardiac resuscitation equipment should be available and ready at the bedside, as rhythm acceleration and subsequent hemodynamic instability are possible. The pacer electrodes and pacing unit setup remain the same to perform overdrive TCP for a tachydysrhythmia.

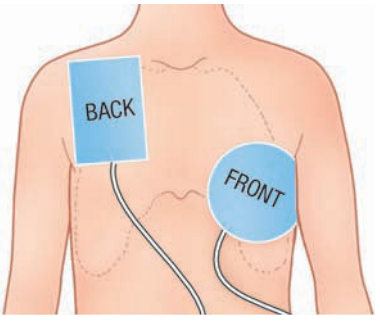


FIGURE 31-4. Alternative transcutaneous pacing electrode positions. The negative electrode is positioned over the cardiac apex. The positive electrode is positioned on the right anterior chest wall.



FIGURE 31-5. Monitor dials demonstrating separate defibrillation and pacing functions; also demonstrating electrical current (mA) and heart rate dials to set for TCP.

Administer sedative and analgesic medications as required. Set the current output at 120 mA, as this current generally will exceed the threshold value for most patients. Turn on the unit and initiate asynchronous cardiac pacing at a rate of 20 to 60 beats per minute higher than the intrinsic rate of the tachydysrhythmia.[14] Once capture is achieved, decrease the current output to just above the threshold current. Slowly lower the pacing rate to decrease the patient's heart rate to the desired level. TCP for overdrive pacing may not be possible due to the upper heart rate limit of the available pacing unit.

PACING PEDIATRIC PATIENTS

There is limited data available on the use of TCP in the pediatric population. The indications for the procedure, however, are the same as those in adults. The technique used to accomplish TCP is the same as in an adult. TCP is often more effective in children because their smaller chest wall results in a lower transthoracic resistance to the pacing current.

There are, however, special considerations when performing TCP in the pediatric population. TCP was undertaken in newborns with complete AV node block.[21] This small case series of two patients, as well as others, documented significant thermal injury to the underlying skin.[21,22] This was most likely related to the newborn's thin and fragile skin. Increased monitoring of the skin surrounding the electrodes is mandatory in children, especially in cases of prolonged TCP. Pediatric-sized transcutaneous pacing electrodes are available and should be used to limit surface contact. One study comparing the use of adult versus two specially sized pediatric electrodes for TCP demonstrated a lower mean current output with the smaller pads (63 mA vs. 51 to 53 mA).[23] Appropriately sized electrodes are available for children under 15 kg (33 lbs) and should be used.

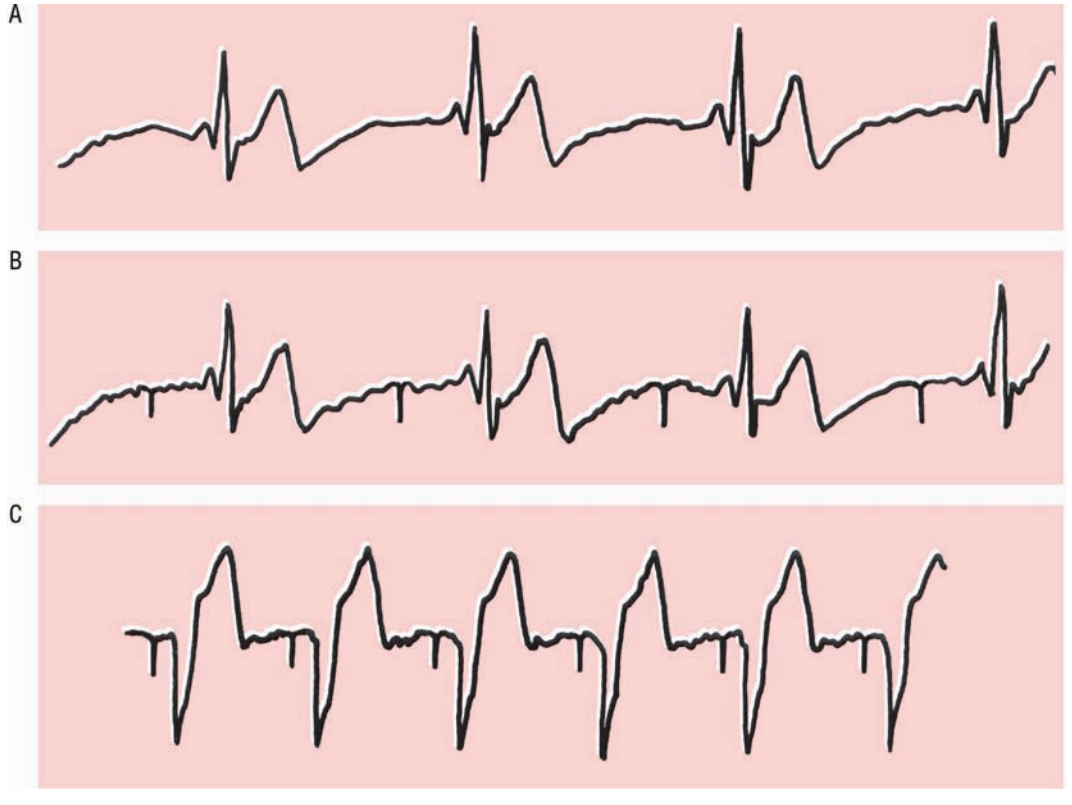


FIGURE 31-6. Assessing electrocardiographic capture with transcutaneous pacing. **A.** Intrinsic patient bradycardic rhythm. **B.** No electrical capture as TCP is below the threshold level. **C.** TCP with electrical capture.

Only one study has documented the outcomes of TCP in pediatric out-of-hospital cardiac arrest.[24] In six drowning victims and three sudden infant death syndrome patients who received TCP by EMS providers, only two patients achieved electrical and mechanical capture, both with an initial rhythm of asystole. In total, seven patients presented with asystole and two patients presented with ventricular fibrillation. Only one patient, with an initial rhythm of asystole, survived to hospital discharge but was severely neurologically impaired and died 6 months later. Further study in this area is warranted.

ASSESSMENT OF SUCCESSFUL PACING

The Emergency Physician must assess the patient for both electrical capture and associated mechanical capture when considering whether or not the procedure was successful. Successful capture is usually characterized by a wide QRS complex, since it is ventricular in origin, and a broad T wave. It is easy to mistake the wide, slurred afterpotential following an external pacing spike for electrical capture. **Electrical capture is best judged by the presence of a consistent ST segment and T wave after each generated pacer spike (Figure 31-6C).** Paced beats below the patient's intrinsic cardiac rate may not produce an associated QRS complex (**Figure 31-6B**), and electrical capture is not achieved. In this situation, the pacing rate must be increased to achieve capture. **Table 31-1** discusses common causes of failure to capture and suggested solutions.

Once electrical capture is achieved, mechanical capture must be ensured by either a palpable pulse rate or arterial catheter blood pressure monitoring. The patient will have a pulse rate that is exactly equal to that of the paced rhythm on the cardiac monitor if mechanical capture is achieved. Assess the pulse using palpation of the carotid or femoral artery to avoid confusion with skeletal muscle contractions generated by the pacing current. If the palpated pulse rate is less than that of the paced rate, mechanical capture has not been achieved. Increase the threshold current. Mechanical capture is also achieved when the invasive arterial blood pressure line demonstrates a pulse rate that is exactly equal to that of the paced rhythm on the cardiac monitor.

Threshold current values will vary depending on the clinical situation. Transcutaneous pacing thresholds tend to be lowest in healthy individuals or in patients with minimal hemodynamic compromise. In these settings, the threshold is usually in the range of 40 to 80 mA.[10,28] Most patients are paced using a current in the range of 20 to 140 mA.[10] No clear correlation has been established between the pacing threshold and patient age, weight, body size, chest diameter, or etiology of heart disease.[10,29,30] However, thresholds are usually elevated following thoracic surgery or in patients with COPD, a pneumothorax, a pericardial effusion, heavy thoracic chest wall musculature, and after positive-pressure ventilation.[10]

Success rates in achieving ventricular capture vary widely depending on the setting where TCP is being used. Success rates appear to be highest when TCP is used prophylactically or early (within 5 minutes of bradycardic arrest). In these settings, success rates may exceed 90%.[10] Zoll et al. reported a 78% success rate in diverse clinical situations.[10] The time to the initiation of TCP largely determines the success rate. With prolonged pacing, there can be changes in pacing threshold leading to capture failure. Failure to capture may be encountered due to a variety of reasons.

Ultrasound has been used as a method to confirm electrical and mechanical capture.[25,31,32] Use ultrasound to determine the ventricular contraction rate. The patient will have a heart rate that is exactly equal to that of the set paced rate if mechanical capture is achieved. This eliminates the artifact seen on the ECG monitor from chest wall muscle contractions. Refer to Chapter 29 for the complete details of cardiac ultrasonography.

AFTERCARE

The most important assessment in the aftercare period is to ensure continuous electrical and mechanical capture. This should be accomplished by frequent checks of the cardiac monitor, palpation of a pulse, and measurement of a blood pressure. This is more easily established using an arterial line. Threshold current values can change with prolonged TCP. The system can be somewhat tenuous in practical use, so frequent checks are advisable. Insert a transvenous cardiac pacer in the Emergency Department or make arrangements with a Cardiologist to place one in the catheterization lab if the patient requires prolonged TCP.

Patient comfort must be continuously re-assessed. Pain can be due to chest wall muscle contractions or other causes (**Table 31-2**). Do not assume that pain is from chest wall muscle contractions until other etiologies are ruled out. Repeated doses of sedative and/or analgesics may be required to ease the discomfort of chest wall muscle contractions. Periodically assess the skin under the electrodes for burns or damage. Reposition the electrodes if skin erythema or any sign of a burn is present. This is especially important

TABLE 31-1 Common Causes of Failure to Capture and Suggested Solutions

Etiology	Solution
Suboptimal electrode placement	Reposition electrodes, avoiding the spine, scapula, and sternum
Negative electrode placed posteriorly	Place negative electrode anteriorly over the cardiac apex or the V_3 lead position
Poor skin-electrode contact	Clean skin of sweat and debris; dry skin thoroughly; trim hair
Faulty electrical contact	Check electrical connections
Generator battery depletion	Change battery; plug generator into an electric outlet
Increased intrathoracic air	Reduce positive-pressure ventilation; relieve pneumothorax
Pericardial effusion	Pericardiocentesis; pericardial window
Myocardial ischemia/ metabolic derangement	CPR; ventilation; correct acidosis; correct hypoxia; correct electrolyte abnormalities
High threshold	Use stimuli of longer pulse width; shave hair for improved pad attachment; apply pressure to pads; apply pads with fresh gel

Modified from: Ellenbogen KA, Wood MA: *Cardiac Pacing and ICDs*, 5th ed. Oxford: Blackwell, 2008.

TABLE 31-2 Causes of Painful Transcutaneous Pacing and Suggested Solutions

Etiology	Solution
Conductive foreign body beneath electrode	Remove foreign body
Electrode over skin abrasions (shaved)	Reposition electrodes; avoid shaving beneath electrodes
Apprehensive patient or low pain tolerance	Administer parenteral narcotics and/or benzodiazepines
Sweat or salt deposits, saline, conductive jelly, blood, or vomitus on skin	Cleanse and dry skin
High threshold to pacing	Use longer pulse-width stimuli
Thoracic wall muscle contractions	IV sedation and/or analgesics

Modified from: Ellenbogen KA, Wood MA: *Cardiac Pacing and ICDs*, 5th ed. Oxford: Blackwell, 2008.

in patients who are young children, unconscious, or have altered mental status as they cannot complain of pain.

COMPLICATIONS

There are few major complications related to this procedure. One of the most important complications to consider is the failure to recognize underlying rhythm changes in the patient or loss of electrical or mechanical capture once the procedure is completed. A rhythm change to ventricular fibrillation is easy to miss and can be ascribed to pacing artifacts and chest wall muscle contraction. These complications are mitigated by close patient and monitor surveillance during TCP. Tachydysrhythmias related to TCP have been documented, but the overall risk for this complication is considered small.[14] Myocardial damage from TCP has been examined in animals and humans without significant findings.[2,26,27] Thermal injury to the skin from the electrodes is a known complication, especially in situations of prolonged TCP, but can be minimized with careful observation and electrode adjustments. Pain is the most commonly reported complication (**Table 31-2**) and needs to be continually addressed. The most common etiology of the pain is from chest wall muscle contractions.

SUMMARY

TCP is a temporary method of cardiac pacing in patients with severe symptomatic bradyarrhythmias due to high-grade AV blocks, sinus node dysfunction, bradyasystolic cardiac arrest, or rarely for overdrive pacing to suppress ventricular and supraventricular tachyarrhythmias. It is comparatively easy to perform and requires minimal training. Once capture is achieved, the current output should be set at a level slightly higher (5-10 mA) than the pacing threshold. Successful TCP can be established in 80% to 90% of patients. Discomfort and pain due to muscle contraction are the most common side effects. Most patients will require sedation and/or analgesics to tolerate TCP for a significant length of time.

32 Transthoracic Cardiac Pacing

Simon M. Pulfrey

INTRODUCTION

Transthoracic cardiac pacing is a historic technique of pacing the heart with an electrode introduced percutaneously into the ventricular cavity using a needle trocar introducer. There is sparse literature on transthoracic cardiac pacing, and the benefits and complications are not well defined. Before the advent of effective and efficient transcutaneous pacing, transthoracic pacing was a faster alternative to transvenous pacing in the patient with an acutely unstable dysrhythmia. Presently, the indications for transthoracic pacing are extremely rare. The technique of transthoracic pacing is included in this text as it is occasionally performed in situations where transcutaneous pacing is unavailable or ineffective.[1–3]

The history of electrical stimulation of the heart dates back to 1862 when Walsh discussed the possibility of causing the heart to contract through stimulation of the sympathetic nervous trunk by an induced current.[4] By 1910, it was largely understood that the neuromuscular mechanism of the heart was electrically dependant. In 1932, Hyman used a needle electrode to carry stimulating current directly to heart muscle.[5] Zoll accomplished the first successful clinical application of external cardiac pacing in 1952 by resuscitating two patients in asystole following bradycardia from a high-degree AV block.[6] He concluded that external cardiac pacing was a safe and effective means of resuscitating ventricular standstill. Unfortunately, Zoll's devices caused significant chest pain, skeletal muscle spasm, superficial skin burns, and disrupted electrocardiographic patient monitoring.[6] The quest for alternative pacing modalities continued with the refinement of the transesophageal technique, initially suggested by Zoll in 1952, and clinically demonstrated by Shafiroff and Linder in 1957.[7] In 1958, Thevenet et al. reported the emergency use of a lumbar puncture needle introduced 5 mm into the myocardium, through which a conducting wire was introduced, to produce transthoracic cardiac pacing.[8] In 1959, Furman and Robinson passed a transvenous wire catheter and successfully applied an electrical current to the endocardial surface of the right atrium.[9] Transvenous pacing subsequently became the most widely accepted method of emergency cardiac pacing until the reemergence of Zoll with a modified external pacing system in 1981.[10]

ANATOMY AND PATHOPHYSIOLOGY

The heart is the only muscle of the body that generates its own electrical impulses. The initial cardiac impulse starts in the right atrium of the heart at the sinoatrial (SA) node. The sympathetic and parasympathetic nervous system controls the rate of impulse generation at the SA node. Once the electrical stimulus is generated, it is conducted along the internal conduction pathways of the heart to the muscular atrial and ventricular walls. A delicate balance between electrolyte flux to create action potentials, myocardial integrity to allow impulses to become contractions, and an intact conduction system must be maintained. The blood supply to the conduction system of the heart originates from the right coronary artery. Arrhythmias and conduction delays are often the result of inadequate blood flow to the heart due to ventricular infarction and coronary artery occlusion.

INDICATIONS

Considering the proven efficiency and efficacy of transcutaneous pacing modalities, the indications for transthoracic pacing appear extremely limited. Preston estimated a 40% success rate in achieving pacing by the transthoracic route.[11] Transcutaneous pacing success rates of greater than 80% have been routinely demonstrated.[12]

Transthoracic cardiac pacing is a simple procedure and can be accomplished rapidly. **Transthoracic pacing should be reserved for clinical situations where there is no transcutaneous pacing available, or when transcutaneous pacing in the perimorbid patient has been unsuccessful and the placement of a transvenous pacer is thought to be too time consuming.**[13,14]

Unstable bradydysrhythmia is the obvious indication for emergency cardiac pacing. Several case reports document successful transthoracic pacing intervention in two patients with asystolic arrest.[1] Other studies document successful pacing out of asystole in patients with in situ pacemakers.[15] A more recent and prospectively designed study of approximately 300 patients with witnessed or early asystole demonstrated no improved outcome with early transcutaneous pacing intervention by first response emergency medical personnel.[16] It can be concluded that although emergency transthoracic cardiac pacing has a very low success rate in asystole, the procedure may be lifesaving in the rare case.

Transthoracic cardiac pacing would be most effective following cardiac arrest from primary cardiac disease.[13] Transthoracic cardiac pacing may not be effective in cardiac arrest secondary to hypovolemia (e.g., trauma), severe electrolyte or acid–base abnormalities,

sepsis, or drug intoxication. Transthoracic cardiac pacing may be lifesaving when bradycardia or asystole secondary to prolonged ischemia during hypovolemic shock persists despite correction of the underlying pathology.

The use of transthoracic cardiac pacing in unstable patients is more controversial. Transthoracic cardiac pacing may be considered in patients with unstable sinus bradycardia, junctional bradycardia, atrial fibrillation with high-degree atrioventricular (AV) block, and AV dissociation with inadequate ventricular response, producing pulmonary edema, seizures, ventricular fibrillation, or ventricular tachycardia.[13]

CONTRAINDICATIONS

Transthoracic cardiac pacing should not be performed in stable, awake patients. It is also contraindicated if the patient has a dysrhythmia that could be quickly and easily corrected by medication, cardioversion, or electrical defibrillation.

Transthoracic cardiac pacing may be ineffective in pulseless electrical activity and ventricular fibrillation. In ventricular fibrillation, the heart becomes insensitive to pacemaker activity, and in pulseless electrical activity, any mode of pacing is ineffective.[20–23] Bellet et al. demonstrated that a pacemaker was ineffective in patients with prolonged cardiac arrest.[15] Patients with cardiac arrest for more than 5 to 10 minutes could not be resuscitated with the use of cardiac pacing; but patients who had pacemakers placed within 2 to 4 minutes after cardiac standstill were successfully resuscitated. Hence, as shown in many studies, transthoracic cardiac pacing may be ineffective if used as a last alternative, as any technique of pacing would be.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Transthoracic cardiac pacing wires/kit
- Pacemaker generator
- 10 mL syringe
- Water-soluble lubricant
- Sterile gauze 4 × 4 squares
- Sterile drapes
- Sterile gloves and gown
- Face mask
- Cap

The widely used instrumentation for transthoracic cardiac pacing is a sterile, one-time-use, prepackaged kit. One example is the Elecath 11-KTM 1 kit (**Figure 32-1**). The apparatus consists of a 37 cm bipolar J-shaped pacing wire, a 6 inch 18 gauge blunt-end steel cannula with a pointed inner trocar, and a plastic electrical connector that accepts the pacing wire and can be attached to a battery-powered external pacemaker generator. The cannula and trocar function as a catheter-over-the-needle.

PATIENT PREPARATION

Explain to the patient the risks and benefits of the procedure if they are awake and alert. A signed consent is not required and time is often lacking to obtain a signature. Document in the medical record that the patient was informed of the risks and benefits of the procedure. Place the patient supine. Clean the chest and subxiphoid area of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the chest and subxiphoid area. Allow it to dry if time permits. Apply sterile drapes to delineate a sterile field.

Cardiopulmonary resuscitation (CPR) can be continued during most of the procedure but should be stopped while the intracardiac needle is being inserted to avoid possible damage to the lung or myocardium. Full ventilation of the lungs is recommended during subxiphoid cannula placement to depress the diaphragm and thus minimize the risk of injury to the liver and stomach. Insert a nasogastric tube to decompress the stomach prior to performing the procedure.

The Emergency Physician should prepare themselves and the equipment. Put on a cap, mask, sterile gloves, and sterile gown. Open the transthoracic cardiac pacing kit onto a sterile field. Lubricate the trocar liberally and insert it securely into the steel cannula.

TECHNIQUE

Quickly identify the anatomic landmarks necessary to perform this procedure and determine the approach to be used. The cannula-over-the-trocar can be inserted through the left fifth intercostal space either parasternally, 4 cm lateral to the midsternal line, or 6 cm lateral to the midsternal line (**Figure 32-2A**). The tip of the cannula-over-the-trocar should be aimed toward the second costal cartilage. Alternatively, the cannula-over-the-trocar can be inserted through the left xiphocostal junction and aimed toward the right shoulder, left shoulder, or sternal notch (**Figure 32-2B**).

If bedside ultrasound is available, the parasternal approach through the fifth intercostal space may be the technique of choice. Without ultrasound, the simplest and quickest approach is to insert the trocar at the left xiphocostal junction and aimed toward the sternal notch. This technique is described below.

Briefly stop CPR. Insert the cannula-over-the-trocar from the left xiphocostal region at a 30° to 40° angle to the skin and directed toward the sternal notch. Advance the cannula-over-the-trocar approximately three-fourths of its length. Hold and stabilize the cannula and withdraw the trocar. Attach a 10 mL syringe to the cannula. Apply negative pressure to the syringe. If the cannula is within the ventricle, the aspiration of blood into the syringe confirms

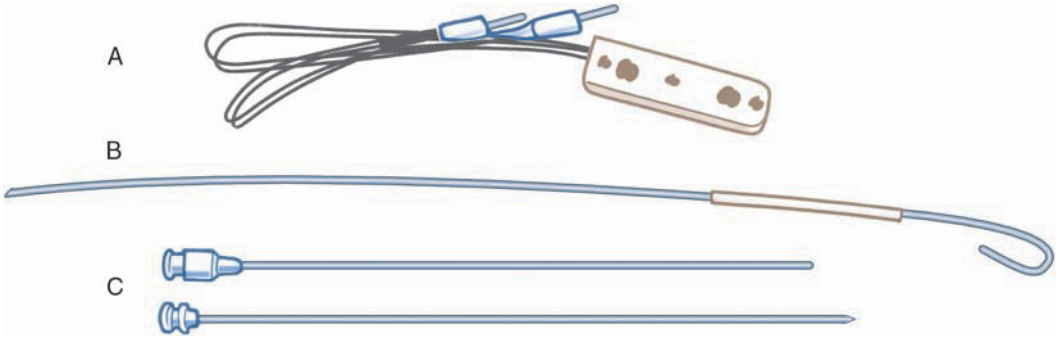


FIGURE 32-1. Equipment required for transthoracic cardiac pacing. **A.** Electrical connector. **B.** Bipolar pacing wire with a sleeve. **C.** Blunt steel cannula with pointed trocar.

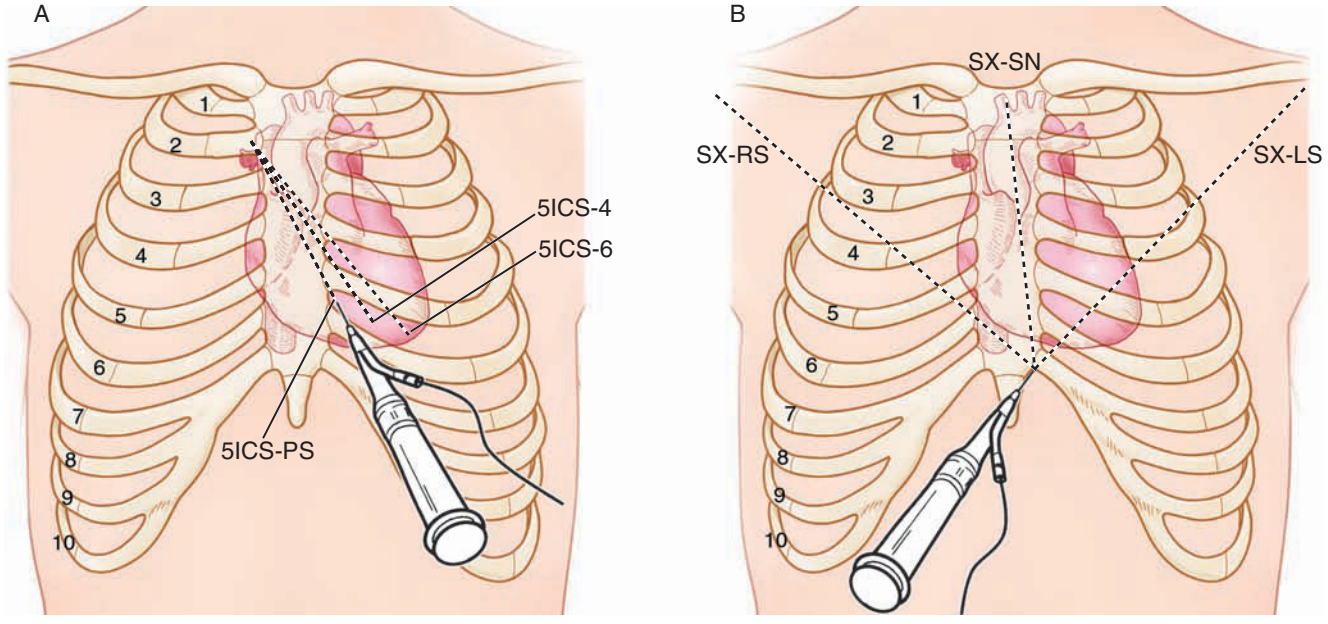


FIGURE 32-2. Placement of a percutaneous transthoracic cardiac pacemaker. **A.** Parasternal approaches. 5ICS-PS, fifth intercostal space immediately to the left of the sternum; 5ICS-4, fifth intercostal space, 4 cm from the midsternal line; 5ICS-6, fifth intercostal space, 6 cm from the midsternal line. **B.** Subxiphoid approaches. SX-RS, subxiphoid—right shoulder; SX-SN, subxiphoid—sternal notch; SX-LS, subxiphoid—left shoulder.

proper positioning. If blood is not aspirated, withdraw the cannula and restart the procedure. Ideally, confirm placement with bedside ultrasound.

Insert the transcutaneous pacing wire. Advance the plastic sheath over the pacing wire until it straightens out and covers the J-shaped end of the pacing wire. Insert the plastic sheath into the cannula hub. Advance the pacing wire through the cannula and into the ventricle. Stop advancing the pacing wire when 4 to 5 cm remains outside the cannula. **No resistance should be felt while the pacing wire is being advanced.** If resistance is felt, the cannula is not within the ventricle. Remove the cannula and pacing wire as a unit and restart the procedure. When it is inside the ventricle, the pacing wire will reform its J shape. Hold the pacing wire securely. Withdraw the cannula over the pacing wire. **Do not release the hold on the proximal end of the pacing wire outside the patient's thorax, so as to prevent it from slipping inside the thorax.**

Insert the proximal end of the pacing wire into the plastic connector. Secure it with the screws in the body of the connector. Connect the positive and negative terminals of the plastic connector to the pacemaker generator. Turn on the pacemaker generator. Set the pacing rate at 70 to 90 beats per minute in an asynchronous mode. Set the current output to the maximum milliampere rate on the pacemaker generator. After myocardial capture of the electrical stimulus is demonstrated (i.e., each pacer spike followed by a QRS complex on the cardiac monitor), lower the current output until 1:1 pacing is lost. Gradually increase the current output to attain stimulation threshold when 1:1 capture is regained. The optimal current output is two to three times the stimulation threshold. Change the mode of the pacemaker to a demand pacemaker with a backup rate of 60 to 70 beats per minute. A complete description of the functioning of the pacemaker generator is reviewed in Chapter 34.

Pacer spikes should be seen on the electrocardiogram (ECG) tracing on the cardiac monitor. If not, check the contact between the pacer wire and electrical connector. Check the batteries in the pacemaker energy source. Pacer spikes not followed by myocardial capture usually indicate inadequate positioning of the pacing electrode. Gently manipulate the transthoracic pacemaker wire to change its position.

ASSESSMENT

The positioning of the pacing wire should be verified by a chest X-ray. Obtain a 12-lead ECG to document capture and to verify the positioning of the pacing wire based on the QRS configuration in the ECG. A left bundle-branch-block configuration will be demonstrated on the ECG if the pacing wire is in the right ventricle. If the pacing wire is in the right atrium or left ventricle, it will still pace the myocardium but the ECG will have a different QRS configuration. If the patient is in AV block, an atrially positioned pacing wire will be ineffective.

AFTERCARE

If the patient survives, secure the pacing wire to the skin with 3-0 nylon suture. A transvenous or permanent pacemaker should be inserted as soon as possible. Consult a Cardiologist immediately and admit the patient to an intensive care unit.

COMPLICATIONS

Analysis of the complications of transthoracic cardiac pacing is greatly limited by the paucity of short-term survivors and the absence of radiographic or pathologic evaluation of nonsurvivors. Complications include laceration of the right atrium, ventricles, coronary arteries, great vessels, vena cava, stomach, liver, and lung. Hemopericardium is a ubiquitous finding in some autopsy studies, and cardiac tamponade has been reported.[17,18] Pneumothorax has been reported and is a particular concern in persons receiving positive-pressure ventilation.[19]

SUMMARY

The technique of transthoracic cardiac pacing has been clinically feasible for more than 50 years, but there is extremely limited literature supporting its regular use. The technique of transthoracic cardiac pacing is simple, can be performed in less than a minute, but carries a high risk for multiple significant complications. There is no clear understanding of the effect of transthoracic cardiac pacing on the outcome of cardiac arrest and the complications associated

with the procedure. Most of the available information comes from animal studies, retrospective analysis, and anecdotal data.

Transthoracic cardiac pacing may be useful in the setting of cardiac arrest with asystole or a pulseless idioventricular rhythm. It may be performed if a transcutaneous cardiac pacing system is not available or not effective. In unstable patients with drug-resistant bradycardia producing cardiovascular collapse or lethal escape rhythms whose clinical condition does not warrant a delay to insert a transvenous pacing catheter, transthoracic cardiac pacing can be initiated promptly. Bedside ultrasound may be useful in guiding and confirming appropriate placement of the transthoracic pacing device.

33 Transvenous Cardiac Pacing

Eric F. Reichman, Myles C. McClelland, and Brian Euerle

INTRODUCTION

Emergency cardiac pacing can be accomplished by several methods. These include epicardial, esophageal, transcutaneous, transthoracic, and transvenous pacing. Emergency cardiac pacing can be a temporizing and lifesaving technique that should be familiar to all Emergency Physicians. It will allow the patient to maintain a cardiac rhythm while providing oxygen and nutrients to the vital organs.

The earliest use of electricity to stimulate the heart can be found in an essay written in the late 1700s.[1] It discusses the use of electric current and artificial ventilation to revive victims of drowning. Transvenous pacing was first attempted on dogs in 1905 by Floresco. The transvenous approach in humans was developed in 1959 using a stiff pacing wire. Semiflexible pacing wires were developed in 1964 and were placed using fluoroscopic guidance. The demand pacemaker was developed in 1966. Catheter technology improved with the semifloating catheter in 1969 and the balloon tip catheter in 1973. The technology and technique have since been developed to allow successful transvenous cardiac pacing in humans. It involves the placement of a pacing wire through the central venous circulation and into direct contact with the myocardium of the right ventricle.

ANATOMY AND PATHOPHYSIOLOGY

The heart is the only muscle of the body that generates its own electric impulses. Its automaticity and subsequent rhythmic contractions propel blood to the tissues of the body. The initial cardiac impulse starts in the right atrium of the heart at the sinoatrial (SA) node. The sympathetic and parasympathetic nervous systems control the rate of impulse generation at the SA node. Once the electric stimulus is generated, it is conducted along the internal conduction pathways of the heart to the muscular atrial and ventricular walls. A delicate balance between electrolyte flux to create action potentials, myocardial integrity to allow impulses to become contractions, and an intact conduction system must be maintained. Conduction system problems are often the result of inadequate blood flow to the heart due to ventricular infarction and coronary artery occlusion. The blood supply to the conduction system of the heart usually originates from the right coronary artery. Occlusion of the right coronary artery can result in arrhythmias and conduction delays.

A transvenous pacing catheter may be introduced through the femoral, internal jugular, or subclavian veins. **In the Emergency Department, the right internal jugular vein and left subclavian vein are the recommended sites (Figure 33-1). These routes allow a more direct and easy access for the pacing catheter to enter the right ventricle.** The right internal jugular vein is preferred, as it allows a relatively straight line of access through the superior vena cava and right atrium into the right ventricle.[2] The left subclavian vein is a good second choice if access to the right internal jugular vein is not accessible. Unfortunately, the left subclavian vein is the site of choice for a permanent pacemaker if required. Thus, many physicians will not use this site. The other routes are technically more difficult to use and often require fluoroscopy for proper placement of the pacing catheter.

The femoral vein is often used in infants and younger children to insert a transvenous cardiac pacing catheter (**Figure 33-2**). Insertion of the pacing catheter via the femoral vein often requires fluoroscopy. The disadvantages of using the femoral vein for vascular access include the potential for deep venous thromboses, infection, restricted mobility, and thrombophlebitis. The infant and young child's relatively large head and short neck make access to the internal jugular vein difficult. The subclavian vein in an infant and a child is situated more posterior to the clavicle than in an adult. This

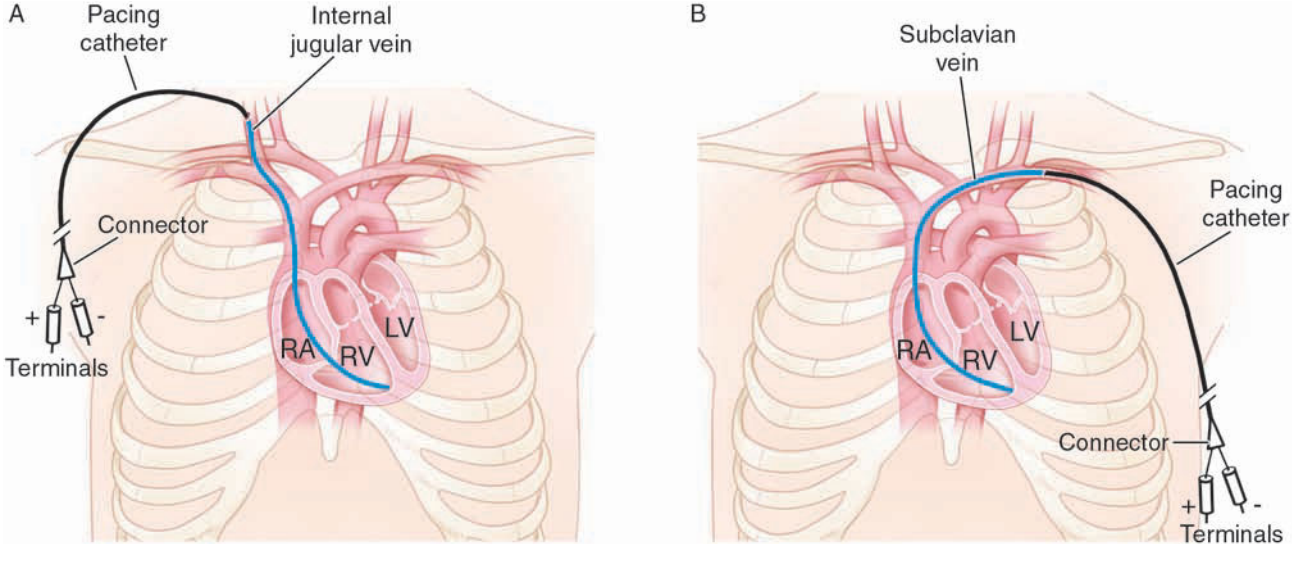


FIGURE 33-1. Common sites for introducing a transvenous pacing catheter. **A.** The right internal jugular vein. **B.** The left subclavian vein.

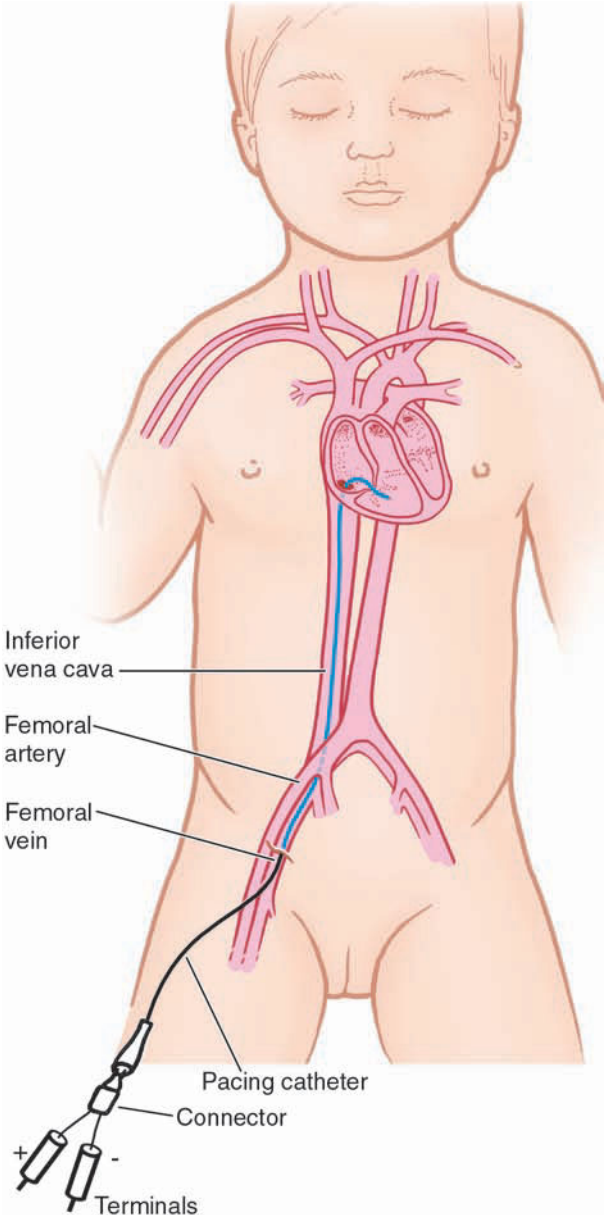


FIGURE 33-2. The femoral vein is used in children to access the central venous circulation and introduce a transvenous pacing catheter.

makes it more difficult to access the subclavian vein while increasing the chance of causing a pneumothorax.

Pacing the left ventricle through a femoral artery approach has been suggested in emergent situations.[3] These instances usually involve the inability to obtain venous access due to scarring, previous procedures, or venous thrombosis. This nonstandard approach has been used successfully in situations when transvenous cardiac pacing was not feasible.[3,4] This technique cannot currently be recommended for routine use, but is a potential alternative technique in the Emergency Physicians armamentarium for use in the most dire of circumstances.

INDICATIONS

The indications for transvenous pacing are the same as for other methods of cardiac pacing. Patients with symptomatic bradycardia unresponsive to drug therapy, conduction delays that may degenerate into complete heart block, atrioventricular dissociation, and atrial or ventricular arrhythmias that require overdrive pacing can benefit from transvenous pacing.[1,2,5,6] Specific bradycardic conditions that may benefit from transvenous cardiac pacing include sinus node dysfunction, sinus arrest, sick sinus syndrome, sinus bradycardia, atrial fibrillation with a slow ventricle response rate, second-degree heart block, and third-degree heart block. Patients with myocardial infarctions and symptomatic bradycardia or new heart blocks require cardiac pacing. Tachyarrhythmic conditions that may benefit from overdrive cardiac pacing include atrial flutter, atrial fibrillation, Wolff–Parkinson–White tachyarrhythmias, supraventricular tachycardias not responsive to drugs or cardioversion, ventricular tachyarrhythmias due to drug toxicity (quinidine or digoxin), and torsades de pointes. Transvenous pacing may be used in patients who do not tolerate or whose heart does not capture with transcutaneous pacing. If a permanent pacemaker is not functioning, a transvenous pacing catheter may be temporarily inserted to pace the myocardium. A more complete discussion on the indications for cardiac pacing is presented in Chapter 31 (transcutaneous cardiac pacing).

CONTRAINDICATIONS

Patients who are hypothermic should not have a transvenous pacing catheter inserted into the heart. These patients have increased irritability of the myocardium and are prone to life-threatening ventricular fibrillation if the pacing wire contacts the heart muscle.[1,2] Digoxin toxicity and other drug ingestions that may increase the irritability of the myocardium are relative contraindications to the placement of a transvenous pacing catheter. Patients who are asystolic for extended periods of time have a low likelihood of successful resuscitation.[2] These patients are not candidates for transvenous pacer placement. Do not insert a pacing catheter through infected skin or areas with any skin lesions (e.g., burns, cellulitis, or dermatides) to prevent possible infections such as endocarditis, myocarditis, or sepsis. Avoid areas that contain subcutaneous devices (e.g., permanent pacer, AICD, port-a-cath, etc.) and choose an alternative site. Do not prophylactically place a transvenous pacing catheter in a patient with a myocardial infarction unless they have a new heart block or symptomatic bradycardia. Patients with bleeding diatheses, anticoagulant therapy, or concurrent thrombolytic therapy should not have a transvenous pacing catheter placed except in truly emergent situations due to the risk of hemorrhage and bleeding complications. Other relative contraindications include the presence of a prosthetic tricuspid valve, coagulopathy, distortion of local and anatomic landmarks, and known abnormal cardiac anatomy.

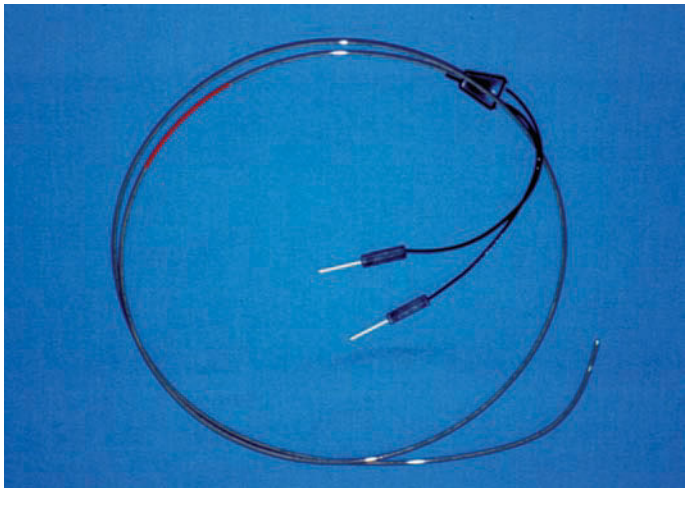


FIGURE 33-3. The flexible transvenous pacing catheter.

EQUIPMENT

- Flexible transvenous cardiac pacing catheter (**Figure 33-3**):
  - 3 or 4 French for infants and children
  - 5 or 6 French for adolescents and adults
- Pacemaker generator (**Figure 33-4**)
- Spare battery for pacemaker
- Sterile drapes
- Sterile gloves and gown
- Face mask with face shield or goggles
- Povidone iodine or chlorhexidine solution
- Cordis or Swan introducer catheter kit, one size larger than the pacing catheter
- Cardiac monitor



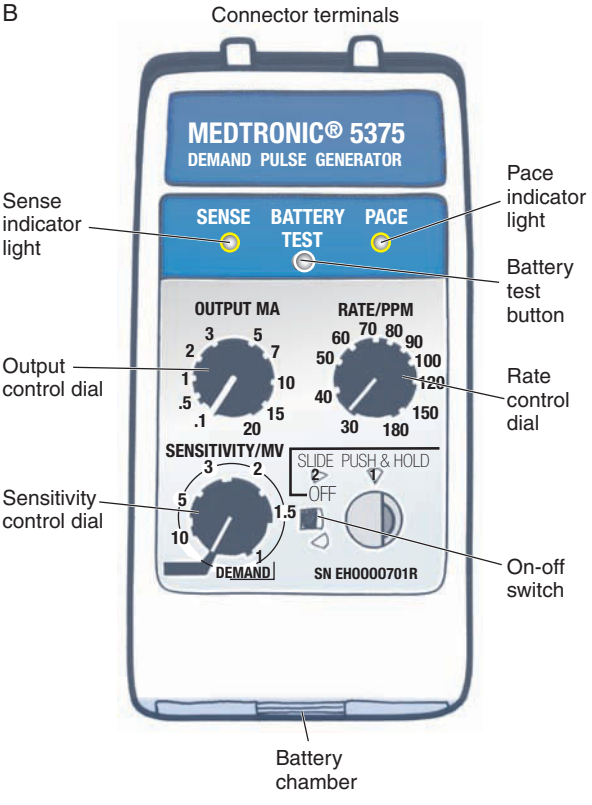




FIGURE 33-4. Examples of pacemaker generators.

- Local anesthetic solution
- 3-0 nylon suture
- Gauze squares
- Skin tape
- Alligator clips and connecting wire
- Towels for shoulder rolls
- Defibrillator
- Airway management equipment
- Resuscitative drugs
- Ultrasound machine with a 3.5 MHz curvilinear or cardiac array probe
- Sterile ultrasound gel
- Sterile ultrasound probe covers

Transvenous cardiac pacing kits are commercially available. They contain the central venous introducer catheter, transvenous pacing wire, and all the required supplies except the pacemaker generator. These single patient use and disposable kits are convenient and worth the expense so that time is not expended gathering multiple kits and supplies in an emergent situation when time may be of the essence.

The pacemaker generator is a simple device (**Figure 33-4**). An example is the Medtronic 5375 demand pulse generator (**Figures 33-4A & B**). Newer models of pacemaker generators (**Figure 33-4C**) have digital displays and other more sophisticated pacing options, but function essentially the same as older models. **The Emergency Physician must be familiar with the pacemaker generator and its use prior to needing it in an emergent situation.** The on/off switch is used to turn the unit on. In the "on" position, a spring-loaded safety prevents the unit from accidentally being turned off. The rate-control dial allows the physician to adjust the number of pacing stimuli per minute. The upper rate limit is often inadequate if overdrive pacing is required. A pacemaker generator with higher rates for overdrive pacing is available. These are rarely kept in the Emergency Department, but are usually available from the hospital catheterization lab. The pace indicator light is illuminated whenever a pacing stimulus is generated. The sense indicator light is illuminated whenever a cardiac impulse is sensed. The battery test button is used to determine if the battery has sufficient voltage to operate the pacemaker generator. Depress the battery test button to check the battery voltage. If both the pacing and sensing indicator lights illuminate simultaneously, the battery has sufficient voltage. The output control dial is used to adjust the amplitude of the stimulus current. The sensitivity control dial is used to suppress the pulse generator. The bottom of the pacemaker has an access panel under which the battery is located. The top of the pacemaker has positive and negative terminals where the electrodes of the pacemaker catheter insert. Numerous pacemaker generators are available, each with its own idiosyncrasies. The above instructions/functions are similar to most models.

The pacemaker wires are enclosed in a catheter and come in a variety of lengths and sizes (**Figure 33-3**). They are typically 100 cm in length with markings at intervals of every 10 cm. They come in both flexible and rigid styles. The rigid catheters are not often used due to the possibility of venous and myocardial perforation. The flexible catheters have a balloon at the tip, which allows the catheter to flow with the blood into the chambers of the heart.

The pacemaker catheter should ideally be inserted under electrocardiographic (ECG) guidance. An insulated wire with an alligator clip at each end is required. One end is attached to the pacemaker wire and the other to the ECG lead. This allows the Emergency Physician to observe the ECG waveforms as they change while the catheter is advanced through the heart.[2,5,7] This technique is known as ECG positioning and requires the patient to have intrinsic cardiac activity.

PATIENT PREPARATION

Explain the risks, benefits, and possible complications to the patient and/or their representatives. If the patient is unable to consent, an appropriate representative may accept for the patient. The patient may also give verbal consent if they are unable to sign but fully understands the risks and benefits of the procedure. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids. **While time is of the essence and this is an emergent procedure, aseptic technique should always be followed.**

Place the patient supine and, if possible, in the Trendelenburg position. Place the patient on continuous pulse oximetry, cardiac monitoring, and supplemental oxygen. Establish peripheral intravenous access. Clean and prep the skin in a sterile fashion with povidone iodine or chlorhexidine at the site chosen to access the central venous system. If the internal jugular vein or the subclavian vein is being used as the site of vascular access, place rolled towels under the patient's shoulders. Turn the patient's head to the opposite side of venous access. Apply sterile drapes to fully cover the patient except the site used for vascular access.

TECHNIQUE

Access the central venous circulation by placing a Swan or Cordis introducer catheter sheath. Some authors recommend using the supraclavicular approach for central venous access.[8] This approach may decrease complications due to well-defined surface landmarks, high success rates of vascular access, minimal interference with other procedures, location away from the pleural dome, avoidance of scarring and thrombosis from previous central venous access attempts, minimization of catheter movement, and having a straight path into the right ventricle. Refer to Chapter 49 for the complete details on inserting central venous catheters.

Prepare the pacing catheter (**Figure 33-5**). Attach the precordial lead V_1 to the pacemaker catheter negative terminal. This is accomplished using an insulated wire with an alligator clip at each

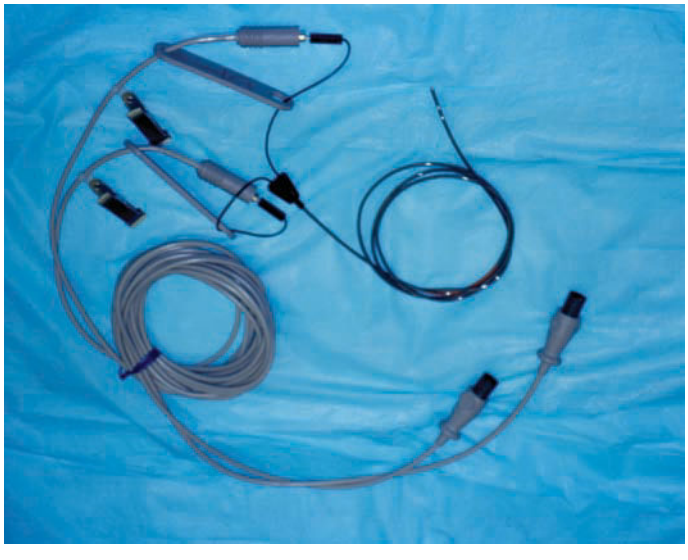


FIGURE 33-5. The negative pacemaker terminal is connected to an insulated wire. The insulated wire will be connected to the ECG lead V_1.

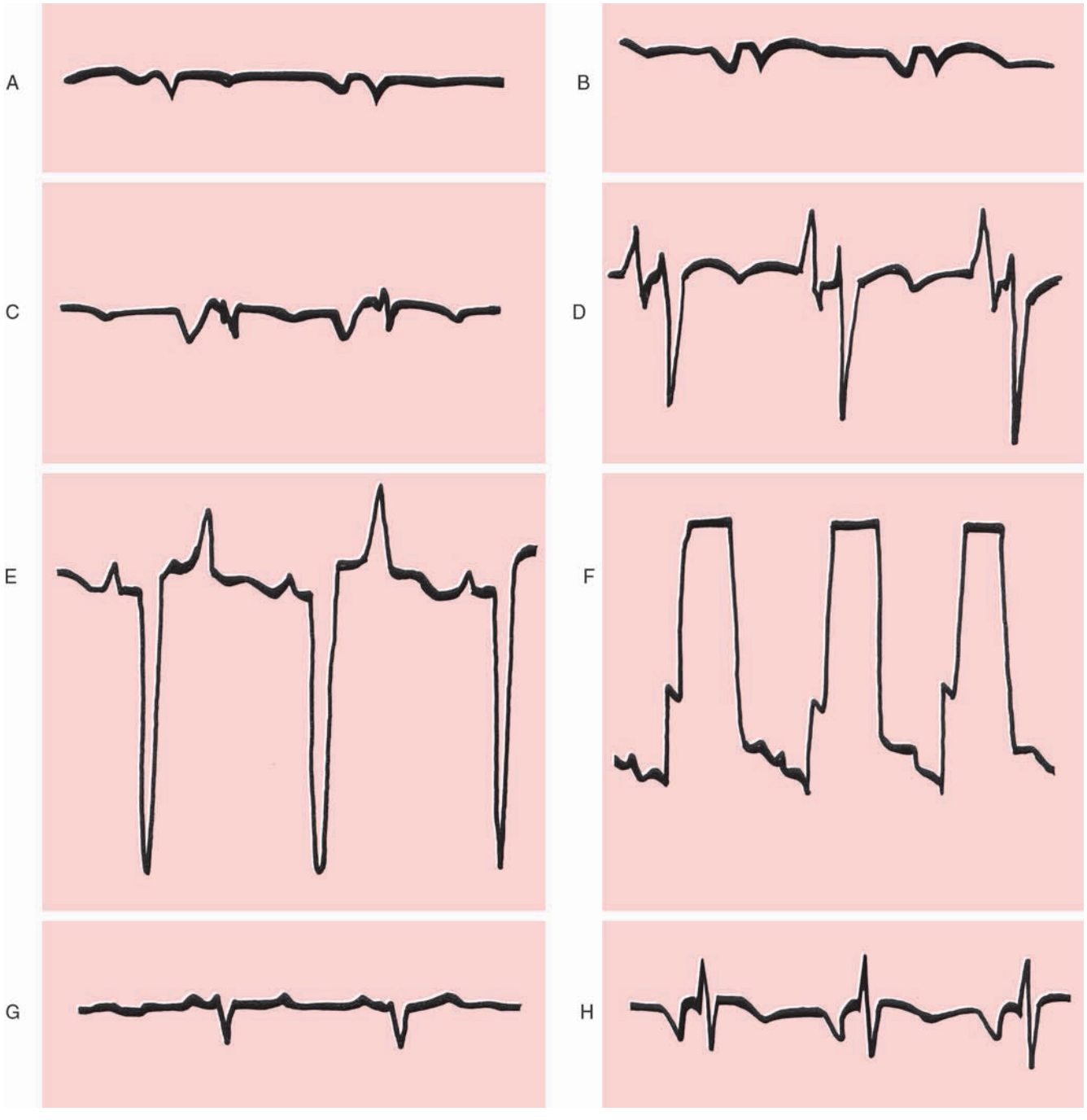


FIGURE 33-6. Typical ECG tracings seen with the transvenous pacing catheter within the different anatomic sites. **A.** The subclavian or internal jugular vein. **B.** The superior vena cava. **C.** The high right atrium. **D.** The low right atrium. **E.** Free-floating in the right ventricle. **F.** Abutting the right ventricular wall. **G.** The inferior vena cava. **H.** The pulmonary artery.

end. Attach one alligator clip to the negative pacemaker wire. Attach the other alligator clip to the V_1 lead of the ECG monitor. Inflate the pacing catheter balloon with 1.5 mL of air in a container of sterile saline to assess the integrity of the balloon. The presence of bubbles in the saline indicates a balloon leak. Turn on the ECG monitor and set it to lead V_1. Touch the tip of the pacing catheter and observe the monitor to confirm that the monitor is recording. A large pressure wave should be seen that soon returns to the baseline.

Insert the pacemaker catheter through the rubber diaphragm of the central venous introducer sheath. Advance the catheter 10 cm. This ensures that the pacing catheter balloon is past the introducer catheter and within the vascular system. Inflate the balloon with 1.5 mL of sterile saline. **Slowly advance the catheter while always observing the ECG monitor (Figure 33-6).** In the subclavian or internal jugular vein, the P wave and the QRS complex are both small in amplitude and inverted (**Figure 33-6A**). In the superior vena cava, the P wave increases in amplitude but is still inverted while the QRS complex is unchanged (**Figure 33-6B**). When the pacing catheter reaches the right atrium, a large P wave with a negative polarity and a small QRS complex will be observed (**Figure 33-6C**). Continue to advance the catheter. As the lower atrium is entered, the P waves become upright and the QRS complex increases in amplitude (**Figure 33-6D**). Continue to advance the catheter into the right ventricle. The QRS complex should appear normal on



FIGURE 33-7. The transvenous pacing catheter connected to the pacemaker generator.

the V_1 lead. When the catheter is floating freely in the right ventricle, the P waves are upright with a large-amplitude QRS complex (**Figure 33-6E**). Stop advancing the catheter once the right ventricle is entered and deflate the balloon. Slowly advance the catheter until ST-segment elevation is observed (**Figure 33-6F**). This indicates that the catheter is abutting the right ventricular wall.

Occasionally, the transvenous pacing catheter may not enter the right ventricle or it may advance past the right ventricle. If the catheter exits the right atrium and enters the inferior vena cava, the amplitude of the P wave and QRS complex will decrease (**Figure 33-6G**). Withdraw the catheter several centimeters until the atrial waveforms are again seen (**Figures 33-6C & D**), then readvance the catheter. If the catheter exits the right ventricle and enters the pulmonary artery, the P wave will become negative and the QRS amplitude will decrease (**Figure 33-6H**). Withdraw the catheter several centimeters until the right ventricle waveforms are again seen (**Figure 33-6E**), then readvance the catheter.

Connect the pacemaker generator to the catheter (**Figure 33-7**). Disconnect the negative terminal of the pacemaker catheter from the ECG lead. Connect the pacemaker catheter terminals on the proximal end of the catheter to the negative and positive terminals of the pacemaker generator. **The positive (+) lead connects to the proximal port on the pacemaker generator. The negative (–) lead connects to the distal port on the pacemaker generator.** Set the pacemaker generator on demand mode with a rate of 70 to 80 beats per minute. Start with 5 mA of energy on the output dial. Turn on the pacemaker. Increase the energy until capture is seen on the monitor. This is signaled by pacing spikes and a wide QRS complex in lead V_1 in a left bundle branch pattern. **Once capture is attained, decrease the pacemaker generator output to just below where pacing stops. This is known as the threshold point. Resume pacing at 2 mA above the threshold point.**[2]

ULTRASOUND-GUIDED TECHNIQUE

It is often difficult to successfully place the tip of the pacing catheter into the apex of the right ventricle. Lead placement can be guided and confirmed with the assistance of ultrasonography.[9] The pacing electrode is easily visible on ultrasound, and its correct position can be confirmed. Aguilera and colleagues reported success in eight of nine patients in whom ultrasound-guided transvenous pacing was attempted in the Emergency Department.[9] In three of these patients, initial misplacement of the electrode was visualized, allowing correct repositioning. They concluded that ultrasound has promising potential use as an adjunct in emergency cardiac pacing. Ultrasound can delineate the right ventricle as well as provide quick and noninvasive confirmation of lead placement. It is useful as an aid to detecting and repositioning misplaced pacer leads. Given the time-sensitive nature of transvenous pacing, consider using ultrasound in conjunction with ECG guidance.

The subxiphoid view is preferred as it allows visualization of the right atrium and right ventricle. It is also a view easily obtained with the patient in the supine position. The subxiphoid view is likely to be the cardiac window with which Emergency Physicians are most familiar and comfortable. The transvenous pacing electrode is a strong reflector of ultrasound waves and will appear as a linear hyperechoic structure.[9] In the subxiphoid view, the electrode can be seen passing through the right ventricle to the apex (**Figure 33-8**). The apical cardiac view is an option. However, obtaining an apical view is more technically difficult and is preferentially performed with the patient in the left lateral decubitus position, which may not be practical. **Care must be taken not to mistake the ventricular septum or wall for the electrode.**

There are limitations in the use of ultrasound. Visualization may be difficult in the obese or those with COPD and resultant expanded lung volumes. Mechanical heart valves may cause significant artifacts that obscure the images. The pacing catheter often lies in multiple echo planes, making visualization more difficult. The lack of catheter visualization may require multiple repositionings of the catheter. Visualization of the catheter may require tilting of the probe, looking at several different angles with the probe, and looking at additional views of the heart. All these maneuvers can result in delays before being able to pace the heart.

Visualize the patient's heart using a subxiphoid view with a 3.5 MHz curvilinear array probe. Instruct an assistant to hold the probe in position while the Emergency Physician performs the procedure. Insert the pacing catheter as described above using the

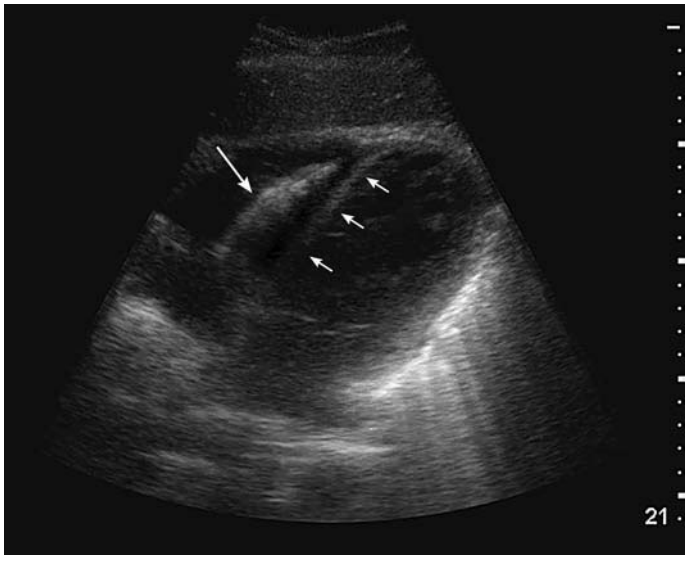


FIGURE 33-8. Subxiphoid cardiac ultrasound image. The transvenous pacing electrode (*large arrow*) is seen as a linear hyperechoic structure passing through the right ventricle to its apex. The interventricular septum is denoted by the *small arrows*.

ECG-guided technique. Visualize the pacing catheter using ultrasonography after it enters the right atrium and then as it enters the right ventricle as also noted by the changing ECG waveforms. Continue to advance the pacing catheter under ultrasound guidance until its tip is lodged in the apex of the right ventricle (**Figure 33-8**). This may require manipulation of the pacing catheter and/or ultrasound probe to maintain visualization. Continue the remainder of the procedure as noted in the previous section. Ventricular capture is noted as cardiac contractions on the ultrasound monitor that are at the same rate as the pacemaker generator setting.

ALTERNATIVE TECHNIQUE

Blind transvenous catheter placement is an alternative to the above method. The pacing catheter is inserted "blindly" and without ECG guidance. This technique is often used when alligator clips are not available to connect the pacing catheter terminals to the ECG monitor. A flexible catheter should always be used. **Never place a rigid catheter blindly due to the risk of myocardial perforation.**

Prepare the catheter. Test the balloon as described previously. Make sure the pacemaker generator is off. Connect the pacemaker catheter terminals to the pacemaker generator. Insert the pacemaker catheter through the rubber diaphragm of the central venous introducer sheath. Advance the catheter 10 cm. Inflate the balloon with 1.5 mL of sterile saline.

Turn on the pacemaker. **Set the pacemaker on demand mode with a rate twice the patient's native heart rate.** This usually ranges from 80 to 120 beats per minute. Set the output dial to 1.5 to 2.0 mA.

Advance the catheter while observing the sensing indicator light. When the catheter enters the right ventricle, the sensing indicator will illuminate with every other native heartbeat. Stop advancing the catheter. Deflate the balloon. Increase the output dial to 10 mA. Slowly advance the catheter until ventricular capture occurs on the cardiac monitor. **Electrical capture is indicated when the ECG monitor attached to the patient's skin by electrodes shows pacer spikes and the development of wide QRS complexes. Do not advance the catheter more than 10 cm past the point where the sensing indicator began to illuminate.** If ventricular capture is not successful within 10 cm, withdraw the catheter and rotate it 90°. Readvance the catheter up to 10 cm. The pacemaker generator output may be set at 20 mA and the pacing catheter readvanced. Continue to repeat the process until ventricular capture is successful. Once this occurs, slowly decrease the ventricular rate to 70 beats per minute. Decrease the pacemaker generator output to 2 mA above the threshold point.[2]

This blind procedure can be modified to be used with ultrasound. Visualize the pacing catheter after it enters the right ventricle. Use ultrasound to help guide the tip of the pacing catheter into the apex of the right ventricle or to confirm proper positioning of the pacing catheter (**Figure 33-8**).

ASSESSMENT OF SUCCESSFUL PACING

The Emergency Physician must assess the patient for both electrical capture and associated mechanical capture when considering whether or not the procedure was successful. Successful capture is usually characterized by a wide QRS complex, since it is ventricular in origin, and a broad T wave. It is easy to mistake the wide, slurred afterpotential following an external pacing spike for electrical capture. **Electrical capture is best judged by the presence of a consistent ST segment and T wave after each generated pacer spike (Figure 31-6C).** Paced beats below the patient's intrinsic cardiac rate may not produce an associated QRS complex (**Figure 31-6B**), and electrical capture is not achieved. In this situation, the pacing rate must be increased to achieve capture.

Once electrical capture is achieved, mechanical capture must be ensured by either a palpable pulse rate or arterial catheter blood pressure monitoring. The patient will have a pulse rate that is exactly equal to that of the paced rhythm on the cardiac monitor if mechanical capture is achieved. Assess the pulse using palpation of the carotid or femoral artery to avoid confusion with skeletal muscle contractions generated by the pacing current. If the palpated pulse rate is less than that of the paced rate, mechanical capture has not been achieved. Increase the threshold current. Mechanical capture is also achieved when the invasive arterial blood pressure line demonstrates a pulse rate that is exactly equal to that of the paced rhythm on the cardiac monitor.

Ultrasound can confirm electrical and mechanical capture. Use ultrasound to determine the ventricular contraction rate. The patient will have a heart rate that is exactly equal to that of the set paced rate if mechanical capture is achieved. Refer to Chapter 29 for the complete details of cardiac ultrasonography.

AFTERCARE

Secure the pacing catheter by suturing it to the chest wall. Infiltrate subcutaneously with 2 mL of local anesthetic solution 1 cm from where the catheter exits the central venous sheath. Using 3-0 nylon, secure the catheter to the skin. Apply antibacterial ointment to the site where the pacing catheter exits the central venous sheath. Apply an adhesive dressing, such as Tegaderm, over the sheath and catheter. Obtain an ECG. It will show the characteristic left bundle branch block pattern. Obtain a postprocedural chest radiograph to assess the catheter position and to rule out an iatrogenic pneumothorax and/or hemothorax. Admit the patient to an intensive care unit. Consult a Cardiologist for possible permanent pacemaker placement.

The most important assessment in the aftercare period is to ensure continuous electrical and mechanical capture. This should be accomplished by frequent checks of the cardiac monitor, palpation of a pulse, and measurement of a blood pressure. This is more easily established using an arterial line.

COMPLICATIONS

Perforation of the ventricular septum, the atria, or the free wall of the ventricle may occur during catheter placement.[10] This is more commonly seen with the rigid catheters, and in elderly patients with kyphoscoliosis where right heart catheterization can be more difficult.[11] Septal perforation should be suspected if the pattern on the ECG changes from a left to a right bundle branch block.[2,12] Septal perforation should also be suspected if there is an increase in the pacing threshold. Ventricular perforation can present as a failure to capture or as cardiac tamponade. A friction rub may be audible on cardiac auscultation if a perforation is present. Perforation of the inferior wall could stimulate and pace the diaphragm.[2,12] The treatment for these complications is to withdraw and reposition the pacing catheter. The patient must then be evaluated and observed for the possibility of cardiac tamponade.

Multiple attempts to place the tip of the pacing catheter in the apex of the right ventricle can result in complications. Movement of the catheter forward and backward can form a loop within the cardiac chambers. The catheter tip can advance through the loop and result in a knot being formed in the pacing catheter. This requires an Interventional Cardiologist to unknot and remove the catheter in the cardiac catheterization laboratory under fluoroscopic guidance.

Advancement of the pacing catheter through a patent foramen ovale will result in left ventricular pacing.[13] This is recognized as a right bundle branch pattern on the ECG. Ultrasonography can be

used to visualize the pacing catheter in the left ventricle or the lack of it in the right ventricle. Radiographic or angiography studies will be needed to determine if the tip of the catheter passed through the foramen or perforated the interatrial or interventricular septum.

Cardiac arrhythmias may occur during insertion of the pacing catheter. Ventricular arrhythmias can occur during the procedure and even after the procedure is completed. Immediately withdraw the catheter a few centimeters and observe the rhythm. If that resolves, readvance the catheter. A defibrillator and cardiac resuscitation drugs must be available to facilitate immediate treatment of any rhythm disturbance.[2,12]

In transvenous pacing, as with any procedure, infection can be a delayed complication. **Always use strict aseptic techniques when inserting the central venous introducer sheath and the transvenous pacing catheter.** There is currently no clinical evidence to suggest that the use of prophylactic antibiotics decreases infections or infectious complications. The use of prophylactic antibiotics cannot be currently recommended. The most common organisms are skin flora. The types of infection can range from cellulitis at the puncture site to myocarditis and florid sepsis.[2,5,12] Antibiotic therapy should be started and the catheter removed and cultured. If the pacing catheter is absolutely required, a new puncture site should be selected and a new pacing catheter inserted.

The pacing catheter balloon can be a source of complications.[14,15] Air embolism has been reported. This can be prevented by assessing the balloon for leaks prior to inserting the catheter. Do not overinflate the balloon. An air embolism or a piece of ruptured balloon may obstruct part of the pulmonary circulation. Do not inflate the balloon after it is inserted more than 10 to 15 cm into the ventricle. If the balloon is inflated when the catheter tip is in a branch of the pulmonary artery, the vessel may rupture. Forward and backward movement of the pacing catheter with the balloon inflated may result in rupture of the chordae tendineae with subsequent tricuspid regurgitation.

The pacing circuit (i.e., catheter, wires, and pacemaker) can also be a source of complications. The catheter may become dislodged or fractured. The pacemaker may fail due to battery drainage, generator failure, or electrical interference.

Anatomic variations may be present and not known to the patient or the Emergency Physician. These include persistent left-sided superior vena cava, congenital lack of a vein, or congenital duplication of a vein.[16] Anatomic variations can increase the technical difficulty of the procedure. It might be necessary to use a femoral approach if the internal jugular or subclavian vein approaches are unsuccessful, regardless of the reason.[16]

Complications related to obtaining central venous access are discussed in Chapter 49. They include air embolism, infection, sepsis, cellulitis, pneumothorax, improper placement, arterial puncture, venous thrombosis, venous thrombophlebitis, and guidewire complications. Complications may be decreased by using the supraclavicular approach rather than the subclavian or internal jugular approaches.[8]

SUMMARY

Placement of a transvenous cardiac pacing catheter can be a lifesaving procedure. It is a safe method to electrically stimulate the heart. It is indicated when an unstable rhythm of the heart is refractory to medications and transcutaneous pacing. Proper placement of the pacing catheter is cardinal to its functioning. Recognition of the ECG changes that occur in the different anatomic areas helps to guide its placement. One must also be aware of the potential complications and their management. This procedure should be mastered by all Emergency Physicians caring for critically ill and/or injured patients.

34 Pacemaker Assessment

Nnaemeka G. Okafor

INTRODUCTION

Pacemakers are common among Emergency Department patients. Patients may present due to symptoms referable to pacemaker malfunction or symptoms unrelated to the pacemaker, and its presence may modify the investigation and therapeutic approach. It is important for the Emergency Physician to understand the workings of a pacemaker, the problems that may be encountered, the etiologies of the problems, and the assessment of a patient with a pacemaker.

There are numerous indications for the implantation of a cardiac pacemaker.[1–8] However, a detailed discussion regarding the indications for permanent pacemaker insertion is beyond the scope of this chapter.[1,6,7] The most common indication for permanent pacemaker placement is symptomatic bradycardia. Mortality rates can be decreased in these patients with pacing. A permanent pacemaker is inserted prophylactically when intrinsic cardiac rhythms can degenerate to higher-degree blocks or in patients who may develop symptoms in the near future even though the initial presentation was asymptomatic. An example would be the Mobitz type 2 second-degree atrioventricular (AV) block. In addressing the treatment modalities for cardiac rhythm disturbances, the decision to implant a pacemaker can be difficult and must be reached by a careful review of each patient on an individual basis.

The pacemaker unit is implanted by a Cardiologist in the cardiac catheterization laboratory. The pacemaker unit consists of the pacemaker generator, the pacemaker wires (also known as electrodes or leads), and the terminal electrodes. The square or rectangular pacemaker generator is implanted subcutaneously in the left or right upper chest. It is responsible for the functioning of the unit and contains the battery that powers it. **A reed switch in the pacemaker generator can be used to inactivate its sensing mechanism and cause it to perform in an asynchronous mode.** The pacemaker wires are embedded in plastic catheters and attached to the pacemaker generator. The wires are inserted through the subclavian vein or, less commonly, through the cephalic vein and into the right side of the heart. The terminal electrodes are at the distal end of the pacing wires and are designated as unipolar or bipolar. The terminal electrodes are placed under fluoroscopic guidance in the right ventricle for single chamber pacing or the right atrium and right ventricle for dual chamber pacing. After insertion, the unit is programmed and tested.

The North American Society for Pacing and Electrophysiology and the British Pacing and Electrophysiology Group have accepted a five-letter pacemaker code, which is also followed by the pacemaker industry (**Table 34-1**). The code is generic in nature. The character position is labeled in Roman numerals I through V. The first letter designates the chamber(s) in which pacing occurs. It can be designated as none (0), atrial (A), ventricular (V), or both atrial and ventricular (D or dual). The second letter designates which cardiac chamber(s) the pacemaker uses to sense intrinsic electrical cardiac activity. It can be designated as none (0), atrial (A), ventricular (V), or both atrial and ventricular (D or dual). The third letter designates how the pacemaker responds to sensed intrinsic electrical activity. A sensed event may inhibit (I), trigger (T), both inhibit and trigger (D), or cause no response (O) from the pacemaker generator. To have a designation other than O, the pacemaker must be a dual-chamber system. The fourth letter reflects the programmability and rate modulation of the unit. The fifth letter designates the antitachyarrhythmia function(s) of the pacemaker. The fourth and fifth letters are rarely used, as these functions are not often required.

TABLE 34-1 The Generic and Standard Pacemaker Codes

Position	I	II	III	IV	V
Interpretation	Chamber(s) paced	Chamber(s) sensed	Response to sensing	Programmability rate modulation	Antitachyarrhythmia function(s)
Variable	0	0	0	0	0
	A	A	T	P^1	P^2
	V	V	I	M	S
	D (A + V)	D (A + V)	D (T + I)	C	D (P + S)
				R	

Key: A, atria; C, communicating; D, dual; I, inhibited; M, multiprogrammable; 0, none; P^1, simple programmable; P^2, pacing; R, rate modulation; S, shock; T, triggered; V, ventricle.

The code does not describe the characteristics, specific functions, or unique functions that are specific to each pacemaker unit or the manufacturer of the unit. The most common mode for a pacemaker is VVI. The reader is referred to other references for a more complete discussion of pacemaker modes.[1,6,7]

EVALUATION OF PACEMAKER FUNCTION

Pacemaker patients who present to the Emergency Department with a complaint that may be associated with their pacemaker require a thorough evaluation. Place the patient on the pulse oximeter and cardiac monitor and apply a noninvasive blood pressure cuff. Provide supplemental oxygen via a nasal cannula or face mask. A history and physical examination should be performed while simultaneously obtaining a 12-lead electrocardiogram (ECG). Obtain posteroanterior and lateral chest radiographs if the patient is stable. If not, a portable anteroposterior chest radiograph will suffice. Perform a magnet examination of the pacemaker. **A Cardiologist should always be consulted regarding a patient with an actual or a potential pacemaker problem.**

HISTORY AND PHYSICAL EXAMINATION

The initial evaluation begins with a complete history. Palpitations, dizziness, near syncope, syncope, or any symptom that may resemble those prior to pacemaker implantation may reflect a potential pacemaker malfunction. In patients who have had their pacemaker placed recently, the complaints related to potential pacemaker infection should also be explored. Determine if the patient is taking medications that can raise the myocardial threshold to pacing. Traumatic injury to the torso can cause the leads to displace or fracture. Direct trauma over the pacemaker generator can render it inoperable.

Ask the patient if they have a pacemaker card. This is a business card-size piece of paper that is given to the patient after pacemaker implantation to identify the pacemaker type, manufacturer of the unit, programmed rate, the five-letter code programmed in the pacemaker, and the manufacturer's phone number. The patient should be questioned regarding any known changes in the pacemaker settings since receiving the pacemaker card.

Perform a thorough examination of the patient. Observe the vital signs for bradycardia, fever, hypertension, hypotension, or tachycardia. Evaluate the veins of the head and neck for venous engorgement suggesting a central venous thrombosis or a superior vena cava syndrome. Edema of the ipsilateral upper extremity indicates thrombosis and possible occlusion of the subclavian vein. Identify the location of the pacemaker pocket and implantation scar on the skin. Note if the pacemaker generator has moved from its original position. This can cause a partial or complete disconnection of the pacemaker wires from the generator. Inspect the pacemaker pocket for signs of infection, including a discharge, edema, skin erosion, erythema, redness, tenderness, and/or warmth.

ELECTROCARDIOGRAM

Obtain a 12-lead ECG. This recording will disclose whether the patient is presently being paced and in what manner (e.g., ventricular or atrioventricular pacing). If not, the underlying rhythm and PR interval of an intrinsic cardiac beat can be readily established (**Figure 34-1A**). Bipolar spikes tend to be smaller, and examination of various leads of the ECG tracing may clarify the presence or absence of capture. A paced beat occurs when ventricular depolarization is secondary to pacer stimulation (**Figure 34-1B**). The pacer spike is seen immediately preceding the QRS complex. A fusion or pseudofusion beat can occur due to pacemaker firing on an intrinsically occurring P wave or QRS complex. A fusion beat is a QRS complex that has been formed by depolarization of the myocardium that was initiated by both the pacemaker spike and the patient's intrinsic electrical activity (**Figure 34-1C**). The QRS configuration of the fusion beat is different from the paced QRS morphology and the intrinsic cardiac QRS morphology. It is a hybrid of the paced and intrinsic QRS complex morphology. A pseudofusion beat is a QRS complex that is formed by the depolarization of the myocardium initiated by the patient's intrinsic electrical activity, and a pacemaker spike is present distorting the terminal QRS complex. The morphology is similar to that of the intrinsic QRS complex (**Figure 34-1D**). It is often due to the pacemaker firing during the refractory period of an intrinsic P wave or during the beginning of the QRS complex before intracardiac voltage increases to activate the sensing circuit and inhibit the pacemaker. Pseudofusion beats can be normal occurrences in pacemaker patients.

A properly functioning pacemaker will sense intrinsic cardiac electrical activity. If the intrinsic cardiac activity is below the programmed rate, a pacemaker spike will be seen followed by a QRS complex in a single-chamber or ventricular pacemaker (**Figure 34-2**). If the patient has a dual-chamber pacemaker, a

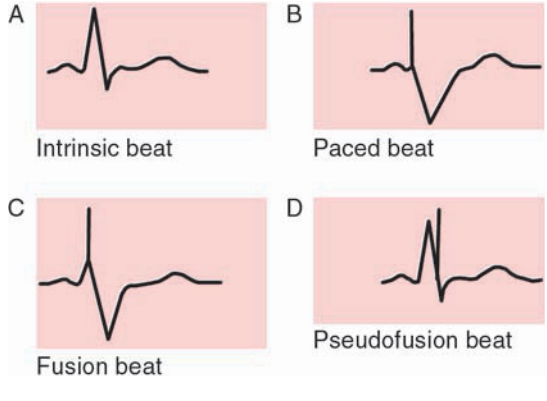


FIGURE 34-1. Schematic of typical electrocardiographic beats.

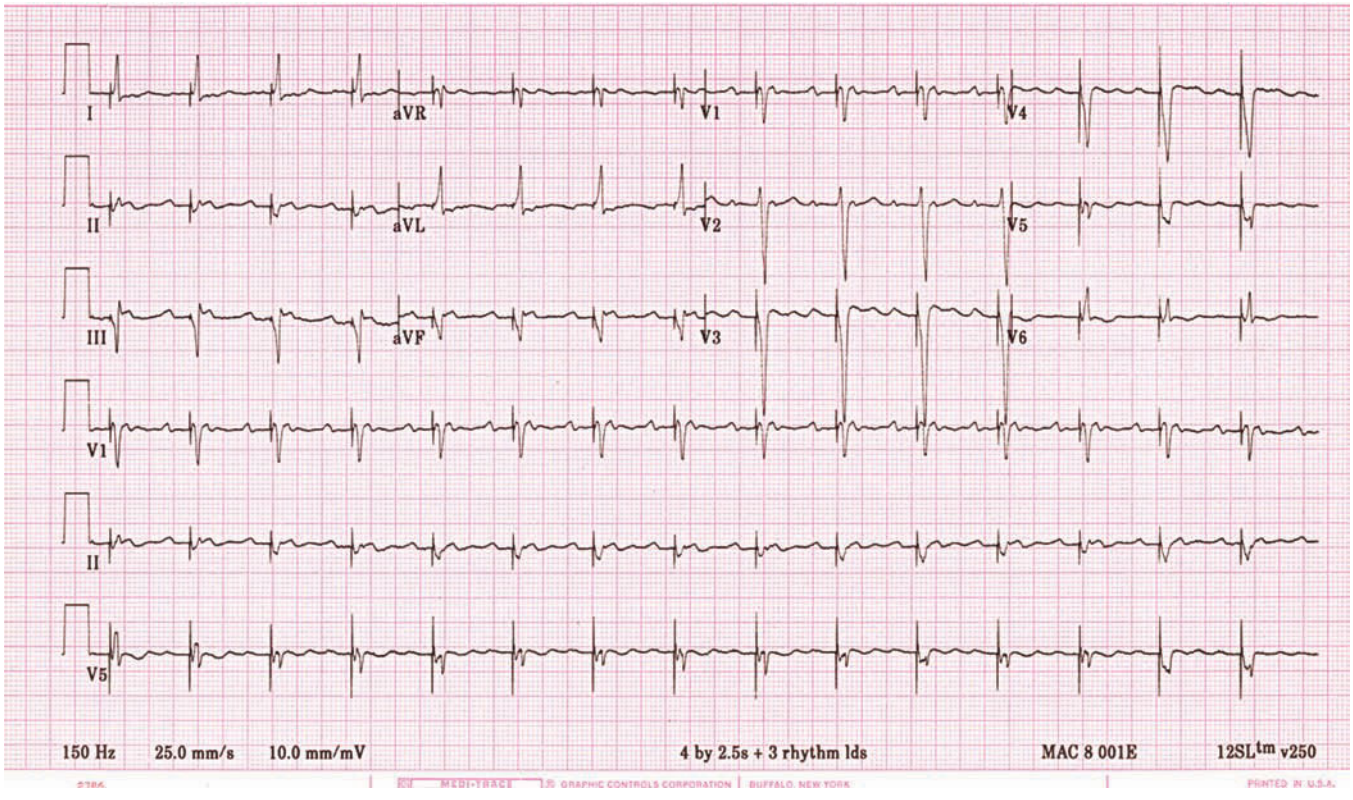


FIGURE 34-2. A 12-lead electrocardiogram of a single-chamber or ventricular pacemaker.

pacemaker spike will be followed by a P wave; then a second pacemaker spike will be seen followed by a QRS complex (**Figures 34-3 & 34-4**). If the intrinsic cardiac electric activity is above the programmed rate, no pacemaker spike should be seen on the ECG. Since the pacemaker wire is usually implanted in the right ventricle, a typical paced QRS complex will have a left bundle branch pattern (**Figures 34-1 to 34-4**). Occasionally, the pacing wire will be implanted in the left ventricle and the QRS complex will have a right bundle branch pattern.

Examine the current ECG and determine the electrical axis of the pacemaker spike, the electrical axis of the QRS complex, and the morphology of the QRS complex. These must be compared to the same features on previously obtained ECGs. A change in the axis of the pacemaker spike may be seen in cases of lead migration. A change in the ECG morphology from a left bundle branch pattern to a right bundle branch pattern suggests that the lead has perforated the interventricular septum and is now within the left ventricle.

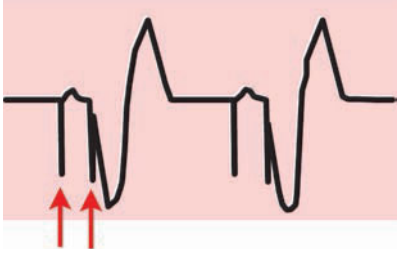


FIGURE 34-3. Schematic of an electrocardiographic monitor strip of a dual-chamber pacemaker. Atrial (*first arrow*) and ventricular (*second arrow*) pacing spikes are clearly visible.

MAGNET EXAMINATION

A magnet may be used to assess battery depletion, failure of a component of the system, or the possibility of oversensing. It can also be used in an attempt to terminate pacemaker-mediated tachycardia (PMT, discussed further on in this chapter). A doughnut-shaped magnet is required for this procedure. A standard or generic magnet may be used. Occasionally, but rarely, a brand-specific magnet may be required to evaluate a pacemaker. **A transcutaneous pacemaker generator, defibrillator, the required cables and skin electrodes, and ACLS resuscitation medications must be available in case of an emergency during the magnet examination.**

To obtain the magnet rate, place a standard magnet over the pacemaker generator while simultaneously obtaining a 12-lead ECG and rhythm strip. **The magnetic field causes the reed switch to close, bypass the sensing amplifier, and temporarily convert the pacemaker into the asynchronous (VOO or DOO) mode (Figure 34-5). This essentially turns off the sensing mode and the pacemaker fires at the programmed rate.** The magnet rate may be slower or faster than the program rate and depends on the model of the pacemaker. Pacemaker spikes occurring during the refractory period of an intrinsic QRS complex will not be captured (**Figure 34-5B**). Theoretically, a pacing spike occurring on the T wave could induce ventricular arrhythmias, but this is rarely a practical problem.

The application of the magnet over the pacemaker generator can have a variety of results. If it is working properly, the pacemaker will fire at the programmed rate. This indicates that the failure to pace the myocardium in a patient with bradycardia is due to oversensing. The unit may be sensing a large T wave as a QRS complex. Alternatively, it may be sensing a normal T wave as a QRS complex if the QRS complexes are small in amplitude. If a patient's bradycardia is corrected, tape the magnet in place over the pacemaker generator.

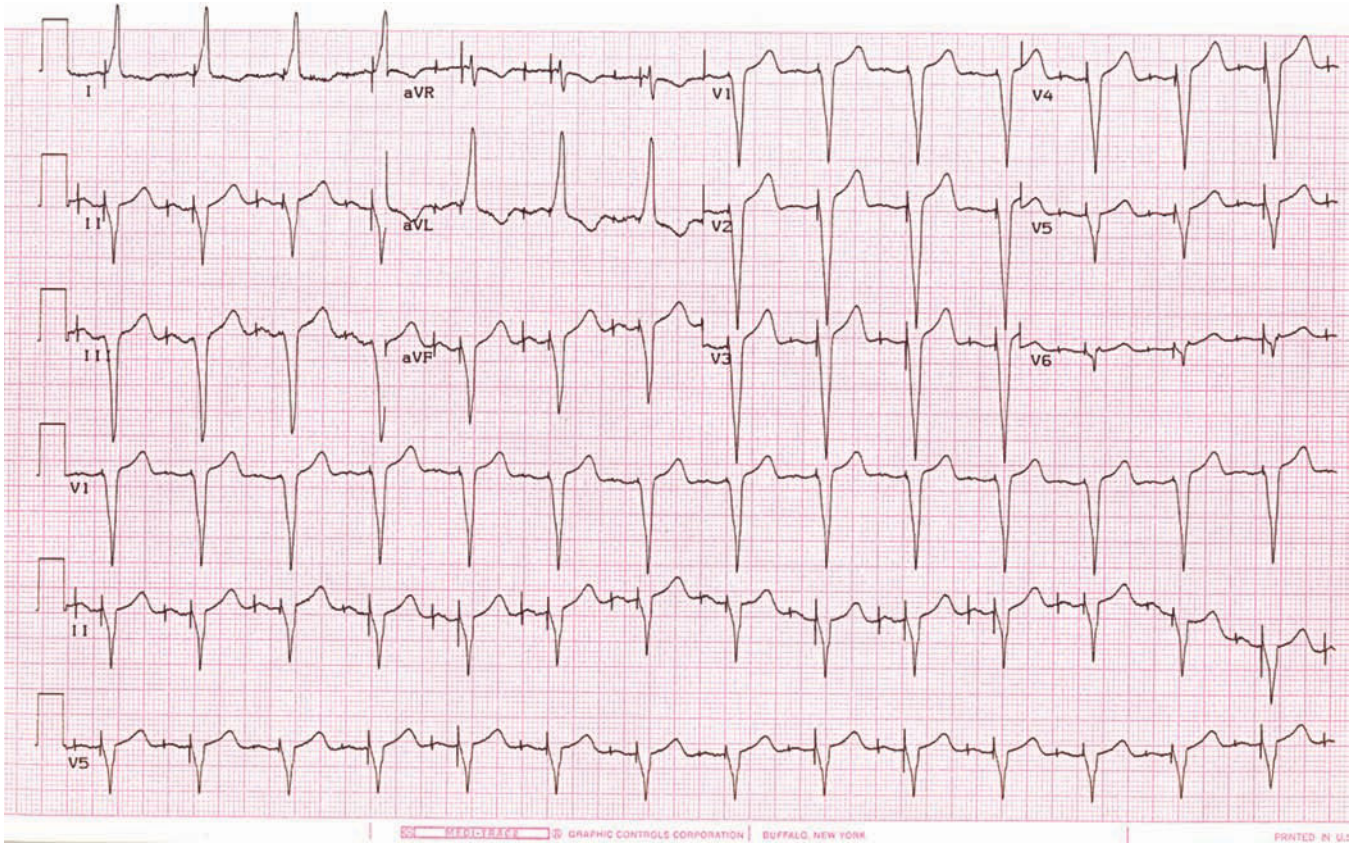


FIGURE 34-4. A 12-lead electrocardiogram of a dual-chamber or atrioventricular sequential pacemaker.

If the generator is pacing intermittently, the magnet may not be directly over the pacemaker generator. Reposition the magnet and observe the results. If no pacemaker spikes are seen on the ECG, a component of the system (i.e., generator, battery, or leads) has failed. If the pacemaker spikes occur at less than the programmed rate, the battery may be depleted or the set rate has been changed.

CHEST RADIOGRAPHY

Obtain overpenetrated posteroanterior and lateral chest radiographs. This is helpful in locating the pacemaker generator and lead positions. Look for a loose connection where the lead connects to the pacemaker generator. Manipulation of the pulse generator within the pocket may relieve or reproduce the patient's problem. A pneumothorax and/or hemothorax may be detected in patients whose pacemakers have been recently implanted.

The pacemaker lead may have become dislodged from its implantation site. This is extremely uncommon with current systems, as they have safety mechanisms to prevent lead dislodgement. Ensure that the distal end of the pacing wire is within the cardiac silhouette and against the myocardium. It may be free-floating within the ventricle or may have perforated the ventricular wall. Previous chest radiographs should be obtained and compared to the current radiographs to help determine if the leads have been displaced.

Lead fractures can occur anywhere along the length of the pacing wire. They most often occur at stress points adjacent to the pacemaker or just under the clavicle as the pacing wire enters the subclavian vein. The lead also has a J-shaped retention wire to help maintain its shape. The tip of the retention wire may occasionally protrude from the plastic-coated lead. This protruding wire has the potential to puncture the right atrium or superior vena cava and cause a hemorrhagic pericardial effusion that may result in cardiac tamponade.

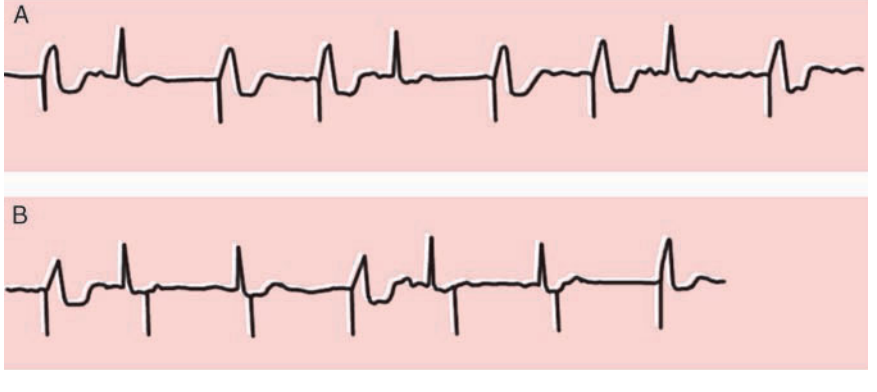


FIGURE 34-5. Schematic of a pacemaker's electrocardiographic monitor strip. **A.** Pacemaker activity without a magnet applied. **B.** Pacemaker activity with a magnet applied.

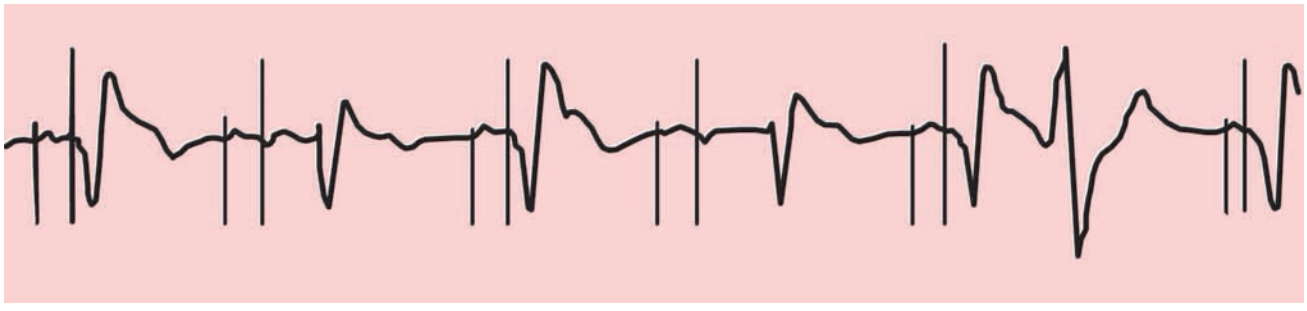


FIGURE 34-6. Schematic of an electrocardiographic monitor strip of an AV sequential pacemaker demonstrating lack of capture or intermittent capture.

PACEMAKER INTERROGATION

Recent pacemakers contain crucial information such as the range of heart rate, percentage of pacing, intracardiac ECG recordings as well as arrhythmia logs.[9] The pacemaker can be interrogated to obtain generator life, lead integrity, false discharges, undersensing, and oversensing. The device interrogation by the industry representative or a cardiology technician is a vital part of the Emergency Department evaluation of a patient presenting with symptoms that might be attributed to the pacemaker. The interrogator, in consultation with the patient's Cardiologist, may have the capability of changing the threshold setting on the device to resolve certain problems and negating the need for admission.[10]

ELECTROCARDIOGRAPHIC ABNORMALITIES

FAILURE TO PACE

Failure to pace is a result of either pacemaker output failure (i.e., lack of a pacer spike) or failure to capture (i.e., lack of a myocardium stimulation after a pacer spike). **Failure to pace is noted by a lack of the pacemaker spike on the ECG and the failure to deliver a stimulus to the myocardium when there is a pause in the intrinsic cardiac electrical activity.** The pacer-dependent patient may complain of chest pain, dizziness, lightheadedness, weakness, near-syncope, syncope, or other signs of hypoperfusion.

The failure of pacemaker output is detected by the lack of pacing activity (i.e., pacer spikes) on the ECG in a patient with a heart rate lower than the programmed rate. It can be the result of oversensing or an inherent problem with the device. Total or nearly total battery failure, complete inhibition of a demand pacemaker by skeletal muscle contraction or electrical magnetic interference, oversensing, insulation failure, lead fracture, or an improper connection between the electrode and the pulse generator can all cause total lack of pacemaker stimulus. The incorrect diagnosis of a failure to pace and a lack of pacemaker output can be made if the patient's pacemaker spike is very small. The evaluation of multiple leads of the ECG tracing usually prevents this misdiagnosis.

Oversensing is the inappropriate inhibition of the pacemaker due to its sensing of signals that it should otherwise ignore. For instance, P or T waves or skeletal muscle activity may be misinterpreted as QRS complexes resulting in the inhibition of pacemaker function. Oversensing has decreased in prevalence due to the use of bipolar pacing devices.[9] Oversensing can be detected by placing a magnet over the pacemaker. If it is working properly, the pacemaker will fire at the programmed rate. This indicates that the failure to pace the myocardium in a patient with bradycardia is due to oversensing. The unit may be sensing a large T wave as a QRS complex. Alternatively, it may be sensing a normal T wave as a QRS complex if the QRS complexes are small in amplitude. If a patient's bradycardia is corrected, tape the magnet in place over the pacemaker generator. If the generator is pacing intermittently, the magnet may not be directly over the pacemaker generator. Reposition the magnet and observe the results. If no pacemaker spikes are seen on the ECG, a component of the system (i.e., generator, battery, or leads) has failed. If the pacemaker spikes occur at less than the programmed rate, the battery may be depleted or the set rate has been changed.

FAILURE TO CAPTURE (LACK OF CAPTURE OR INTERMITTENT CAPTURE)

Failure to capture is detected by the lack of a QRS complex after an appropriately timed and placed pacemaker spike on the ECG (Figure 34-6). It occurs when the generated pacing impulse is incapable of effectively depolarizing the myocardium. Lack of capture or intermittent capture could be as a result of the inadequate energy generation by the pacemaker (i.e., battery failure), increased resistance at the electrode–myocardium interface (i.e., lead fracture or displacement), poor electrode positioning, prolongation of the refractory state of the myocardium (e.g., myocardial infarction, electrolyte abnormalities, supratherapeutic levels of antidysrhythmic drugs), or perforation of the myocardium by the electrode.[10] For patients with failure to capture as a result of high antidysrhythmic drug levels, isoproterenol has been shown to be an effective therapy.[10,11]

Failure to capture during the postimplantation period could result from an elevated voltage threshold for pacing due to tissue changes at the electrode–myocardium interface.[10,11] The occurrence of postimplantation failure to capture typically occurs in the first few weeks after implantation. However, its incidence has decreased because of recent advances in steroid-eluting leads.[10,11]

A poor threshold may be present from the time of implantation. A chronic rise in threshold can be related to fibrosis around the tip of the lead, causing lack of capture or intermittent capture. Severe metabolic abnormalities and drugs can increase the pacing threshold. A myocardial infarction involving the myocardium at the tip of the pacer leads will cause a rise in the pacing threshold. Lead fracture and poor connections between the electrode and generator can present as lack of capture or intermittent capture. The pacemaker generator battery may fail and present with too low a voltage to capture the heart but enough voltage to generate a pacemaker spike. Insulation breaks in the pacemaker lead allow parallel electrical circuits to occur in the system and may cause various pacemaker abnormalities.

RATE CHANGE

Rate change is defined as a stable change in the pacemaker's rate of firing compared to the pacemaker's rate at the time of implantation. Minor chronic changes in the pacemaker rate of one or two beats per minute can occur in some patients. The most common cause for a marked drop in the paced rate is battery depletion.



FIGURE 34-7. Schematic of an electrocardiographic monitor strip demonstrating intermittent or erratic prolongation of the pacing spike interval.



FIGURE 34-8. Schematic of an electrocardiographic monitor strip demonstrating lack of appropriate sensing or failure to sense.

This is a sign that the elective battery replacement time is nearing. Inappropriate sensing of the preceding T wave as a QRS complex can also result in a paced rate several beats per minute slower than the programmed rate.

INTERMITTENT OR ERRATIC PROLONGATION OF THE PACING SPIKE INTERVAL

A prolongation of the pacing spike interval can be due to inappropriate sensing of the T wave, pacemaker afterpotential, or skeletal muscle activity (**Figure 34-7**). Intermittent fracture of leads, poor electrode–generator connection, breaks in the insulation of the leads, external electromagnetic interference, or radiofrequency interference can also cause this malfunction.

FAILURE TO SENSE OR UNDERSENSING

Failure to sense is a result of the inability of the pacemaker to sense the native cardiac activity. It is recognized by noting pacemaker spikes on the ECG despite the patient's intrinsic cardiac rate being higher than the pacemaker's programmed rate (Figure 34-8). Patients with an undersensing pacemaker might present with weakness, lightheadedness and syncope due to alterations in rhythm due to competition with the native cardiac rhythm. The pacemaker does not sense the preceding QRS complex appropriately and fires. Causes of undersensing include conditions that alter the nature of cardiac signals such as new bundle branch blocks, myocardial ischemia, premature ventricular contractions (PVCs), or premature atrial contractions.[10] Other etiologies of failure to sense include poor electrode position, lead dislodgement, reed switch malfunction, breaks in the lead insulation, battery failure, and inappropriate programming of the sensitivity of the pulse generator. However, many of these etiologies can also result in failure to capture. Low-amplitude QRS complexes or broad QRS complexes with a low slow rate, as in a bundle branch block, may be responsible for pacemaker sensing problems.

PACEMAKER-MEDIATED TACHYCARDIA

Pacemaker-mediated tachycardia (PMT) is a paced rhythm in which the pacemaker is firing at a very high rate (Figure 34-9). PMT can occur only when the pacemaker is programmed to an atrial synchronized pacing mode (e.g., DDD). PMT is a reentry dysrhythmia commonly precipitated by a PVC in a patient with a dual-chamber pacemaker. If the PVC is conveyed in a retrograde fashion through the AV node, it may be sensed as a retrograde P wave. The sensed retrograde P wave is considered by the pacemaker as atrial activity and the pacemaker initiates ventricular pacing.[10,12] This continues via an endless loop involving the pacemaker. Modern pacemakers have algorithms to prevent and terminate PMT. Management includes the application of a magnet, Valsalva maneuvers, transcutaneous pacing, and various isometric pectoral exercises. Other methods to terminate this rhythm include a precordial thump, reprogramming the pacemaker, and cutting the leads as they exit the pacemaker generator. Consult a Cardiologist prior to performing any of these maneuvers.

COMPLICATIONS OF CARDIAC PACING UNRELATED TO ELECTROCARDIOGRAPHIC ABNORMALITIES

IMPLANTATION-RELATED COMPLICATIONS

Complications may occur from the implantation procedure. Discomfort and ecchymosis at the incision site or the pacemaker pocket are common in the first few days. Dehiscence of the incision can occur, especially if a large hematoma in the pocket puts excessive stress or pressure on the incision. Nonsteroidal anti-inflammatory drugs, excluding aspirin, are adequate and appropriate to alleviate the discomfort. Assure the patient that the discomfort and ecchymosis will resolve spontaneously. The patient should not be taking aspirin in the immediate postimplantation period unless authorized and/or prescribed by the Cardiologist. The pacemaker can migrate, cause pressure on the overlying skin, and result in skin erosions that require pacemaker relocation and wound debridement.

The most common insertion site for the pacemaker wires is through the subclavian vein using a blind insertion technique. Complications include air embolism, arteriovenous fistula formation, brachial plexus injury, hemothorax, pneumothorax, subclavian artery puncture, subcutaneous emphysema, and thoracic duct injury. Refer to Chapter 49 for complete details on complications related to the placement of a central venous line.

A hematoma may form at the site of the subcutaneous pacemaker generator. This can be due to anticoagulation therapy, aspirin therapy, or an injury to a subcutaneous artery or vein. A hematoma can be managed with the application of dry, warm compresses to the area and oral analgesics. The Cardiologist may evacuate the hematoma if it continues to expand and threatens to compromise the incision site. Otherwise, a hematoma is self-limited and resolves spontaneously. **Do not attempt to aspirate a hematoma.** This is usually unsuccessful, can introduce an infection, may damage the pacemaker or leads, and does not address the etiology of the bleeding.

The ventricular wall may be perforated during the implantation of the pacemaker lead or postimplantation. The patient may be asymptomatic, complain of chest pain and/or dyspnea, or have signs and symptoms of cardiac tamponade. Other signs suggestive of ventricular perforation include diaphragmatic contraction or hiccups at a rate equal to the pacemaker rate, a friction rub, intercostal muscle contractions at a rate equal to the pacemaker rate, pericardial

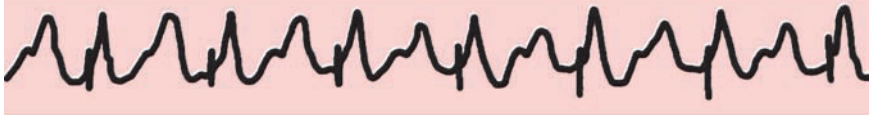


FIGURE 34-9. Schematic of an electrocardiographic monitor strip demonstrating pacemaker-mediated tachycardia.

effusions, pericarditis, or a right bundle branch pattern on the ECG. The evaluation may include chest radiography, echocardiography, and/or pacemaker interrogation and evaluation.

PACEMAKER SYNDROME

The pacemaker syndrome is defined as adverse hemodynamic effects that cause the patient to become symptomatic or limit their ability to be fully functional even though the pacemaker system is functioning normally. Patients may complain of anxiety, apprehension, dizziness, fatigue, pulsations in the neck, or shortness of breath. Ventricular pacing can cause a lack of atrioventricular synchrony, leading to decreased left ventricular filling and subsequent decreased cardiac output. Syncope and near-syncope are thought to be associated with a vagal reflex initiated by elevated right and/or left atrial pressures caused by dissociation of the atrial and ventricular contractions. The high wedge pressure can result in shortness of breath. Patients with the pacemaker syndrome most commonly have documented one-to-one ventricular-to-atrial conduction during ventricular pacing. Patients with retrograde AV conduction are more symptomatic. However, a pacemaker syndrome can occur in the absence of retrograde atrioventricular conduction. Provide supportive care until the pacer can be upgraded to one that restores AV synchrony, such as changing a single-chamber pacer to a dual-chamber pacer.

RUNAWAY PACEMAKER

The runaway pacemaker is a rare medical emergency in which rapid pacer discharges occur above its preset upper limit. Ventricular tachycardia or fibrillation may be induced. The cause is a malfunction in the pacemaker pulse generator, unlike PMT, which is caused by an external re-entrant loop.[10,11,13] Runaway pacemaker can be differentiated from PMT by the response to the application of a magnet. PMT will usually stop temporarily by inducing asynchronous pacing with a magnet. However, magnet application generally has little or no affect on a runaway pacemaker.[12] Treatment requires emergent pacemaker interrogation and reprogramming. If this fails, emergent surgical intervention to disconnect or cut the leads in the pacemaker pocket is necessary. Fortunately, all modern pacemakers are programmed to prevent discharges at rates above a set limit, usually 180 beats per minute.[13]

INFECTION

Infection often occurs shortly after implantation and is usually localized to the pacemaker pocket area. However, endocarditis has also been reported in association with pacemakers. Infection may present as localized erythema and tenderness, localized inflammation, purulent discharge from the skin incision, skin erosion, sepsis, and/or bacteremia. *Staphylococcus aureus* is responsible for many acute infections while *Staphylococcus epidermidis* is a frequent culprit of late or chronic infection.[14] The pacemaker generator and leads usually have to be removed to eradicate an infection. In some instances, the infection has been treated successfully with vancomycin or other parenteral antibiotics and the pacemaker did not require removal.

The pacemaker electrode becomes endothelialized in a few weeks postimplantation. Patients generally do not require prophylactic antibiotics when they undergo a procedure that is likely to produce transient bacteremia. Prophylactic antibiotics are required only in the first few weeks after permanent pacemaker implantation.

STIMULATION OF THE DIAPHRAGM AND PECTORAL MUSCLE

Stimulation of the diaphragm may be caused by perforation of the right ventricular wall by the pacing wire and can occur with very few complications. Diaphragmatic stimulation can also occur without perforation of the right ventricular wall. Decreasing the pulse width and/or voltage output can minimize the stimulation until the defective component can be replaced.

Pectoral muscle stimulation is less common with the currently available bipolar pacemakers. An insulation break or a defect in the pacing wire before it enters the subclavian vein will allow the current to flow in the area of the pacemaker generator and cause skeletal muscle stimulation. This can also be seen with current leakage from the connector of the pacing wires or sealing plugs. In rare instances, erosion of the protective coating of the pacemaker generator can cause this phenomenon. Decreasing the pulse width and/or voltage output can minimize the stimulation until the defective component can be replaced.

THROMBOSIS

Thrombosis of the vein (e.g., subclavian or cephalic) containing the pacemaker lead occurs commonly, but rarely causes clinical symptoms. Patients with symptomatic thrombosis and occlusion of the subclavian vein may present with ipsilateral edema and pain in the upper extremity. Occlusion of the superior vena cava can result in a superior vena cava syndrome. Thrombus formation in the right atrium and/or right ventricle can result in pulmonary emboli and hemodynamic compromise. Fortunately, these events are extremely rare.

ALLERGIC REACTIONS

Allergic reactions to the metal components of the pacemaker have been noted in the past. Current pacemaker generators and leads are coated with a substance to prevent the body from being exposed to the metal. Allergic reactions to the pacemaker covering are very rare but have been reported.

SUMMARY

Routine follow-up of patients with pacemakers in the pacemaker clinic helps to identify pacemaker malfunction earlier and often before problems occur. Patients presenting to the Emergency Department with symptoms referable to pacemaker malfunction should have a history and physical examination, chest radiograph, routine ECG, and ECG recording with a magnet over the pacemaker. This helps to identify patients with pacemaker malfunction who require detailed pacemaker interrogation. A Cardiologist should be consulted on every patient who presents with an actual or a potential pacemaker problem.

35 Automatic Implantable Cardioverter-Defibrillator Assessment

Carlos J. Roldan

INTRODUCTION

The introduction of implantable cardioverter-defibrillator (ICD) technology has revolutionized the fields of cardiology and electrophysiology. More than 100,000 such devices are implanted annually in the United States alone. ICDs allow life-threatening ventricular tachycardia and ventricular fibrillation to be safely controlled and benefit patients at risk for sudden cardiac death. Multiple

studies (e.g., CABG patch, MADIT, MADIT II, MUSTT, DINAMIT, AMIOVIRT, COMPANION, SCD-HEFT) have examined the prophylactic indication for ICD therapy in high-risk groups.[1–7] The ICD is becoming a more common therapeutic option for the young population with a diagnosis of Brugada syndrome, prolonged QT syndrome, and hereditary cardiomyopathies to name a few.

The Emergency Department is often the initial contact point for these patients. Now more than ever Emergency Physicians must be familiar with the problems that can be encountered by a patient with an ICD. This chapter describes technical aspects, basic interrogation of the device, and a general approach to a patient who presents to the Emergency Department with an ICD.

TECHNICAL CONSIDERATIONS

The ICD has four main functions. It recognizes and records local atrial and ventricular electrogram signals. It then classifies the sensed signals according to programmable heart rate zones. The ICD provides therapy (i.e., a shock) to terminate ventricular tachycardia or ventricular fibrillation. It has a pacing capability for bradycardia and/or cardiac resynchronization therapy. When detection criteria are satisfied, therapy to terminate the arrhythmia is initiated with high-energy shock of up to 40 Joules (J).

ICD technology has progressed exponentially since its introduction by Mirowski and colleagues in the early 1980s.[8] The ICD system is comprised of a pulse generator, a battery, and a lead system. The lead system is required for sensing, pacing, and the delivery of therapy. Earlier systems required that the pulse generators be placed abdominally due to their large size (**Figure 35-1**). Defibrillation was delivered via two epicardial patches positioned anteriorly and posteriorly. Occasionally, a transvenous spring electrode in the superior vena cava was utilized with an epicardial patch. Sensing was achieved through separate epicardial screw-in electrodes. Initial lead placement required either a sternotomy, lateral thoracotomy, or a subxiphoid approach, making early implants quite cumbersome.[9]

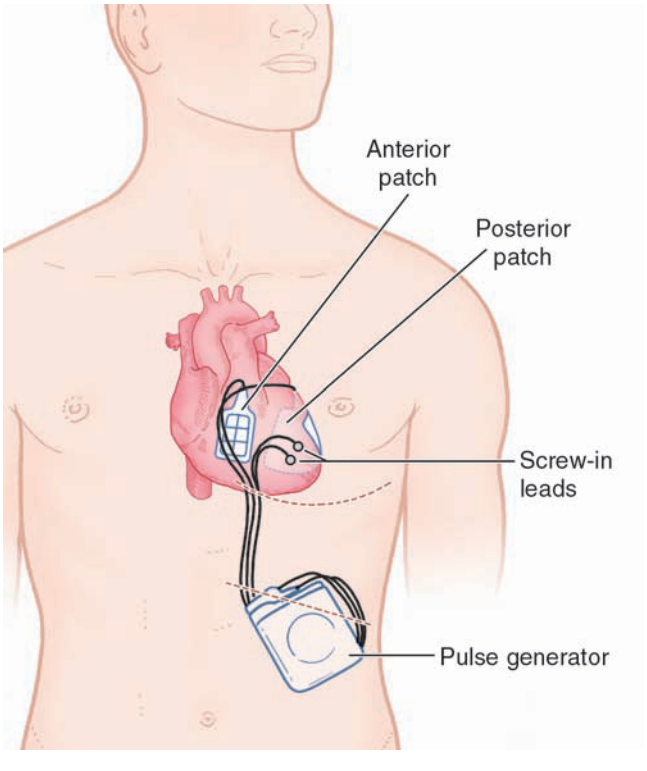


FIGURE 35-1. Abdominal placement of the ICD generator. Initial implants required a thoracotomy to position the epicardial patches needed for defibrillation as well as the screw-in sensing leads. The leads were tunneled abdominally to the ICD generator.

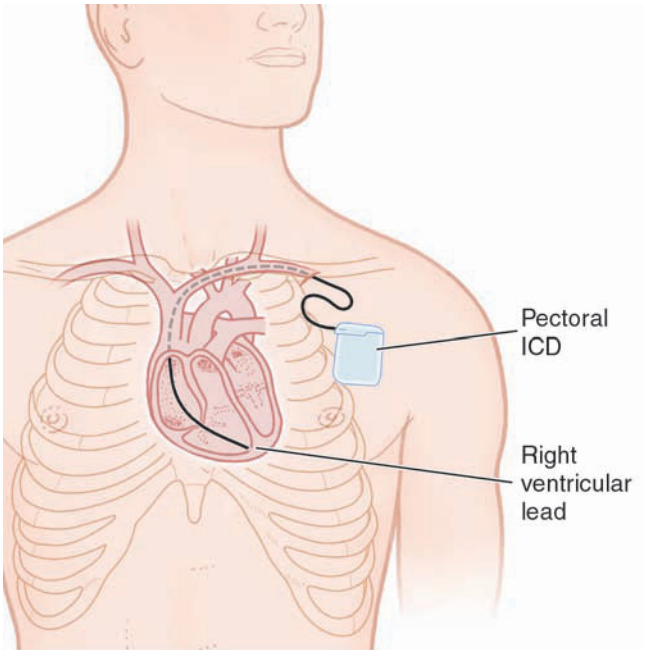


FIGURE 35-2. The current nonthoracotomy system. The development of smaller generators and biphasic waveforms for defibrillation allowed for transvenous positioning of the ICD leads and a pectorally located generator.

The smaller size of the newer devices allows for superficial implantation of the pulse generator in the anterior chest wall, similar to a pacemaker (**Figure 35-2**). The current ICD systems are comprised of three main parts. The pulse generator is programmable and capable of analyzing and recording the patient's heart and rhythm. The ICD generator houses the batteries, high-voltage capacitors, and microprocessors necessary to process sensed intrinsic cardiac electrical activity. In essence, the generator is a minicomputer within a hermetically sealed titanium can (aka case) capable of generating shocks. Typical ICDs contain lithium silver vanadium oxide cells that store between 2 and 7 Volts (V).[12] The high voltages necessary for defibrillation are generated with the aid of high-voltage capacitors that are able to generate 700 to 800 V of defibrillation energy in under 20 seconds. The lead system or wires are inserted into the right ventricle for single chamber devices or both the right atrium and right ventricle for dual chamber devices. The leads are required for sensing, pacing, and the delivery of therapy. The final component is the battery to power ICD system.

ICD implantation has evolved quite rapidly due to advancements in lead technology, generator technology, and the development of biphasic defibrillation waveforms, which lowered the energy requirements necessary for successful defibrillation.[10] The creation of a (bipolar) lead combining pacing and sensing capabilities with a high-voltage electrode coil allowed for nonthoracotomy system implants, which reduced surgical morbidity and mortality.[11] The leads were now positioned transvenously via the subclavian vein and fixed to the inside of the right ventricle. However, the leads still had to be tunneled subcutaneously to the abdomen, as the generators remained fairly large. Technology has advanced the development of more compact generators. The smallest commercially available devices today are under 40 cm^3 and weigh well under 100 grams. Smaller generators allow for subcutaneous pectoral implantation and simplification of the implantation process (**Figure 35-2**).[12]

Current ICDs allow extensive programmability for tiered antitachycardia pacing (ATP), tiered high voltage therapies, single or dual chamber bradycardia pacing, supraventricular tachycardia (SVT) discrimination algorithms, and detailed diagnostics of tachycardic and bradycardic episodes. Implantable loop recorders and home monitoring (HM) functions extend the technical capabilities for automatic detection of arrhythmias that may not be symptomatic. It also allows for a fully automatic and wireless data transmission, including episode counters.[9,10] This allows alterations in device programming or medication dose modifications in the outpatient setting, thus avoiding hospitalization.[13,14]

ATP may be enabled to manage ventricular tachycardia. ATP commonly consists of a burst of pacing (i.e., 6 to 10 beats) at a rate faster than the ventricular tachycardia rate. ATP may be felt by the patient. It is painless and often terminates the ventricular tachycardia before the patient becomes symptomatic. ATP is the initial preferred treatment, even for fast ventricular tachycardias, with shocks programmed as a backup if ATP fails.[15] In addition, current ICDs have an antibradycardia function that works like a pacemaker. If the heart rate falls below the programmed rate, the ICD will provide a pacing function with significantly less forceful shocks.

Exercise testing should be performed with the realization that increasing the heart rate above the programmed ventricular tachycardia and ventricular fibrillation detection rate is likely to elicit therapy (i.e., a shock) from the ICD. **Consult the patient's Electrophysiologist before any exercise or stress testing.** Determine the programmed the ICD arrhythmia detection rate. During the exercise or stress test, if the programmed rate is approached, stop the test to avoid the delivery of inappropriate therapy (i.e., a shock).

ROUTINE ICD FOLLOW-UP

A systematic follow-up procedure to assess the integrity of the ICD system is recommended every 1 to 6 months depending upon the device, battery status, and arrhythmia frequency (**Table 35-1**). The device should be interrogated with the appropriate system analyzer to assure battery voltage, lead and electrode integrity, and capacitor charge times. System integrity test results can reveal malfunctions that may compromise the device's ability to treat an arrhythmia effectively.[16,17] Once the system's integrity has been verified, each recorded arrhythmic episode should be analyzed to determine the appropriateness and effectiveness of therapies. This is achieved by examining the stored diagnostic information contained within the ICD, which may include intracardiac electrograms, arrhythmic interval values, classification markers for each interval, episode plots, textual episode descriptions, energy, charge time and impedance values for shocks, and device classifications of therapy success. This diagnostic information can be extremely valuable to determine whether programming changes should be made.[18]

TABLE 35-1 The ICD Follow-Up Checklist

- Detailed history of shocks, palpitations, light-headedness, syncope, chest pain, and dyspnea, or symptoms of congestive heart failure
- Note any changes in medications (i.e., antiarrhythmic therapy)
- Physical examination (examine incision site for any indication of infection)
- Interrogate device with appropriate system analyzer
- Check lead parameter including pacing thresholds and lead impedances (sensing is established by examining intracardiac R waves)
- Determine capacitor reformation times
- Check battery voltage (longevity is typically 5–10 years dependent on use)
- Measure impedance of the high-voltage coil (In older ICDs, this may require the administration of a subthreshold shock)
- Analyze arrhythmia counters. Examine corresponding intracardiac electrograms to determine appropriateness of therapy
- Make the necessary program changes. These include adjusting the tachycardia zones, changing the detection cutoff rates, turning on special features to aid tachycardia discrimination (stability, sudden-onset criteria, and electrogram width), and adjusting the sensitivities
- Confirm changes and reinterrogate device

BATTERY AND CAPACITORS

Battery longevity is significantly different among manufacturers. Battery voltages and capacitor charge times must be noted. Capacitors with smaller or larger capacities and changes in the initial shock polarity have not significantly improved defibrillation efficacy.[19] A variation in the number and position of electrodes can significantly influence the defibrillation threshold.[19] Generator replacement is usually recommended when voltages fall below the elective replacement indicator (ERI), which is approximately 2.6 V. When battery voltage falls below 2.2 V, the battery has reached its end of life (EOL). This signifies a more urgent need for battery replacement. The need to replace a generator is also dependent on capacitor charge times. Two consecutive charge times greater than 16 seconds is considered prolonged and may warrant urgent replacement regardless of the battery voltage. Automatic capacitor reformation is usually set to every 6 months to replenish their charge. This function can be programmed at preset time intervals. More frequent reformation is required and performed as the device reaches the battery EOL.

LEAD INTEGRITY

With the growing number of prophylactic ICD implantations and generator replacements, concern about the long-term reliability of chronically implanted leads increases. ICD lead failure can be caused by an insulation defect or conductor disruption. Lead failure can affect the high voltage lead or the pace–sense circuit of the lead. Newer ICDs provide lead-impedance monitoring for early detection of lead failure. An abnormal impedance indicates conductor fracture or insulation defect. An audible signal (Patient Alert™) notifies the patient who should then immediately contact their Cardiologist or present to the Emergency Department. Retrospective data from single centers suggest a potential clinical benefit of Patient Alert™ for ICD lead failure detection.[20]

Various parameters are checked to ensure lead integrity, including pacing thresholds, lead impedance, and the size of intracardiac R waves. At the time of implantation, a pacing threshold of ≤1.0 V at a pulse width of 0.5 milliseconds is desired. An acute rise in threshold may be seen initially; it generally falls with time. Chronic thresholds range between 0.5 and 2.0 V. Epicardial leads generally exhibit higher thresholds. Any change in thresholds must be compared with prior trends to assess its significance. Pacing thresholds may also change with the administration of antiarrhythmic drug therapy. Potential complications of ICD lead failure include oversensing of electrical noise, undersensing of ventricular tachyarrhythmias, inappropriate therapy, and lethal antiarrhythmic therapy.[21]

Current devices measure lead impedance only once a day. It is unlikely that such discrete measurements will reveal abnormal impedance if lead failure causes sporadic dysfunction. Thus, multiple impedance measurements per day may be necessary to enhance the sensitivity of the Patient Alert™.[22] Lead impedances will vary based on the type of lead. The high voltage impedance measurement differs between devices.[23] Normal impedances range from 300 to 1200 Ohms (Ω). A sudden change in impedance may signal a problem with lead integrity. A high impedance reading suggests the possibility of lead or patch fracture. A low impedance indicates a problem with the insulation. The impedance of the high-voltage coil must also be evaluated. Epicardial and active can systems

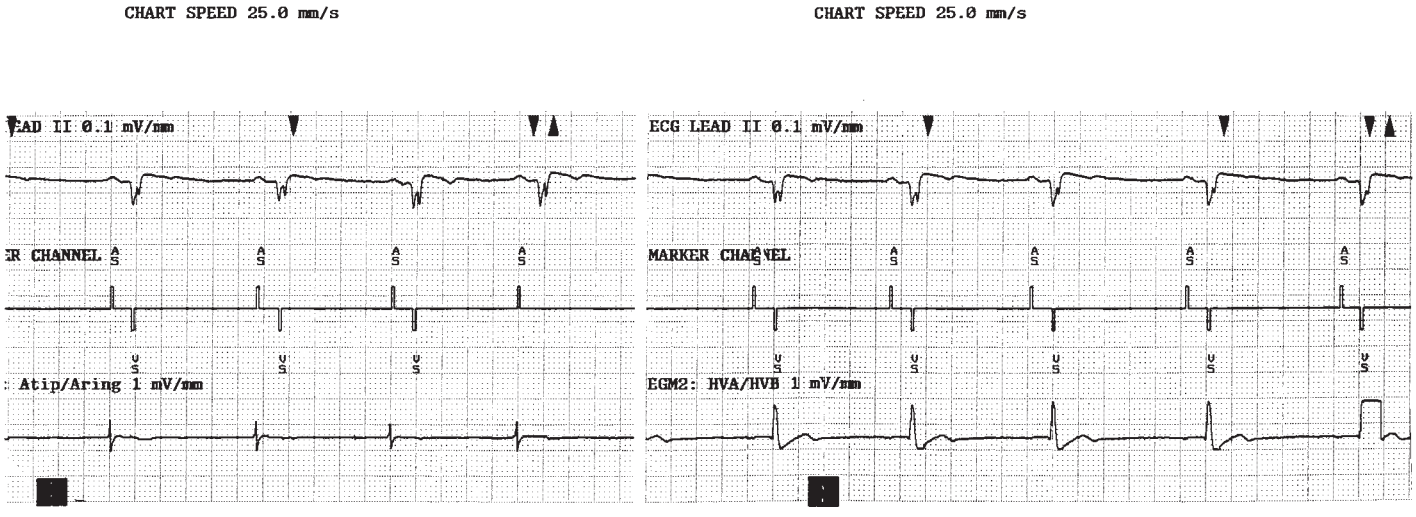


FIGURE 35-3. The intracardiac electrogram as recorded by the ICD. Printouts were obtained from a Medtronic Gem II DR dual-chamber ICD. The first line shows an ECG rhythm strip (lead II). The marker channel directly under the rhythm strip indicates behavior (sensing/pacing) in each chamber. The third line represents the intracardiac electrogram from the atrium (*left*) and ventricle (*right*). Measured in millivolts per millimeter, larger signals imply better sensing.

demonstrate lower impedance values compared to endocardial systems due to their larger surface area. Normal values generally range between 20 and 80 Ω. High impedance values, as with the pace/sense leads, usually indicate a fracture in the defibrillation system. Any stark changes in impedance levels may suggest a patch problem. This includes crinkling, seroma formation, or migration. Any impedance change in an endocardial system may indicate lead dislodgement.

R-wave amplitude is a direct measure of intracardiac electrogram activity and determines the device's ability to sense. At implantation, an R wave of ≤5 mV is desired to ensure adequate detection of ventricular fibrillation. The most common explanations for a decrease in R-wave amplitude after an implant are lead dislodgment or local factors such as edema or fibrosis. This change may be associated with an increase in lead impedance and pacing thresholds.

ANALYZING APPROPRIATENESS OF THERAPY

Current ICDs have simultaneous marker channels with real-time intracardiac electrograms (**Figure 35-3**). It is important to document intracardiac activity during sinus rhythm. These electrograms can be used as a basis of comparison with tachycardia events. The signals should be examined for evidence of noise, which may be an indicator of sensing problems, a connector issue, or a faulty adaptor. In the event of noise detection, electrograms must be examined during various maneuvers including deep breathing, arm maneuvers, and bending. Intracardiac electrograms should be examined for T-wave oversensing or detection of pacemaker spikes as ventricular signals. In dual-chamber devices, oversensing by the atrial lead should be ruled out. Wide variations in electrogram size may suggest that the lead is not stable or well fixed.

THE ICD IN THE EMERGENCY DEPARTMENT

A patient with an implantable defibrillator may present to the Emergency Department for various reasons. Manufacturers offer 24 hour technical support. They also maintain a registry of devices implanted and evaluations performed. A staff of field engineers are often available for help with the assessment, interrogation, and management of ICD function. The US Food and Drug Administration (FDA) is responsible for assessing both the premarket and postmarket safety and effectiveness of medical devices marketed in the United States. They require manufacturers to submit annual reports detailing the number of device implants and malfunctions that have occurred.[24]

Individuals with recently implanted devices may be quite anxious and may seek medical attention even after a single ICD discharge. Patients may also present after multiple ICD discharges or in full cardiac arrest, requiring cardiopulmonary resuscitation (CPR). The warmth, local redness, and pain associated with a potential infection of the ICD pocket may prompt the individual to seek medical attention. Questions regarding interactions between ICDs and electromagnetic interference (EMI) will arise more frequently. These clinical situations are discussed in more detail below.

Patients with ICDs must be placed on continuous telemetry. Perform a detailed and complete history and physical examination. The patient should be questioned regarding the number of shocks received, symptomatic palpitations, presyncope, symptoms of congestive heart failure, or symptoms consistent with angina. The pocket site must be examined for evidence of local infection, including warmth, tenderness, and discharge. Upper extremity or neck swelling ipsilateral to the inserted endocardial lead suggests the possibility of a subclavian vein or superior vena cava thrombosis.[25] Bilateral head edema and neck vein swelling suggest the possibility of a superior vena cava thrombosis or a superior vena cava syndrome. It is important to document any changes in medications or whether antiarrhythmic therapy has recently commenced. Routine blood work should be obtained, including a complete blood count, serum electrolytes, magnesium level, renal function indices, and quantitative levels of measurable medications.

The ICD model should be identified. Patients are generally given identification cards that list the manufacturer, lead system, generator model, and a 24 hour emergency contact number. Often this information is not available. However, in an emergency situation, an overpenetrated chest radiograph showing the generator will demonstrate the radiopaque identifier of the manufacturer.

The chest radiograph may be of diagnostic importance. It is not only important for device identification but can also give useful information about lead integrity. In a recent implant, a chest radiograph is routinely performed to assure lead positioning, slack in the lead, and to rule out other thoracic pathology. In patients with

epicardial patches, the chest radiograph is an excellent tool for demonstrating patch crinkling, fracture, or migration. With endocardial systems, the lead can again be assessed for fractures or discontinuities. Fractures can occur anywhere along the lead. They are most commonly seen near the junction of the first rib and the clavicle, a condition referred to as "subclavian crush."

If the patient presents with a ventricular arrhythmia and is hemodynamically stable, attempts should be made to obtain a 12-lead electrocardiogram (ECG) before any interventions are made to terminate the arrhythmia. Often this may be difficult due to concomitant discharges from the device, an anxious staff, and an anxious patient. Antiarrhythmic medications such as amiodarone, procainamide, and β-blockers may have to be considered in the event of recurrent ventricular tachycardia. Despite the absence of clinical trials examining the efficacy of lidocaine, it is generally considered the treatment of choice in the setting of an acute myocardial infarction or acute ischemia if the patient is experiencing a ventricular arrhythmia.

EMERGENCY DEACTIVATION (MAGNET BEHAVIOR)

The ability of an ICD to identify and treat tachyarrhythmias can be temporarily disabled with the use of a magnet. This situation may arise in the setting of multiple ICD discharges where the shocks are not tolerated or prior to a surgical procedure where electrocautery is necessary. Emergency deactivation with a magnet can result in serious complications such as causing a battery indicator to switch to "end of life" and the loss of some antitachycardia therapies.[26] **The application of a donut-shaped magnet overlying the ICD pulse generator forms a magnetic field that trips a reed switch in the ICD generator circuit.** This results in a suspension of tachycardia detection and therapy delivery. Generally, a single magnet will suffice. In obese patients or in the presence of pockets with significant edema, two or more magnets may be required to achieve deactivation.[27] **The patient must be fully monitored, a cardioverter-defibrillator unit must be readily available, and Advanced Cardiac Life Support (ACLS) medications must be readily available if an ICD is to be deactivated.**

The magnet response of an ICD varies subtly from manufacturer to manufacturer. In Medtronic devices, the application of a magnet temporarily disables tachycardia detection and therapy with no effect on bradycardia pacing. Removal of the magnet will resume arrhythmia detection. When activated, newer Medtronic ICDs (Gem II DR, patient alert function) will elicit a continuous beep lasting for 15 seconds if a magnet is placed directly over the ICD. A magnet applied over Guidant (CPI) ICDs also inhibits tachycardia therapy with no effect on bradycardic pacing. These devices will generate beeping tones, which change to a continuous tone. The constant tone indicates that the device is off and will not deliver tachycardia therapy. The device can be turned back on by reapplying the magnet over the ICD for 30 seconds. Tones will now change from continuous to beeping synchronous with R waves, signifying that the device is on again. Newer-generation Guidant ICDs (Prism II) have a built-in electrocautery feature that can be activated by use of the Guidant programmer. This will suspend tachyarrhythmia therapies and pace in the DOO mode. Regular functioning of the ICD is restored by turning this feature off.

ICD DISCHARGES

Patients who experience a shock but feel unwell after the event or who receive more than one symptomatic ICD therapy within a short period of time (i.e., minutes to hours) require emergent evaluation.[27,28] Most ICDs have a limit to the number of shocks it can generate before it stops producing shocks. This number is usually five to seven shocks. However, if the patient's cardiac rhythm reverts to normal sinus rhythm, the ICD can reset and start shocking the patient again to the set maximum number of shocks. Multiple ICD discharges or shocks in a short period of time can cause severe battery depletion. Ongoing arrhythmias not adequately treated by the device, myocardial infarction, electrolytes imbalances, and ICD malfunction are all possible etiologies that warrant medical attention.

Emergency Department patients presenting with multiple ICD discharges require immediate attention. From a psychological perspective, multiple discharges are usually not well tolerated and can be emotionally devastating to the patient.[25] Myocardial injury and transient reduction in left ventricular function can occur as a result of multiple shocks.[28] This has been associated with a poorer long-term prognosis. Multiple discharges can lead to premature depletion of battery life.

ESTABLISHING THE ETIOLOGY

It is important to establish the etiology of the shocks in order to administer proper and prompt management (**Table 35-2**). It is of the utmost importance to determine whether the shocks are appropriate for ventricular tachycardia or fibrillation, inappropriate therapy, or phantom shocks.[49] More than one-third of patients with a history of ventricular tachycardia or ventricular fibrillation receive a shock within 2 years of the ICD implantation.[29] Recurrent ventricular tachyarrhythmia is a common cause of repeated ICD firing. Ineffective termination of a tachyarrhythmia in this situation can be the result of an increase in defibrillation thresholds secondary to concomitant antiarrhythmic drug therapy and lead migration or lead dislodgement. Inefficient termination can occur if inappropriately low amounts of energy are programmed for the initially administered shock. Shocks may also be the result of inappropriate detection of SVTs, the most frequent of which include sinus tachycardia and atrial fibrillation.[30] The administration of a low-energy shock may convert a benign SVT into an unstable ventricular arrhythmia resulting in an ICD proarrhythmia. The introduction of an atrial lead in dual-chamber devices has aided in the discrimination process between SVTs and ventricular tachyarrhythmias. Rapid SVTs are particularly a problem in children and athletic individuals in whom exercise or reductions in

TABLE 35-2 Causes of Frequent ICD Discharges

Appropriate
Sustained ventricular tachyarrhythmias
Recurring episodes, each one terminated by a shock
One shock needed to terminate each episode of sustained ventricular tachyarrhythmia
Nonsustained ventricular tachyarrhythmias
Inappropriate
Supraventricular tachyarrhythmia that satisfies detection criteria
Atrial fibrillation
Sinus tachycardia
Paroxysmal SVT
Oversensing of signals
Sensing lead failure (migration or dislodgement)
Environmental electrical noise
Double and triple counting of pacing artifacts
P-wave oversensing
T-wave oversensing
Electromagnetic interference
Increase in defibrillation thresholds (antiarrhythmic drug therapy)
Phantom (absence of both arrhythmia and ICD discharge)
Random component failure



FIGURE 35-4. Inappropriate ICD discharge. Intracardiac electrogram of a patient with a Ventak Mini III presenting with repetitive ICD discharges. Examination of the intracardiac electrograms (line 2) demonstrates noise sensed as ventricular fibrillation (FS) resulting in an inappropriate shock (CD). Noise was traced to an insulation break in the ICD lead. Lead replacement corrected the problem.

medications that slow the heart rate, such as β-blockers, are commonly encountered causes of inadequate shocks from sinus or SVT. Inappropriate ICD firing can occur because of the erroneous detection of noise or interference that can be the result of insulation breakdown or a loose set screw (**Figure 35-4**). Oversensing of T waves, pacing artifacts, R waves, and electromagnetic interference may also lead to inappropriate detection and discharge. Patients who have received painful shocks occasionally suffer from phantom shocks, which are the perception of a shock in the absence of any arrhythmia or therapy from the ICD.[49] Finally, random component failure should be considered if all other causes have been ruled out.

APPROACH TO THE PATIENT WITH MULTIPLE ICD DISCHARGES

These patients must be under constant ECG monitoring. Apply defibrillator pads in anticipation of the development of an unstable cardiac arrhythmia. In devices with limited stored diagnostic capabilities, this may be the only means of establishing a shock-rhythm correlation. Sedation is reasonable in extremely anxious patients. Once the patient is stabilized, obtain an electrophysiology consultation for assistance in interrogating the ICD. The device should be interrogated and stored electrograms obtained for analysis.[31] For instance, it is often useful to inquire about the pattern of ICD discharge. Consecutive shocks occurring within a few seconds suggest an inappropriate discharge for SVT, oversensing, or device failure. On the other hand, isolated shocks occurring every few minutes may be indicative of recurrent ventricular tachycardia. Progressive dyspnea on exertion, shortness of breath, orthopnea, or paroxysmal nocturnal dyspnea suggests new onset or worsening heart failure, which can precipitate ventricular arrhythmias. Potential reversible causes, such as electrolyte abnormalities, need to be identified and promptly corrected.

Careful examination of the 12-lead ECG is crucial. Specific ST-segment changes may imply an acute coronary syndrome and determine the need for primary intervention or thrombolytic therapy. An ECG obtained during an actual shock may establish whether the culprit arrhythmia is a supraventricular or ventricular tachycardia.

If the discharges are inappropriate, the ICD should be emergently deactivated, as previously described. Supraventricular tachyarrhythmias should be managed with intravenous drug therapy, such as adenosine, diltiazem, or verapamil. In the situation where discharges are secondary to rapid atrial fibrillation, attempts must be made to control the patient's ventricular response with atrioventricular (AV) nodal blocking agents such as diltiazem, verapamil, β-blockers, and digoxin. Chemical cardioversion or electrical cardioversion may be attempted in the event of hemodynamic instability. Shocks secondary to prolonged episodes of nonsustained ventricular tachycardia can be prevented by adjusting initial detection parameters coupled with the addition of antiarrhythmic drug therapy.

Patients with an ICD can develop "electrical storm." Patients in electrical storm require immediate attention. This condition involves recurrent, hemodynamically unstable ventricular tachycardia or fibrillation occurring two or more times in a 24-hour period.[32] Potential triggers can be found in approximately 66% of patients and include new or worsened heart failure, changes in antiarrhythmic medication, psychological stress, and hypokalemia. In most patients, electrical storm consists of monomorphic ventricular tachycardia indicating the presence of a reentry mechanism. Ventricular fibrillation is rare and may be indicative of acute ischemia. The key intervention in electrical storm is reduction of the elevated sympathetic tone by intravenous β-blockers, benzodiazepines, and amiodarone.[33]

An Electrophysiologist should be promptly consulted and the patient stabilized prior to transfer to the intensive care unit (ICU). Defibrillator pads should be applied in anticipation of the development of unstable cardiac arrhythmias. Potential reversible causes, such as electrolyte abnormalities, need to be identified and promptly corrected. If torsades de pointes is established, the treatment of choice is magnesium and/or temporary cardiac pacing. Thrombolysis or urgent catheterization/intervention may be needed in the setting of an acute myocardial infarction. If analysis of stored electrograms demonstrates ineffective discharges, the ICD should be deactivated. Attempts to terminate the arrhythmia in the hemodynamically stable patient via ATP is a useful option. Intravenous antiarrhythmic drugs are a necessary adjunct in these situations. The administration of amiodarone in combination with β-blocker therapy has been shown to be successful in the management of electrical storm.[34] Often a combination of antiarrhythmic drugs will be required. Bretylium should be reserved until other antiarrhythmic agents have failed.

ICDs AND CARDIAC RESUSCITATION

Patients who have an ongoing arrhythmia when evaluated emergently should be managed according to ACLS guidelines regardless of the presence of an ICD. Although in the vast majority of instances ICD function will be found to be appropriate, this cannot

be assumed.[18] ACLS guidelines should be followed and the device considered inactive.[35,36] If the clinical situation permits and an ICD programmer is readily available, the device should be deactivated. This will prevent the reinduction of ventricular fibrillation or tachycardia due to concomitant ICD discharges that may occur during CPR. **There is often some hesitation to initiate resuscitative measures in patients with an ICD for fear of getting shocked. This fear is understandable but unwarranted.** Although a mild electric shock might be perceived, these discharges do not pose a risk to persons administering CPR, nor do they damage external monitoring devices.

External defibrillation is permissible, although the paddles or pads should be positioned away from the ICD. Individuals with epicardial patches may require higher energies for defibrillation. Current can be shunted from the myocardium through the patches. Moreover, the insulated portion of the patch serves as a shield from the administered shock. In patients with epicardial patches, an anteroposterior paddle configuration has been suggested for changing the defibrillation vector.[37]

The ICD may be reset after external defibrillation is delivered, especially if the paddles or pads are located in close proximity to the generator. It is important that ICDs be reinterrogated after the successful completion of a resuscitation to ensure that programmed parameters have not been altered, including the pacing thresholds.

INFECTION OF AN ICD

Technological advances have made a gradual reduction in the size of the pulse generator possible. This small size permits superficial implantation of the pulse generator in the anterior chest wall.[38] The ICD implantation technique is similar to pacemaker implantation. ICD infections can involve the generator pocket, the leads, or both. Infection is more likely after a recent generator replacement.[39] **An infected ICD system represents a serious medical situation that should be dealt with urgently.** The incidence of infection ranges from 2% to 11% in systems that were implanted via thoracotomy or sternotomy.[40] The infection rates for nonthoracotomy implants approach those of pacemakers and range from 0.8% to 1.5%.[39–43] Infections generally present clinically within 6 months of the implant, but more typically within the first 3 months. Infection should be suspected when local and systemic signs and symptoms of inflammation are apparent. Prompt referral to a specialist is warranted. In almost all cases, removal of the ICD and all leads is required. Endocarditis prophylaxis with antibiotics is not generally warranted.

Systemic symptoms are seen in up to 50% of patients, especially in those with infections caused by *Staphylococcus aureus*.[44] The pocket and/or incision site is often visibly erythematous, warm, and tender. A fever may be present. Blood work often reveals a leukocytosis. Frank suppuration or device erosion may be seen. Pericarditis may be evident if epicardial patches are infected. Blood cultures may aid in documenting the culprit organism. Infections occurring late are generally indolent and rarely present with fever or leukocytosis; moreover, blood cultures are generally negative.

The most common microorganisms in 50% of infections include *S. aureus* and coagulase-negative staphylococci. Other common organisms include *Escherichia coli, Pseudomonas, Serratia, Corynebacterium, Propionibacterium acnes, Candida* spp., Streptococci, and atypical mycobacteria.[45] Infection is generally the result of skin contamination during implantation of the ICD. It can also occur due to hematogenous seeding from distant intravenous sites, indwelling catheters, or from concomitant respiratory or urinary tract infections.

APPROACH TO AN INFECTED ICD

The goals of therapy include identifying the culprit organisms, establishing the extent of the infection, and containment of the infection. In the Emergency Department, routine laboratory tests should be obtained that include a complete blood count and differential. Blood for cultures should also be drawn, but it must be kept in mind that they are often negative. Wound cultures and gram stains may be helpful in differentiating an infection from a pocket hematoma, sterile subcutaneous fluid accumulation, or an inflammatory reaction to pacemaker components. Attempts to aspirate the pocket should be performed in consultation with an Electrophysiologist and/or a Surgeon. A sterile pocket or hematoma can often become infected after an aspiration.

There is no single diagnostic modality that can determine the extent of the infection. **ICD infections should never be assumed to be localized, as organisms can migrate from the leads into the heart.** In patients with epicardial patches, a chest radiograph may reveal patch deformities or wrinkling, suggesting distal migration of the infection. A computed tomography (CT) scan can also detect localized fluid accumulation and patch wrinkling. Echocardiography has been utilized to confirm the presence of vegetations on the leads or coil. Gallium and indium scans may be helpful in localizing an infection.

Although a few reports suggest that infection of a defibrillator system may be controlled, the treatment of choice continues to be removing the entire system followed by the administration of parenteral antibiotic agents. Some localized infections restricted to the ICD generator have been managed with the removal of the generator, debridement, and systemic antibiotic therapy. Vancomycin is frequently used as an empiric agent when cultures are still pending given its good coverage against coagulase-negative staphylococci and methicillin-resistant *S. aureus* (MRSA). Empiric gram negative and fungal coverage may be necessary in the immunocompromised patient.

ELECTROMAGNETIC INTERFERENCE AND ICDS

The ability of ICDs (and pacemakers) to function is dependent on their ability to sense intrinsic cardiac electrical activity. Hermetic shielding, filtering, interference rejection circuits, and bipolar sensing have safeguarded ICDs (and pacemakers) against the effects of common electromagnetic sources. However, exposure to electromagnetic interference (EMI) may still result in oversensing, asynchronous pacing, ventricular inhibition, and spurious ICD discharges. EMI may also lead to loss of output, increased pacing thresholds, and decreased R-wave amplitude. Common sources of EMI include cellular phones, electronic article surveillance (antitheft) devices, and metal detectors. Occupational sources of EMI include high-voltage power lines, electrical transformers, arc welding, and electric motors. Interference can also be encountered through medical equipment and procedures such as magnetic resonance imaging, electric cautery, spinal cord stimulators, transcutaneous electric nerve stimulator units, radiofrequency catheter ablation, therapeutic diathermy, and lithotripsy.[46]

Patients with ICDs and pacemakers should be instructed to avoid environments with large magnetic fields. The use of cellular phones is permissible. However, the US Food and Drug Administration (FDA) recommends that direct contact of the phone with the device should be avoided. Use of the contralateral ear while using the phone is suggested. Although inappropriate shocks have been documented through electronic article surveillance systems, recent studies have deemed it safe for patients to walk through these systems as long as they avoid lingering around these devices. New concerns have

been raised regarding household appliances. Patients can be reassured that EMI is unlikely to affect their devices if induction ovens are used in their kitchens.[47]

The strong magnetic fields of MRI can interfere with ICD functioning and induce electrical current flow in the ICD lead that can initiate an arrhythmia or be sensed as an arrhythmia and precipitate spurious therapies. In general, patients with an ICD should not be placed in an MRI field. Ongoing work is aimed at developing MRI-compatible ICDs. There is no such problem with fluoroscopy, CT scanning, or nuclear-based imaging.

FUTURE DIRECTIONS IN ICD TECHNOLOGY

There are constant improvements being made in ICD technology. A minimally invasive, entirely subcutaneous ICD (S-ICD®) has been developed (Cameron Health Inc., San Clemente, CA). The advantages include a simplified implantation procedure, it does not require vascular access or intracardiac leads, no imaging or fluoroscopy equipment is required, and the device may be as effective as current ICD systems.[48] Potential complications such as deep venous thrombosis, intracardiac thromboses, tricuspid valve disease, as well as those related to central venous access can be eliminated. The electrode is implanted parasternally, and the ICD generator is implanted on the anterolateral chest wall. Small trials have demonstrated that this system can effectively treat ventricular fibrillation.[48] Further clinical trials are required before this technology can be routinely implanted.

SUMMARY

Expanding clinical indications, advanced new technology, and the increasing number of annual implants require Emergency Physicians to become familiar with problems typically encountered by the patient with an ICD. Complications associated with ICDs are not uncommon. Troubleshooting and programming should ideally be performed in conjunction with a trained Electrophysiologist. Patients presenting with cardiopulmonary arrest may require the device to be deactivated and external defibrillation performed. Do not apply external defibrillation paddles directly over the ICD.

36 Pericardiocentesis

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INTRODUCTION

Pericardiocentesis is the removal of fluid from the pericardial space surrounding the heart. The fluid is usually aspirated with a needle and syringe. Occasionally, a catheter is placed within the pericardium or a surgical approach is used. This may be performed for diagnosis, to obtain pericardial fluid; to relieve a pericardial effusion and improve cardiac output; or as a lifesaving measure to relieve a cardiac tamponade. **The technique is relatively simple to perform yet has a significant rate of complications.**

Since humanity's earliest times, penetrating cardiac injuries have held a dramatic place in both romantic and medical literature.[1–8] In 1649, Riolanus first described pericardial tamponade.[3] He noted that an abundance of moisture is collected therein [the pericardium], which causes suffocation, and overwhelms the heart. In 1827, Thomas Jowett described the first use of pericardiocentesis as an intervention for pericarditis.[4] In 1829, Baron Larrey, Napoleon's Surgeon, is reported to have performed the first successful pericardiocentesis.[5] By 1939, Bigger had suggested that some patients with cardiac tamponade could be managed with pericardial tubes alone, with prompt operation for recurrence.[7]

ANATOMY AND PATHOPHYSIOLOGY

ANATOMY OF THE HEART AND PERICARDIUM

The pericardium is an inverted cone-shaped sack surrounding the heart and lying on top of the diaphragm (**Figure 36-1**). The inner portion, or visceral pericardium, is a single layer of mesothelial cells covering the epicardium. The outer layer is composed of a dense outer fibrous tissue with an inner layer of mesothelial cells known as the parietal pericardium. The fibrous pericardium is attached to the central tendinous portion of the diaphragm inferiorly. Superiorly, the outer fibrous layer blends with the sheath covering the great vessels. Anteriorly, it attaches to the posterior surface of the sternum. Posteriorly, it is attached to the thoracic vertebral column, esophagus, bronchi, and aorta.

The heart is contained within the pericardial sac (**Figure 36-1B**). Numerous portions of the heart are exposed behind the anterior chest wall (**Figure 36-2**). This includes the right ventricle, left ventricle, right atrium, left atrium, aorta, pulmonary artery, and inferior vena cava (IVC). These structures are vulnerable to injury behind the anterior chest wall[9,10] (**Table 36-1**). The surface area that each of these structures contributes to the anterior cardiac silhouette is also listed in this table. These numbers reflect, roughly, the anatomic incidence of injury with cardiac trauma.[11] Traumatic injury to any of these structures can result in a pericardial effusion and cardiac tamponade.

The pericardial cavity is a potential space between the visceral and parietal layers of the pericardium. Up to 50 mL of fluid is normally contained within this space. The fluid acts as a lubricant to the motion of the heart. Accumulation of fluid in the pericardial space requiring drainage can have a variety of etiologies. From a review of several retrospective series, the estimated causes and relative frequencies of pericardial effusions are listed in **Table 36-2**.[12–18]

Cardiac tamponade is a life-threatening condition that must be diagnosed and treated emergently. The diagnosis of cardiac tamponade is primarily clinical. It may easily be overlooked unless a high index of suspicion is maintained in both medical and trauma patients. Sauer and Murdock describe a "danger zone" for penetrating torso trauma[19] (**Figure 36-3**). The superior border is bounded by a line through the sternal notch. The lateral borders are bound by a line through the midclavicle. The inferior border is identified by a line through the epigastric area. Any penetrating injury in the danger zone or through it has the potential to cause a cardiac injury and pericardial tamponade.

PATHOPHYSIOLOGY OF CARDIAC TAMPONADE

The clinical effects of cardiac tamponade occur due to accumulation of fluid under pressure in the pericardial space. This space can become quite large over time. In some chronic disease states, pericardial effusions of 1 to 2 L can occur without signs of cardiac tamponade.[14,20] **The ability of the pericardial sac to acutely stretch is limited. Estimates of the volume of fluid required to acutely accumulate and produce a cardiac tamponade range from 60 to 200 mL.**

Cardiac tamponade should always be considered as a cause of shock in the medical patient. This includes patients who are taking oral or parenteral anticoagulants, have known cancer, have known

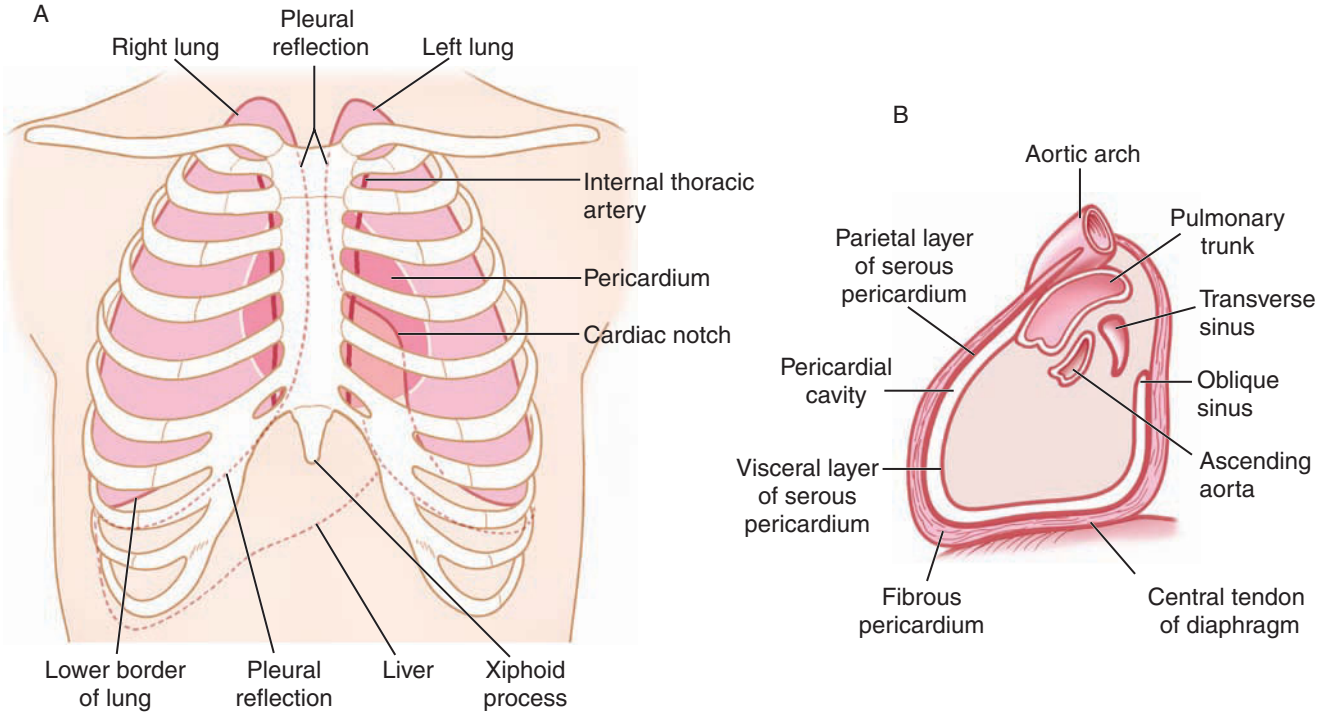


FIGURE 36-1. The pericardium. **A.** Relationship of the pericardium to the major thoracic structures. **B.** Midsagittal section through the heart and pericardium.

pericardial disease, are suspected of having an aortic dissection, or have had a recent myocardial infarction. Cardiac tamponade can also be due to iatrogenic causes, including central venous line placement, transthoracic cardiac pacing, transvenous cardiac pacing, and cardiopulmonary resuscitation.

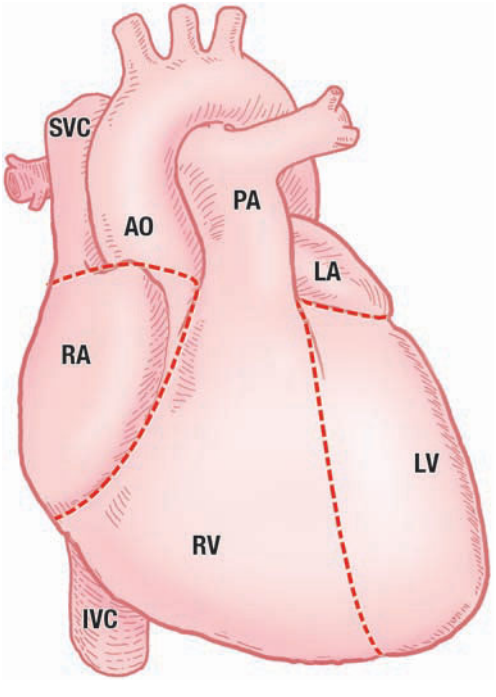


FIGURE 36-2. View of the heart and great vessels, which can become injured behind the anterior chest wall (AO, aorta; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava).

The pressure–volume relationship between the size of the pericardial effusion and the pressure imposed on the cardiac chambers is exponential. The initial accumulation of fluid produces little or no clinical effect. The initial physiologic strategies of compensation include an increase in the systemic venous pressure, catecholamine release, and tachycardia. At some point, the ability of the pericardial space to distend and accommodate more fluid is overwhelmed. From this point on, even small amounts of fluid generate significant and increasing pressure on the heart chambers. As the pericardial pressure rises, venous filling of the right heart is drastically impaired. The interventricular septum bulges into the left ventricle. Left ventricular filling becomes compromised from the lack of flow from the right ventricle and the bulging inward of the interventricular septum. Eventually, cardiac perfusion decreases, the heart suffers injury, and the patient goes into a state of shock.

A progressive decline in cardiac output occurs as pericardial fluid accumulates and intrapericardial pressure increases.[21] Initially, the right atrial pressure is greater than the intrapericardial pressure as the body compensates by increasing venous return. This is followed by the equilibration of the right atrial and intrapericardial pressures. Eventually, as the heart chambers cannot achieve a pressure lower than the surrounding pericardial fluid pressure, equilibration of

TABLE 36-1 Structures Vulnerable to Injury Behind the Anterior Chest Wall

Anatomic structure	%*
Right ventricle	55
Left ventricle	20
Right atrium	10
Left atrium	1
Aorta and pulmonary artery	10
Inferior vena cava	4

*The percentages represent the surface area of each structure and the estimates of incidence of injury with cardiac trauma.[9–11]

TABLE 36-2 The Etiologies and Relative Frequencies of Pericardial Effusions

Etiology	Relative frequency (%)
Cancer	15–40
Connective tissue diseases	2–11
Idiopathic	13–14
Infectious (including HIV)	2–14
Postpericardiotomy	2–16
Radiation therapy	4–7
Trauma	7–9
Uremia	5–10

Source: Adapted from references 12 to 18.

diastolic pressure in each heart chamber occurs and produces the greatest drop in cardiac output. As the intrapericardial pressure continues to increase, the cardiac chambers collapse, resulting in intractable hypotension and death. The disproportionate effects of the later accumulation of small amounts of fluid explain why withdrawal of even a small amount of fluid from the pericardial cavity can produce dramatic temporary improvements in the clinical status of the patient. It also explains why "monitoring" patients for the evolution of cardiac tamponade with central venous pressure lines is dangerous, as the patient will proceed from stable and compensated to profoundly unstable quite suddenly.

PATIENT EVALUATION

Several clinical findings are associated with cardiac tamponade. **Beck's triad of muffled heart sounds, hypotension, and jugular venous distention is associated with cardiac tamponade.** Almost all patients with cardiac tamponade will have at least one of these signs. **Unfortunately, very few patients with cardiac tamponade will have all three signs.** Beck's triad has been found in only up to 40% of patients with cardiac tamponade.[22] **These findings may be absent if the patient is hypovolemic due to hemorrhage.** Restlessness, fatigue, tachycardia, and tachypnea are often present. These can progress to shock, coma, and eventually death.

Changes in the jugulovenous waveforms may be seen in cardiac tamponade. Instead of the normal systolic X descent and diastolic Y descent, only the systolic X descent occurs in cardiac tamponade. This is a result of the increased diastolic pressure being exerted by the accumulating pericardial fluid. The only time the right heart can fill is during systole, when the internal volume of the heart is reduced. The changes in the jugulovenous waveforms cannot be evaluated in the supine and/or immobilized trauma patient.

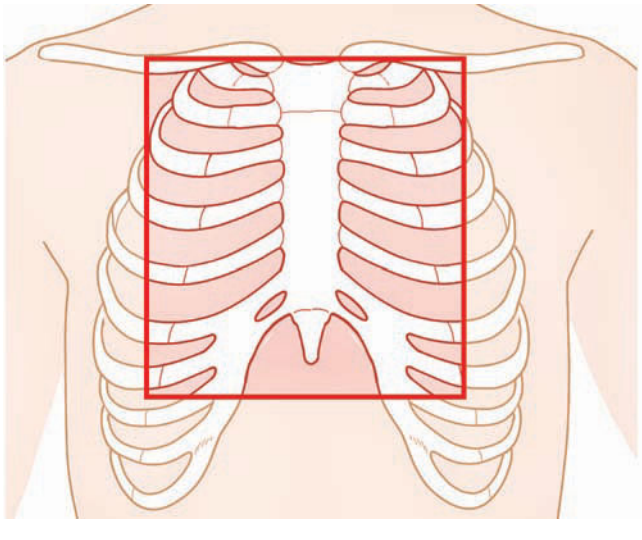


FIGURE 36-3. The "danger zone" for penetrating chest trauma.[19]

Kussmaul's two signs, paradoxical increase of the jugulovenous pressure during inspiration and pulsus paradoxus, may be seen in patients with cardiac tamponade. Pulsus paradoxus is a drop in systolic blood pressure of ≥10 mmHg during inspiration. To measure this, inflate the blood pressure cuff until the cuff pressure is greater than the patent's systolic pressure. Slowly release the cuff pressure until beats are heard only during expiration. Keep deflating the cuff pressure until beats are heard continuously in both inspiration and expiration. The difference between these two physiologic points is the amount of pulsus paradoxus. This normal physiologic finding is exaggerated by the accumulation of pericardial fluid, forcing the right heart and interventricular septum into the left ventricle.

Electrocardiographic and radiographic signs of cardiac tamponade are often not present. Changes on the electrocardiogram (ECG) may be present in patients with cardiac tamponade. A pericardial effusion surrounding the heart, if large enough, can result in a "low voltage" ECG tracing. Electrical alternans is a change in the morphology or amplitude of the QRS complexes on the ECG as the heart swings to and fro within the pericardial fluid (**Figure 36-4**). It may be associated with pericardial tamponade but is not pathognomonic. Pulseless electrical activity (PEA) in the absence of hypovolemia or a tension pneumothorax is highly suggestive of cardiac tamponade. Opinions differ as to the clinical significance of these findings. The finding of an enlarged cardiac silhouette on a chest radiograph may be useful in chronic pericardial effusions but is usually absent or nonspecific in the acute setting.

Traumatic cardiac tamponade can be caused by a variety of agents and etiologies. This includes bullets, knives, ice picks, displaced fractured ribs, central venous line placement, pacemaker insertion, pericardiocentesis, intracardiac injection, surgery, migrating pins or needles, nails ejected from machinery, and venous bullet embolization. **Cardiac tamponade is the most common presentation of penetrating cardiac injuries overall. It occurs in 80% to 90% of stab wounds and 20% of gunshot wounds.**[11]

Cardiac ultrasound has become the diagnostic procedure of choice to identify cardiac tamponade (**Table 36-3**). A prospective study showed that bedside ultrasound performed by Emergency Physicians and Trauma Surgeons was 96% accurate and 90% sensitive.[23] Cardiac ultrasonography performed on trauma patients can be 98% to 100% accurate and sensitive in diagnosing pericardial fluid and cardiac tamponade.[22,24–27] The series of 261 patients had no false negatives. Other studies have demonstrated false-negative rates in the range of 5% to 40%.[19,28,29]

Bedside ultrasound can rapidly confirm a suspected pericardial effusion or cardiac tamponade and guide drainage. Blind pericardiocentesis has a complication rate as high as 50%, and an associated mortality.[15,16,30] Ultrasound-guided pericardiocentesis can decrease the rate of complications by allowing visualization and avoidance of adjacent anatomic structures. This increased safety factor is supported by multiple studies from the cardiology literature.[31–33]

Other ultrasonographic findings in pericardial tamponade include a swinging heart, collapse of the right and left ventricular chambers, and marked inspiratory changes in ventricular dimensions.[10] Some authors advocate using transesophageal echocardiography, even in unstable patients, because of its superior imaging when compared to transthoracic echocardiography.[34] Other methods of imaging the pericardium include computed tomography (CT), helical CT, and magnetic resonance imaging. These modalities should be used only for stable patients in whom the diagnosis of a pericardial effusion and not cardiac tamponade is being considered.

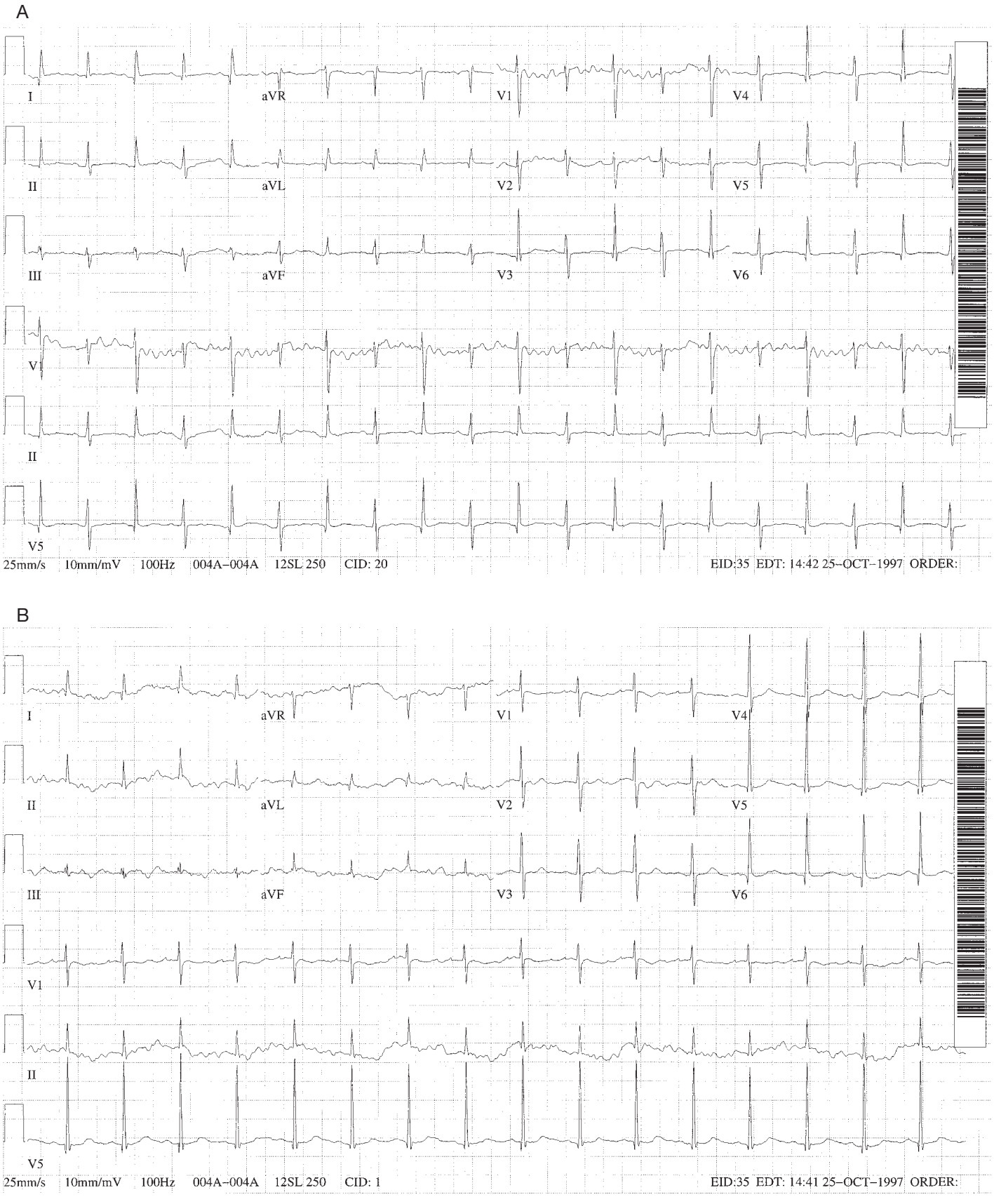


FIGURE 36-4. Electrocardiogram of electrical alternans. **A.** Initial ECG in the Emergency Department. Bedside echocardiography revealed a large pericardial effusion with right ventricular diastolic collapse. **B.** Resolution of electrical alternans after pericardiocentesis.

INDICATIONS

Significant controversy exists over the role of pericardiocentesis.[9] The only indication for emergent pericardiocentesis would be in a patient in whom the life-threatening physiologic changes of cardiac tamponade were present and the diagnosis was consistent with known prior disease, a traumatic mechanism of injury, or a bedside Emergency Department ultrasound demonstrating a pericardial effusion and/or cardiac tamponade. Pericardiocentesis is also performed in the cardiac catheterization laboratory or the intensive care unit to obtain pericardial fluid for diagnostic testing. It may also be performed in a cardiac arrest patient with PEA when other etiologies for PEA have been ruled out or a pericardial effusion is seen on ultrasonography.

CONTRAINDICATIONS

There are no absolute contraindications to performing a pericardiocentesis in the unstable patient with signs of cardiac tamponade. Uncorrected bleeding disorders in a stable medical patient would be an absolute contraindication to performing the procedure. Small, loculated, or posteriorly located effusions in a stable patient are also considered contraindications. It is also contraindicated in cardiac tamponade associated with an aortic dissection.[35]

While the dramatic beneficial effects of withdrawing even a small amount of pericardial fluid are well documented, many authors feel that there is little or no role for pericardiocentesis in the trauma patient. These authors argue that once the diagnosis of a pericardial effusion is made, the patient should receive a prompt sternotomy.[11] If the patient is too unstable for transport to the operating room, an emergent thoracotomy should be performed. Aggressive fluid replacement with crystalloid and blood products, as well as performing a needle thoracostomy (Chapter 38) to rule out a tension pneumothorax before a pericardiocentesis is contemplated in the trauma patient.[36]

EQUIPMENT

Pericardiocentesis

- Povidone iodine or chlorhexidine solution
- Sterile gloves and gown
- Face mask with eye shield or goggles
- Local anesthetic solution (1% lidocaine)
- 25 gauge needle, 5/8 in. long
- 18 gauge needle, 1½ in. long
- Syringes (10, 20, and 60 mL)
- Sterile drapes
- Towel clips
- 16 to 18 gauge spinal needle or catheter-over-the-needle, 7.5 to 12.5 cm long
- 18 to 20 gauge spinal needle or catheter-over-the-needle, 3.75 cm long
- #11 scalpel blade
- 4 × 4 gauze squares
- Alligator clips connected by a wire
- Collection basin
- ECG monitor
- J-tipped guidewire, 0.035 mm in diameter
- Size 6 to 10 French flexible multihole catheter, 5 to 6 in long, with or without a pigtail
- Three-way stopcock
- Plastic tubing
- Ultrasound machine
- 3.5 to 5.0 MHz phased-array or curvilinear ultrasound probe
- Sterile ultrasound probe cover (can be a sterile glove)
- Sterile ultrasound gel
- Variable-angle needle guide attachment if available
- Nasogastric tube

Subxiphoid Pericardial Window

- Electrocautery set
- Forceps
- Small retractor
- Small rib spreaders
- Sutures, 2-0 Vicryl and 3-0 nylon
- Sterile suction device
- Yankauer suction catheter
- Suction tubing

Most Emergency Departments do not have single guidewires and 6 to 10 French flexible catheters readily available to use for a pericardiocentesis. A commercially produced pericardiocentesis kit is available from numerous manufacturers and contains all the required equipment (e.g., Merit Medical, South Jordan, UT; Boston Scientific, Natick, MA). In an emergency situation, a 6 to 10 French single-lumen central venous line access kit may be substituted.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative if time and the patient's clinical condition permit. A signed consent is not necessary as this is an emergent procedure. If possible, place the patient semirecumbent at a 30° to 45° angle (**Figure 36-5**). This position brings the heart closer to the anterior chest wall. The supine position is an acceptable alternative. Assess the patient for any mediastinal shift by physical examination and chest radiography (if time permits). Apply the cardiac monitor, pulse oximeter, and supplemental oxygen to the patient. While the placement of an arterial line is ideal, such a line may not be available. Place the noninvasive blood pressure cuff on the patient's arm. **Insert a nasogastric tube to decompress the stomach and decrease the possibility of gastric perforation during the procedure.**

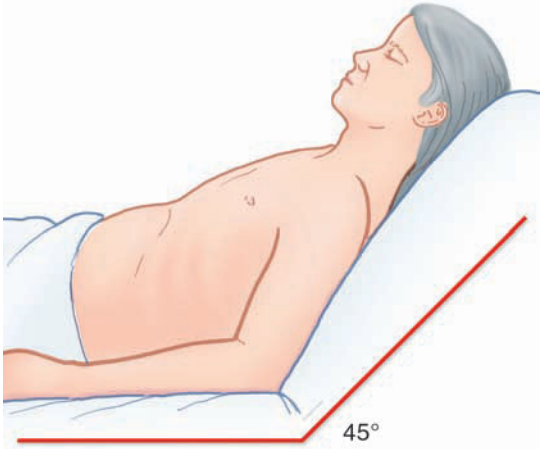


FIGURE 36-5. Ideal patient positioning for performing a pericardiocentesis.

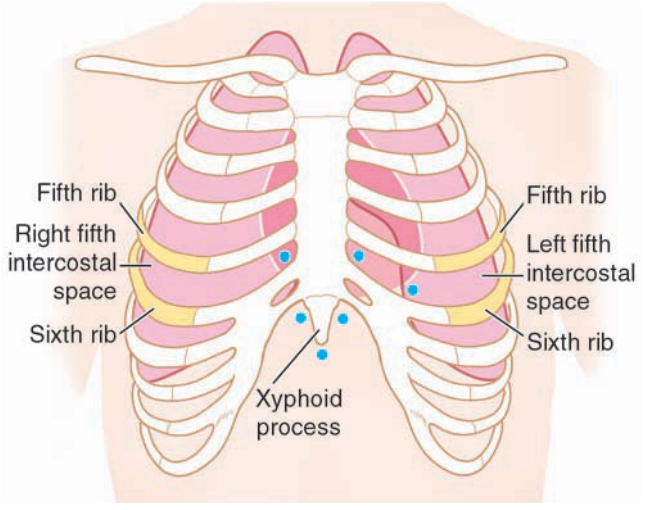


FIGURE 36-6. Potential sites to perform a pericardiocentesis.

Identify the anatomic landmarks necessary to perform this procedure. The needle can be inserted at numerous sites (**Figure 36-6**). These include the following: below the xiphoid process, at the right sternocostal margin, at the left sternocostal margin (subxiphoid approach), in the left or right fifth intercostal space parasternally (parasternal approach), or in the left fifth intercostal space at the midclavicular line (apical approach). The most commonly used site is at the left sternocostal margin or the subxiphoid approach. This is the approach described throughout the "Techniques" section of this chapter.

Surgically prepare the xiphoid and subxiphoid areas. Clean any dirt, debris, and fluid from the area. Apply povidone iodine or chlorhexidine solution to the xiphoid and subxiphoid areas and allow it to dry. Apply sterile drapes to delineate a sterile surgical field. Reidentify the anatomic landmarks. If the patient is awake, anesthetize the needle tract with local anesthetic solution. Place a subcutaneous wheal of local anesthetic solution at the site chosen to insert the needle. Inject local anesthetic solution through the skin wheal and into the subcutaneous and muscular tissues of the wall of the torso.

Prepare the equipment. Set up a sterile field on a bedside table. Open all required equipment and place it on the sterile field. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids. **While time is of the essence and this is an emergent procedure, aseptic technique should be followed.** Attach the spinal needle onto a 20 mL syringe containing 5 mL of sterile saline.

TECHNIQUES

BLIND INSERTION TECHNIQUE

Puncture the skin with a # 11 scalpel blade between the xiphoid process and the left costal margin. Grasp the syringe with the dominant hand. Insert the spinal needle through the skin incision and at a 45° angle to the midsagittal plane (**Figure 36-7A**) and at a 45° angle to the abdominal wall (**Figure 36-7B**). Aim the tip of the spinal needle toward the patient's left shoulder (**Figure 36-7A**). Alternatively, the spinal needle can be aimed toward the patient's left midclavicle, right midclavicle, or sternal notch to theoretically lessen the chance of iatrogenic damage to the coronary arteries.

Advance the spinal needle 4 to 5 cm while applying negative pressure to the syringe and observing the cardiac monitor. Inject 0.25 to 0.50 mL of saline occasionally to ensure that the needle remains patent while advancing the needle. Continue advancing the spinal needle while applying negative pressure until there is a return of blood, cardiac pulsations are felt, or an abrupt change in the ECG waveform occurs. **If the ECG waveform shows an injury pattern, withdraw the needle in 1 to 2 mm increments until the ECG pattern normalizes.** This indicates that the needle is touching or has penetrated the myocardium. Stop advancing the needle.

Aspirate with the syringe. If a large volume of blood is quickly and easily withdrawn, it often means that the tip of the spinal needle is within the ventricle. Techniques to confirm the intraventricular

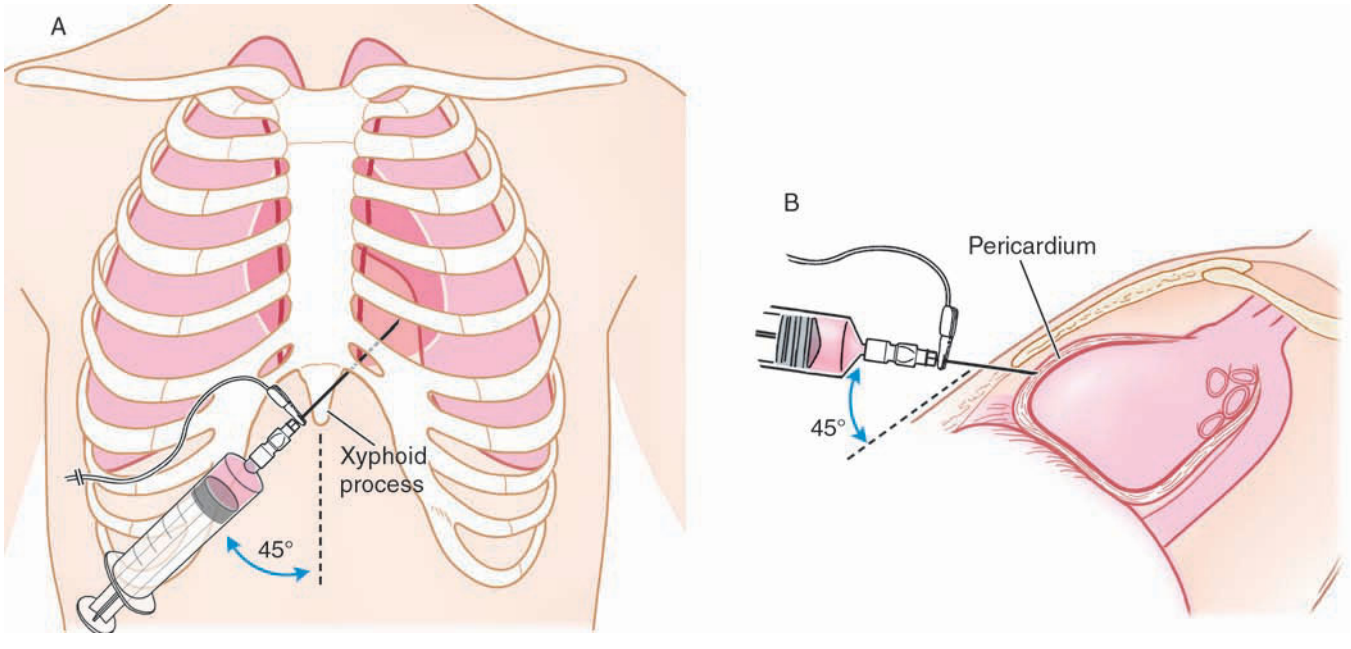


FIGURE 36-7. The subxiphoid approach. The needle is inserted at a 45° angle to the midsagittal plane (**A**) and at a 45° angle to the abdominal wall (**B**). The alligator clip attached to the spinal needle is for the ECG-monitored technique and not the blind technique.

placement of the needle tip have been described and include the following: observing that the aspirate does not form a clot, comparing the patient's hemoglobin to that of the aspirate, injecting fluorescein and looking for a fluorescent flush under the skin of the eyelids, or injecting 3 mL of dehydrocholic acid (decholin) and asking whether the patient experiences a bitter taste. These are time-consuming and less reliable than ultrasound, if available.

When the pericardial space is entered and fluid is aspirated, there should be a marked improvement in the patient's clinical status. The procedure can be terminated at this point. Alternatively, the Emergency Physician may want to withdraw as much fluid as possible. When the syringe is filled with fluid, stop withdrawing the plunger. Stabilize the spinal needle against the patient's torso and remove the syringe. Replace the syringe with a new one and continue the procedure. Alternatively, attach a three-way stopcock between the spinal needle and the syringe. Attach intravenous extension tubing to the stopcock. An assistant can open and close the stopcock while the physician aspirates fluid and ejects it through the intravenous extension tubing and into a basin. As the pericardial space is drained, the epicardium will approach the needle tip. If an injury pattern appears on the cardiac monitor, withdraw the needle slightly and continue to aspirate fluid. Remove the needle when fluid can no longer be aspirated.

ECG-MONITORED TECHNIQUE

The purpose of ECG monitoring is to prevent accidental ventricular puncture with the spinal needle. Attach one alligator clip to the base of the spinal needle and the other to the V_1 lead of the ECG machine or cardiac monitor (**Figure 36-8**). The V_1 lead will serve as an active electrode based at the tip of the spinal needle. As the spinal needle is advanced, an injury pattern noted by ST-segment elevation will be seen if the myocardium is contacted or penetrated by the spinal needle. The presence of a premature ventricular contraction or a ventricular arrhythmia can also signify contact with the myocardium.

Prepare the patient as previously described. Prepare the equipment (**Figure 36-8**). Turn on the ECG machine or cardiac monitor. Insert and advance the spinal needle, as described previously, while observing the ECG monitor or cardiac monitor. If an injury pattern or premature ventricular complexes are seen, withdraw the needle in 1 to 2 mm increments until the injury pattern disappears. Aspirate the pericardial fluid as described in the preceding section.

SELDINGER TECHNIQUE

An indwelling catheter may be placed in the pericardial cavity to drain the pericardial fluid (**Figure 36-9**). This may be done in cases of medical or traumatic pericardial effusions, since the pericardial fluid often reaccumulates. An indwelling catheter allows intermittent drainage of pericardial fluid without the potential complications associated with repeated needle sticks from a pericardiocentesis. This procedure can "buy time" if an operating room and/or a Surgeon is not immediately available to perform a pericardial window.

The technique is similar to that of placing an indwelling central venous line. Clean and prepare the patient. Insert the spinal needle, blindly or with ECG monitoring, as described in the previous sections (**Figure 36-7**). Aspirate to confirm that the tip of the spinal needle is within the pericardial cavity (**Figure 36-9A**). **It is imperative that the tip of the spinal needle be within the pericardial cavity and not within the cardiac chamber. If intracardiac placement of the needle is suspected, the position of the needle must be verified by one of the methods described in the section on "Blind insertion technique," by fluoroscopy, or using ultrasonography.**

Grasp and stabilize the spinal needle with the nondominant hand. Gently remove the syringe from the spinal needle with the dominant hand. Insert the guidewire through the needle and into the pericardial cavity (**Figure 36-9B**). Advance the guidewire until approximately one-third of its length is within the patient. Stabilize the guidewire with the nondominant hand. Remove the needle over the guidewire while leaving the guidewire within the pericardial cavity (**Figure 36-9C**).

Stabilize the guidewire with the nondominant hand. Advance the dilator over the guidewire and into the pericardial cavity (**Figure 36-9D**). **If the guidewire is within the heart, dilating a tract through the myocardium can result in cardiac tamponade and/or exsanguination. It is therefore imperative to know that the guidewire is within the pericardial cavity and not within the heart.** Remove the dilator while leaving the guidewire within the pericardial cavity. Advance the soft multihole catheter over the guidewire and into the pericardial cavity (**Figure 36-9E**). Remove the guidewire while leaving the catheter within the pericardial cavity

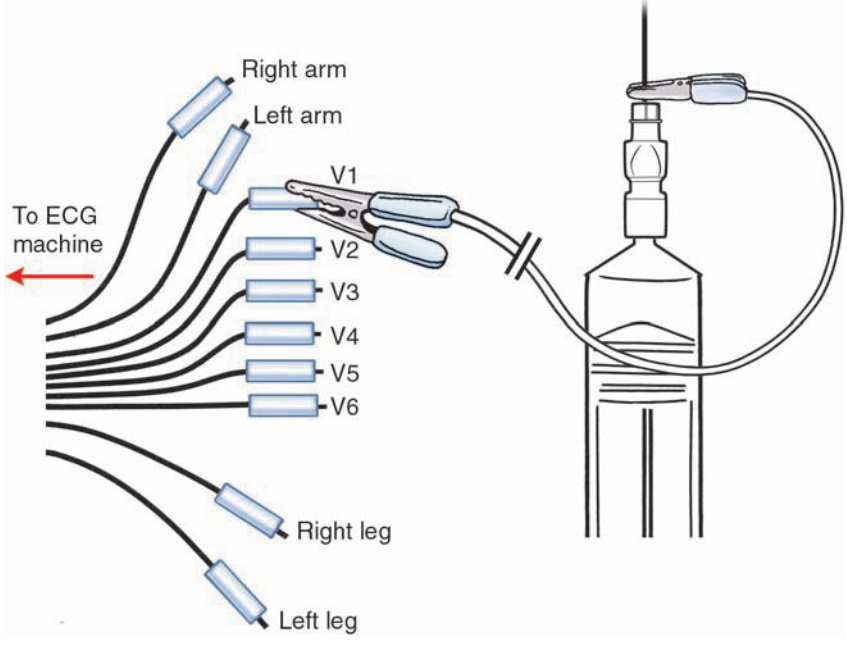


FIGURE 36-8. Equipment preparation for the ECG-monitored technique.

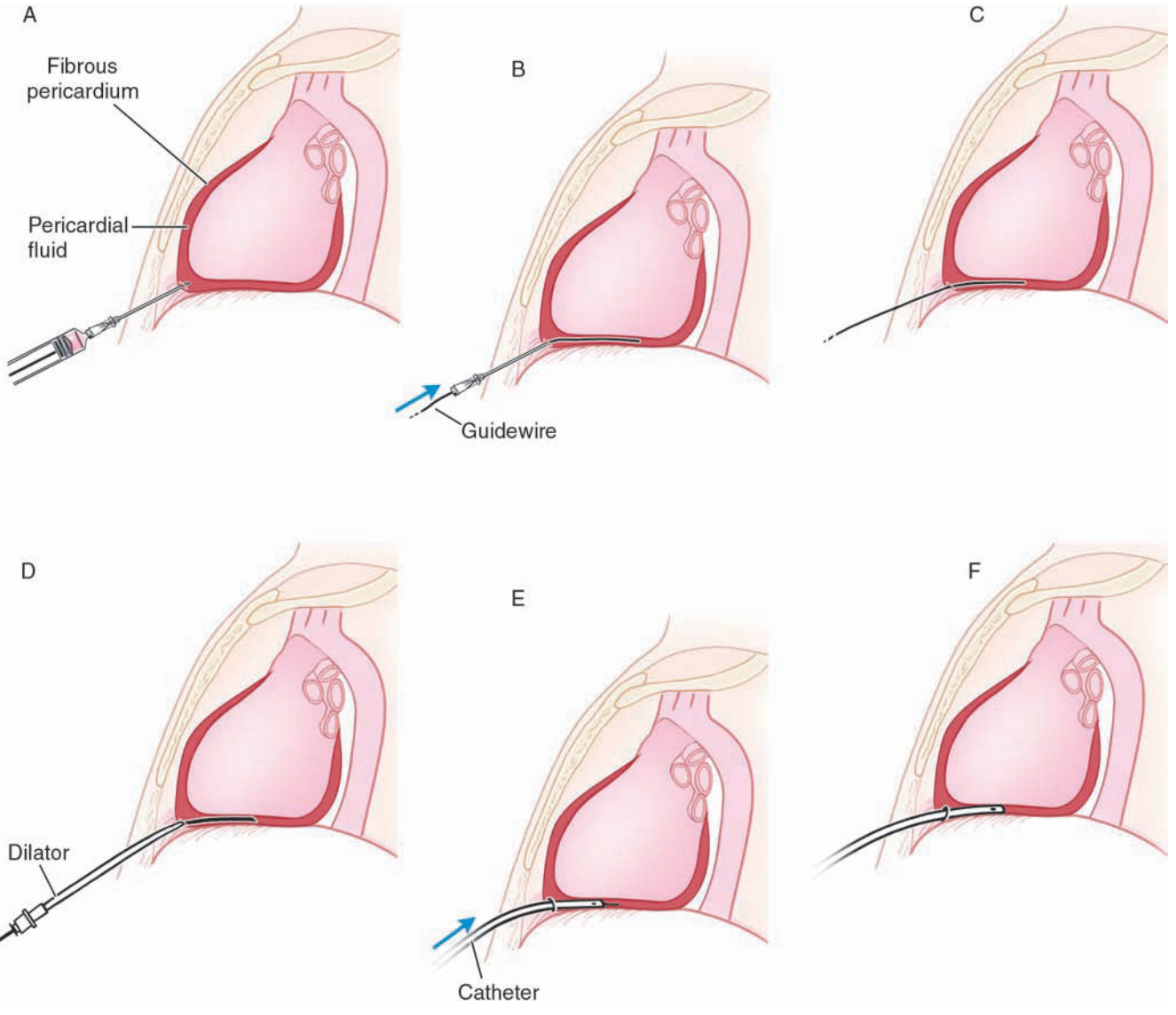


FIGURE 36-9. The Seldinger technique. **A.** The spinal needle is inserted into the pericardial space. **B.** The guidewire is inserted through the needle. **C.** The needle has been removed and the guidewire remains within the pericardial cavity. **D.** The dilator is advanced over the guidewire to dilate the needle tract. **E.** The catheter is advanced over the guidewire. **F.** The guidewire has been removed and the catheter remains within the pericardial cavity.

(**Figure 36-9F**). Secure the catheter at the skin with the nondominant hand. Attach a syringe to the catheter and aspirate pericardial fluid. This should cause a rapid improvement in the patient's clinical status. Detach the syringe and attach a three-way stopcock to the catheter.[20] Secure the catheter to the skin with nylon sutures.

ULTRASOUND-GUIDED TECHNIQUE

Many authors feel that ultrasound-guided pericardiocentesis is now the standard of care.[14,20,37,38,44] The heart is best scanned with the patient in the semierect or left lateral position if no contraindications exist. Use the 3.5 to 5.0 MHz phased-array or curvilinear ultrasound probe. Examine the heart and pericardial space in 2D and Doppler mode to determine the extent of the pericardial effusion and the area with the largest pericardial effusion.[39,40] This is usually around the apex of the heart. There are established ultrasonographic findings that help to distinguish a pericardial effusion from a cardiac tamponade (**Table 36-3**).[35]

View the heart and pericardial space using the three standard cardiac ultrasound views. These are the subxiphoid or subcostal view, the parasternal long axis view, and the apical four-chamber view. Refer

TABLE 36-3 Ultrasonographic Findings of Cardiac Tamponade

Ultrasonographic mode	Findings
Doppler	Mitral flow decreases during inspiration Mitral flow increases during expiration Tricuspid flow increases during inspiration Tricuspid flow decreases during expiration Peripheral flow decreases in expiration
M-mode color Doppler	Mitral flow decreases during inspiration Mitral flow increases during expiration Tricuspid flow increases during inspiration Tricuspid flow decreases during expiration
M-mode/2D	Diastolic collapse of the right ventricular free wall Inferior vena cava dilation Inferior vena cava does not collapse on inspiration Increase left ventricular wall thickness in diastole Left atrial collapse Left ventricular collapse Right atrial collapse Swinging heart to and fro

Source: Adapted from reference 35.



FIGURE 36-10. A phased-array probe placed in the left parasternal window adjacent to the sternum, between the second and fourth interspace. The probe marker is pointing to the patient's left hip.

to Chapter 29 for a more complete discussion on cardiac ultrasonography. Pericardial fluid is anechoic, appears black on ultrasound, and will collect in a dependent location. Thus, small pericardial effusions will be first seen in the posterior pericardium. Large pericardial effusions appear circumferential, extending around the heart.

The decision to use a parasternal (**Figure 36-10**) or an apical (**Figure 36-11**) window depends on which ultrasound views of the pericardial effusion and heart are able to be obtained. The ideal site is where the pericardial effusion is most superficial, has a large stripe or thickness, and where no other structures (e.g., lung or liver) are in the path from the skin to the heart.[33,41] The subxiphoid window (**Figures 36-12 & 36-13**) is not recommended for ultrasound-guided pericardiocentesis. This view commonly includes the left lobe of the liver in the anterior portion of the ultrasound image. Under these conditions, the needle might puncture the liver on the way into the pericardial cavity.



FIGURE 36-11. A phased-array probe placed in the apical window at the point of maximal impulse (PMI). The probe marker is pointing to the patient's right.



FIGURE 36-12. A curvilinear probe placed in the subxiphoid region. The probe is aimed toward the patient's left shoulder. The probe marker is pointing to the patient's right. Note the shallow angle required to visualize the heart.

Ultrasonographic features that suggest cardiac tamponade are noted in **Table 36-3**. This includes right ventricular diastolic collapse (**Figure 36-14**), right atrial systolic collapse, large pericardial effusion, and dilatation of the IVC. Evaluate the IVC. Place the ultrasound probe in the subxiphoid region, with the probe marker pointing toward the patient's head. The IVC runs parallel with and to the right of the aorta. Use M-mode to measure the diameter of the IVC. The normal IVC ranges from 1.5 to 2.5 cm in diameter and displays respiratory variation. In cardiac tamponade, the IVC is dilated, measuring >2.5 cm in diameter, and does not display respiratory variation.

Position the patient. Determine the location to perform the pericardiocentesis. Clean, prep, and drape the patient as described

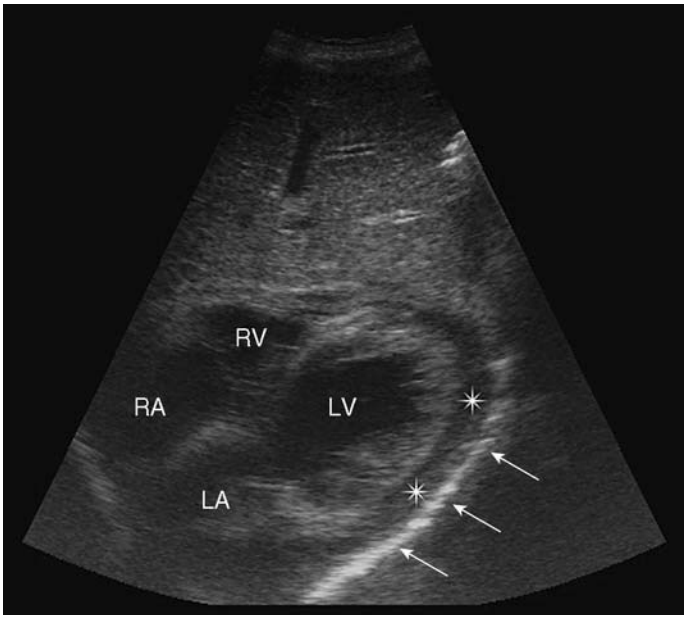


FIGURE 36-13. Subxiphoid ultrasound window demonstrating the four-chamber view (RV, right ventricle; LV, left ventricle; RA, right atrium; LA, left atrium) of a heart with a pericardial effusion (*asterisks*). The liver is noted anterior to the heart. The *arrows* point to the posterior pericardium.

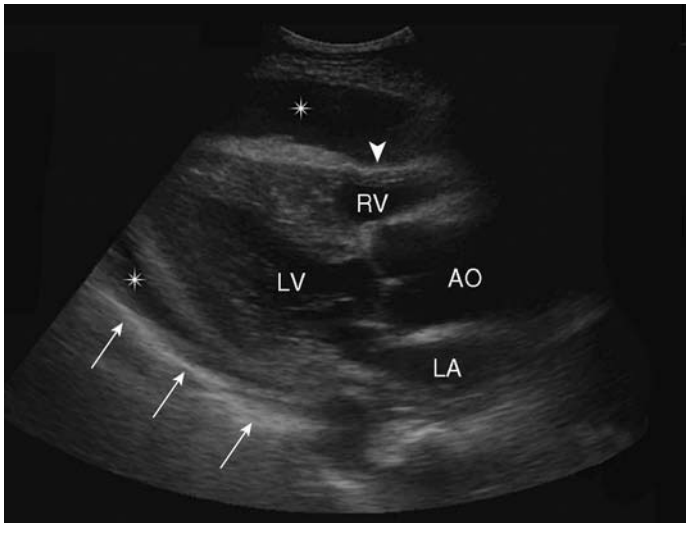


FIGURE 36-14. Pericardial tamponade with right ventricular collapse (*arrowhead*). A large pericardial effusion (*asterisks*) is visible. *Arrows* point to the posterior pericardium (RV, right ventricle; LV, left ventricle; LA, left atrium; AO, aortic root).

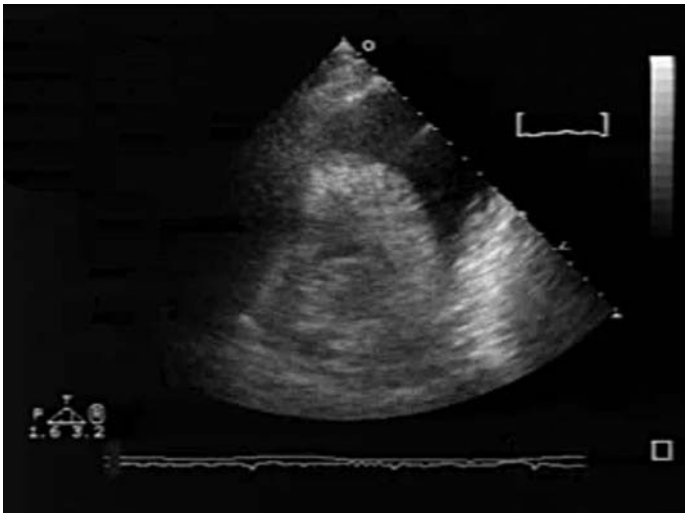


FIGURE 36-16. Needle seen entering the pericardial effusion from the right of the image (Ultrasound image courtesy of Beatrice Hoffman, MD.)

previously. Apply a sterile probe cover over the ultrasound probe. Apply sterile ultrasound gel over the prove cover. Reidentify and confirm the proper ultrasound probe position.[41] This is usually the point where the pericardial effusion is closest to the chest wall.[39,40] Insert the spinal needle under ultrasound guidance into the chest wall (**Figure 36-15**). Insert the needle over the superior border of the rib to avoid the neurovascular intercostal bundle under the inferior edge of the rib. Aspirate as the needle tip is carefully advanced under direct ultrasound visualization into the pericardial space (**Figure 36-16**).

If there is any question as to whether the needle tip is in the pericardial space, or if bloody fluid is aspirated, use agitated saline to confirm proper needle placement.[39–42,46] This requires two 5 mL syringes, one filled with sterile saline and the other filled with air. Attach the syringes to a three-way stopcock. Rapidly move the sterile saline back and forth through the two syringes, creating an aerated saline solution. Rapidly inject the aerated solution through the spinal needle. The identification of hyperechoic "bubbles" on the ultrasound image confirms the location of the needle. An alternative to this technique is to use color Doppler to localize the needle tip.[45]



FIGURE 36-15. Ultrasound probe and the pericardiocentesis needle in the apical window.

SUBXIPHOID PERICARDIAL WINDOW

A pericardial window will minimize false-negative results seen with a pericardiocentesis, iatrogenic bleeding, and cardiac tamponade from myocardial injury by the pericardiocentesis needle. Prepare the patient as previously described. Inject local anesthetic solution subcutaneously from the xiphoid process across the confluence of the lower ribs and 6 cm down the midline (**Figure 36-17A**). Inject local anesthetic solution into the muscular layers in the midline over the xiphoid process and continue approximately 8 cm inferiorly.

Make a midline longitudinal incision from the xiphisternal junction to about 8 cm below the tip of the xiphoid process (**Figure 36-17A**). Incise down to the linea alba. Bluntly dissect the space behind the xiphoid and lower sternum to separate the anterior diaphragm from the sternum. Lift the lower sternum with a retractor (**Figure 36-17B**). Use an electrocautery unit, if available, for hemostasis. Bluntly divide the fatty tissue and retrosternal attachments of the diaphragm to reveal the pericardium beneath the angle of the xiphoid and the left costal margin.[47] It will often appear blue in color due to underlying blood.

Grasp the pericardium with a forceps. Incise the pericardium with a scissors or with shallow strokes of a scalpel (**Figure 36-17B**). Fluid should rush out rapidly. Remove a piece of the pericardium to make sure that it remains open. Gently explore the pericardial space digitally and with the suction catheter to remove any clot and fluid. Allow the skin to stay open to permit free drainage of the pericardial space. Alternatively, place a 28 French chest tube in the pericardial space and secure it with a purse-string suture through the pericardium (**Figure 36-17C**). The chest tube may exit the skin incision or a separate incision in the skin. Attach the chest tube to a suction source. Close the linea alba with interrupted 2-0 Vicryl sutures. Close the subcutaneous tissue and skin with 3-0 nylon sutures.

ALTERNATIVE TECHNIQUES

CATHETER-OVER-THE-NEEDLE TECHNIQUE

A long catheter-over-the-needle mounted on a syringe may be used, if available, instead of a spinal needle mounted on a syringe. Use a

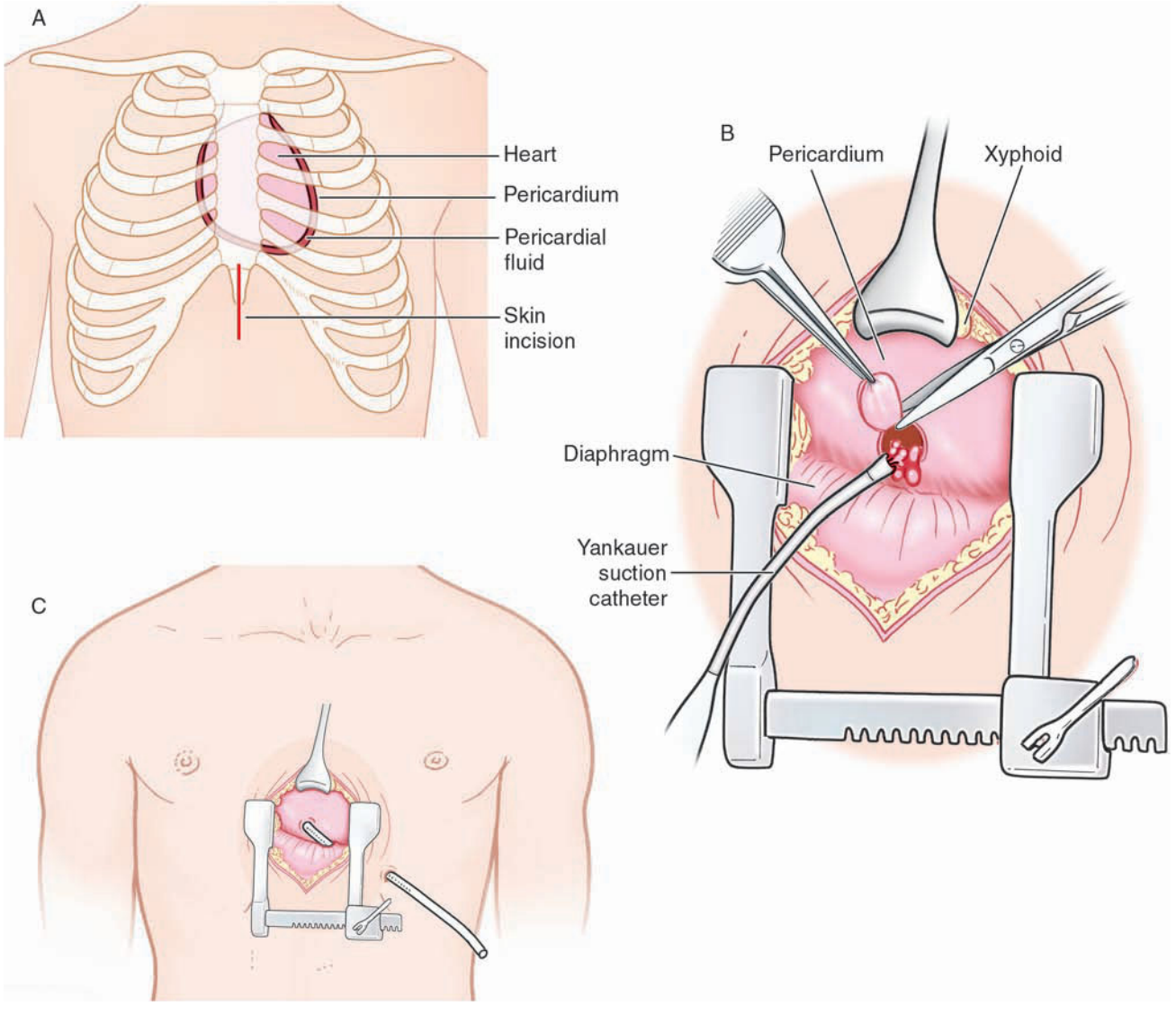


FIGURE 36-17. The pericardial window. **A.** The site of the skin incision. **B.** The xiphoid and sternum are lifted upward to expose the pericardium. An incision is made and a piece of the pericardium is removed. **C.** A chest tube is inserted into the pericardial space to allow continuous drainage of fluid.

16 to 18 gauge, 7.5 cm or longer catheter-over-the-needle for older children, adolescents, and adults. Use an 18 to 20 gauge, 3.75 cm catheter-over-the-needle for infants and small children. The procedure is the same as using a spinal needle up to the point of the needle entering the pericardial space. Stop advancing the catheter-over-the-needle once the pericardial space is entered. Securely hold the syringe so it does not move inward or pull outward. Advance the catheter over the needle and into the pericardial cavity. Continue to advance the catheter until its hub is against the skin. Securely hold the catheter hub against the skin. Remove the syringe and needle as a unit. Attach a 20 mL syringe to the catheter hub and aspirate. The remainder of the procedure is as described previously.

ALTERNATIVE APPROACHES

The subxiphoid approach is the classic or traditional approach, and has been described previously. The use of bedside ultrasonography is changing the technique to a more apical approach.[31,42] This area tends to be closer to the anterior chest wall and where the pericardial effusion is the largest; both of which make the procedure easier to perform under ultrasound guidance.

The blind technique can also be performed using the parasternal, intercostal, or periapical approaches. It was previously recommended to insert the needle perpendicular to the skin and 3 to 4 cm lateral to the sternum for the parasternal approach to avoid the internal mammary artery. Needle insertion just lateral to the sternal border will also avoid the internal mammary artery.[48] The intercostal approach should not be blindly used as it increases the risk of lung penetration by the needle and a subsequent pneumothorax. A blind apical approach is also not recommended. The lingula of the left lung and the pleural space are close to this site. A needle can puncture the lung or aspirate a pleural effusion.

ASSESSMENT

It must be emphasized that the lack of blood return does not rule out the diagnosis of cardiac tamponade. False-negative aspirations from a pericardiocentesis are well documented and are described at rates as high as 80%.[36] The occurrence of false-negative aspirations is often due to clotted blood in the pericardial space that cannot be aspirated or from failure to enter the pericardial space.

A dramatic improvement in the patient's clinical status should be observed after the successful drainage of the pericardial space. This is true even if only a small volume of 15 to 20 mL is drained. The patient's blood pressure and cardiac output should increase while intracardiac pressure and intrapericardial pressure decrease. Obtain a chest radiograph after the procedure to rule out a hemothorax and/or pneumothorax. Obtain an ECG to look for changes consistent with coronary artery injury from the needle.

A pericardiocentesis is often performed in the nontraumatic medical patient. In these cases, send the pericardial fluid for chemical, cytologic, and microbial analyses to determine the etiology of the pericardial effusion. Routine laboratory analysis should include the appearance of the fluid, a cell count and differential, glucose level, lactate dehydrogenase (LDH) level, pH, and total protein level. Cytology may reveal a malignant etiology of the effusion. The microbiology lab should perform a gram stain, acid-fast stain, aerobic and anaerobic bacteria cultures, fungal cultures, and viral cultures.

AFTERCARE

Secure the catheter with sutures to the skin and check for stability. If not already done, consult a Surgeon for definitive care of trauma patients. Prepare these patients for rapid transport to the Operating Room. Monitor patients for reaccumulation of pericardial fluid and for hemodynamic instability. If fluid reaccumulates, the procedure should be repeated or the stopcock opened (if placed) and the pericardial space reaspirated. Flush with sterile saline after each aspiration to maintain the patency of the catheter. Consult a Thoracic Surgeon if purulent fluid is aspirated in medical patients. All patients must be admitted to an intensive care unit for further monitoring, evaluation, and treatment.

COMPLICATIONS

Complication rates vary from 4% to 40%.[14,43] The complication rates of ultrasound-guided aspirations have been reported to be less than 5%.[14] Death may result from recurrence or occurrence of tamponade, bleeding, or dysrhythmias. Few if any deaths have been reported with ultrasound-guided aspirations. Reaccumulation of pericardial fluid may occur in up to 70% of blind aspirations.[14] Continuous drainage with a pericardial catheter can reduce this to 25%.[14] Bleeding, hemothorax, and/or cardiac tamponade can occur due to injury of the myocardium, coronary arteries, pericardial vasculature, or internal mammary vessels by the spinal needle. **To minimize injury, do not rock the spinal needle or change its direction once it is inserted into the patient.** A pneumothorax or pneumopericardium can form from penetration of the lung by the spinal needle. Dysrhythmias, ventricular fibrillation, ventricular tachycardia, or asystole can occur if the needle penetrates the myocardium. Hepatic damage leading to leakage of bile or blood can be seen if the needle penetrates the liver. If the patient is awake and alert, a vasovagal reaction can occur. False-negative aspirations (i.e., a dry tap) occur if the blood in the pericardial cavity is clotted or if the needle is not within the pericardial cavity. False-positive aspirations may be seen if the needle is within the heart chamber or a vascular structure.

SUMMARY

Pericardiocentesis is an infrequently performed procedure. It can be lifesaving when a patient has a pericardial tamponade. The procedure is relatively simple yet has a significant rate of complications, morbidity, and mortality. The use of bedside Emergency Department ultrasonography to assist in making the diagnosis and in guiding the placement of the pericardiocentesis needle dramatically reduces false diagnoses and complications. The exact role of pericardiocentesis in trauma remains controversial, but it may be lifesaving in the unstable patient before they are able to receive definitive surgical therapy.

37 Intracardiac Injection

Payman Sattar

INTRODUCTION

The practice of intracardiac injection originated in the 1800s. It was quite commonly performed throughout the 1960s, as it was thought to be the most expeditious route of drug delivery during a cardiac arrest.[1,2] By the mid-1970s, the practice of intracardiac injection declined. Safer and simpler routes of medication administration (i.e., intravenous, endotracheal, and intraosseous) became available. Experimental data suggested that there was no advantage to intracardiac injection over intravenous administration of medications. Cardiopulmonary resuscitation (CPR) must be interrupted to perform an intracardiac injection. In difficult patients or in inexperienced hands, the time required for this procedure may be too prolonged. Finally, many serious complications may occur as a result of an intracardiac injection.[2]

ANATOMY AND PATHOPHYSIOLOGY

The technique of intracardiac injection is similar to that of a pericardiocentesis (Chapter 36). Both techniques use the same anatomic landmarks, the same anatomic approach, and the transthoracic insertion of a needle through the pericardium. In performing a pericardiocentesis, the tip of the needle is inserted into the pericardial space. Intracardiac injection requires the tip of the needle to be inserted through the myocardium and into a cardiac chamber. Echocardiography or bedside ultrasound may be useful in pericardiocentesis to avoid the lung or myocardium.

Time is of the essence when performing an intracardiac injection. Since the objective is to quickly enter the myocardial cavity, ultrasonographic guidance is generally not necessary. Keeping this in mind, certain situations such as COPD, a prior lung resection, or dextrocardia may benefit from ultrasonographic guidance to avoid puncturing the lung.

The technique of intracardiac injection is easy to teach, is rapid and simple to perform, and requires no special equipment. It begins with identification of the anatomic landmarks required to perform the procedure (**Figure 37-1**). For the subxiphoid approach, identify and palpate the xiphoid process of the sternum and the left costosternal angle. For the left parasternal approach, identify and palpate the left fourth or fifth intercostal spaces immediately adjacent to the sternum.

INDICATIONS

The primary indication for an intracardiac injection is when vascular access is not readily available or unobtainable in a patient with asystole, pulseless electrical activity, pulseless ventricular tachycardia, or ventricular fibrillation. The intracardiac injection of resuscitative medications may be warranted and can be attempted as a last effort to resuscitate the patient if other routes of medication administration have failed.

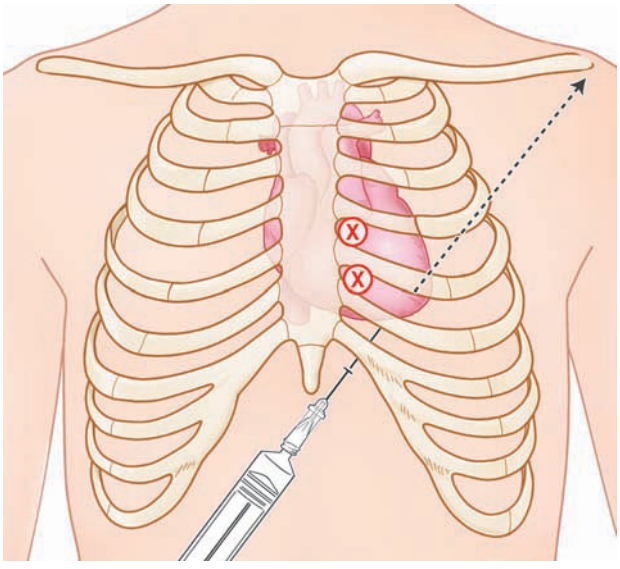


FIGURE 37-1. Intracardiac injection. The needle is inserted 1 cm to the left of the xiphoid process and aimed toward the left shoulder. The needle may also be inserted parasternally in the left fourth or fifth intercostal space (as denoted by the symbol "⊗").

CONTRAINDICATIONS

As candidates for this route of medicinal delivery have undergone a cardiac arrest, there are no absolute or relative contraindications to performing this procedure. A few clinical conditions may make the procedure more difficult to perform. Chronic obstructive pulmonary disease can shift the heart from its normal position and increase the risk of a pneumothorax (with or without tension). Therapeutic or overanticoagulation may result in a hemopericardium and cardiac tamponade. Dextrocardia requires identification of different anatomic landmarks and alterations in needle positioning.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- 18 gauge spinal needle or 18 gauge 3½ in. needle (for adults)
- 22 gauge spinal needle (for children)
- Syringes, 5 and 10 mL
- Nasogastric tube
- Epinephrine, 1:1000 and 1:10,000

Epinephrine is the only resuscitative medication that should be administered by intracardiac injection. Administer 1 mg of epinephrine as the initial and subsequent doses in an adult patient. Administer 0.01 mg/kg (or 0.1 mL/kg) of the 1:10,000 concentration of epinephrine as the initial dose in children. Administer 0.1 to 0.2 mg/kg (or 0.1 to 0.2 mL/kg) of the 1:1000 concentration of epinephrine for subsequent doses in children.

PATIENT PREPARATION

This procedure is often performed on a patient who is clinically "dead" and as a last effort at resuscitation. An informed consent is not required to perform this procedure. The patient will be supine with CPR in progress. If time permits, insert a nasogastric tube to decompress the stomach. Apply povidone iodine or chlorhexidine solution to the area around the lower sternum, xiphoid process of the sternum, upper epigastric, and left costosternal angles. Identify, by palpation, the anatomic landmarks required to perform the procedure. Draw up the required dose of epinephrine into a syringe or use prefilled syringes. Attach a spinal needle to the syringe containing the epinephrine.

TECHNIQUES

The two routes for intracardiac injection are the subxiphoid and left parasternal approaches (**Figure 37-1**). Both are utilized in a similar fashion. The left parasternal approach offers a more direct and shorter route. However, it is associated with a higher rate of complications. Both approaches require cessation of CPR in order to perform the procedure. **The procedure of intracardiac injection should be performed as rapidly as possible to avoid prolonged cessation of CPR, but not at the expense of safety to the Emergency Physician, Nurses, and ancillary staff.** It should take less than 10 seconds to perform an intracardiac injection.

SUBXIPHOID APPROACH

Stop performing CPR. Stop ventilating the patient and allow the lungs to passively deflate. Identify the spot 1 cm to the left of the patient's xiphoid process in the costosternal angle (**Figure 37-1**). Insert the needle with the bevel up, at a 30° to 45° angle to the skin of the abdominal wall, and aimed toward the patients left shoulder. Advance the needle while applying negative pressure to the syringe. Stop advancing the needle when blood flows freely into the syringe. This signifies that the tip of the needle is within the cardiac chamber. Quickly inject the epinephrine, then withdraw the needle. Resume CPR and ventilation of the patient.

If the attempt at intracardiac injection is unsuccessful, the needle should be withdrawn and flushed and intracardiac injection reattempted. The needle can become plugged with subcutaneous fat. **CPR and ventilation must be resumed after each attempt at intracardiac injection, whether successful or not.** Variations on the direction of the needle can be made for subsequent attempts. The needle may be directed toward the suprasternal notch, left midclavicle, or right midclavicle.

As an alternative, the spinal needle can be inserted through the skin and into the subcutaneous tissue with its obturator in place. Remove the obturator when the tip of the spinal needle is in the subcutaneous tissue. Attach the syringe containing epinephrine to the spinal needle. Gently depress the plunger of the syringe to expel the air within the needle into the subcutaneous tissues. Advance the needle while applying negative pressure. Stop advancing the needle when blood flows freely into the syringe. Quickly inject the epinephrine, and withdraw the needle. Resume CPR and ventilation of the patient.

LEFT PARASTERNAL APPROACH

This approach utilizes the fourth or fifth intercostal space, approximately 1 cm (or 1 finger breadth) lateral to the left sternal border (**Figure 37-1**). Stop performing CPR. Stop ventilating the patient and allow the lungs to passively deflate. Insert the needle perpendicular to the chest wall. Stabilize the needle with one hand and the syringe with the other. **Advance the needle with both hands and without excessive force.**[3] It is very easy to plunge into the heart if too much force is applied to the needle. Apply negative pressure to the syringe as it is advanced. Stop advancing the needle when blood flows freely into the syringe. Quickly inject the epinephrine, then withdraw the needle. Resume CPR and ventilation of the patient.

INFANTS AND CHILDREN

The technique of intracardiac injection for infants and children is essentially the same as that described above for the adult patient.[4]

While the subxiphoid approach has been "adopted as the standard," the left parasternal approach can also be effectively utilized. Use a 22 gauge spinal needle for infants and children. **Use caution when inserting and advancing the spinal needle since the pediatric skin and subcutaneous tissue are thin and easily penetrated.** The dose of epinephrine administered is weight-based and varies from the initial dose to subsequent doses (see the "Equipment," section, for discussion).

COMPLICATIONS

Overall, according to pooled data, complications are rare.[2,5–7] A pneumothorax is the most common complication, especially with the parasternal approach. Other reported complications include coronary artery laceration, myocardial laceration, hemopericardium, cardiac tamponade, pulmonary artery laceration, and perforation of the stomach or liver. Intramyocardial injection has been reported and is associated with intractable ventricular fibrillation. **Identification of the appropriate anatomic landmarks for needle insertion and direction can minimize complications. Careful adherence to proper technique can also minimize complications.** The use of a small-gauge spinal needle and the subxiphoid approach may result in fewer complications versus a large-gauge needle and the left parasternal approach.[8]

SUMMARY

Although intracardiac injection is an effective route of medication delivery to a patient in cardiac arrest, its popularity has declined due to safer, simpler, and more effective methods of vascular access. When intravenous access is not readily accessible or when the endotracheal administration has not provided the desired effect, intracardiac injection should be considered as an alternative technique. It is important not to permit prolonged cessation of CPR during the procedure.

38 Needle Thoracostomy

Eric F. Reichman and Elizabeth Sowell

INTRODUCTION

A tension pneumothorax is a unilateral progressive collection of air in the pleural space. If not treated, it results in increasing intrapleural pressures, shifting of intrathoracic structures, hypoxemia, and death. It occurs from a one-way air leak into the pleural cavity from the airway conduits, the lung, or the thoracic wall. The air leak causes air to enter the pleural cavity and become trapped, without a method of egress. Rapid decompression of the tension pneumothorax with a catheter-over-the-needle is known as a needle thoracostomy and can be lifesaving.

A tension pneumothorax is an immediate life-threatening condition that requires prompt recognition and treatment to prevent the patient's imminent demise. The diagnosis must be suspected based upon the patient's prior medical history, the mechanism of injury, physical examination findings, and a patient in extremis. **Importantly, treatment must not be delayed to obtain further diagnostic testing (e.g., chest radiograph).** These patients most often present with acute and dramatic cardiopulmonary compromise, which may be manifest by a combination of the following signs and symptoms: respiratory distress, chest pain, air hunger, hypotension, tachycardia, diaphoresis, unilateral absence of or decrease in breath sounds, hyperresonance to percussion, increased central venous pressure, hypoxemia, cyanosis, deviation of the cardiac point of maximal impulse, and tracheal deviation.

ANATOMY AND PATHOPHYSIOLOGY

The most common cause of a tension pneumothorax is mechanical ventilation with positive pressure in a patient with a visceral pleural injury.[1] A tension pneumothorax is present in 50% of ventilator-associated pneumothoraces.[2] When this occurs in intensive care unit (ICU) patients, they often have minimal functional reserve. To further cloud the issue, they are frequently on other supports (i.e., inotropic agents, complex ventilator settings, etc.), making their physical examination difficult and confusing. They may also have a number of other coexisting factors that are making them unstable. This group of patients has a particularly disastrous course if a tension pneumothorax develops. Rapid diagnosis and treatment are imperative.[3]

The placement of a central venous catheter has been associated with the development of a pneumothorax. The incidence of this is approximately 3% to 6% with use of the subclavian approach. A tension pneumothorax may be delayed in approximately 0.4% of attempts to gain central venous access. In one case report, a patient developed a tension pneumothorax while under general anesthesia 10 days after the placement of a subclavian central venous line.[4]

A tension pneumothorax may also occur in the setting of blunt or penetrating trauma of the lung. It may occur uncommonly following a tracheobronchial or esophageal injury. It may complicate a simple pneumothorax if the parenchymal lung leak does not seal spontaneously. In this case, the site of the lung injury acts as a one-way valve, allowing air entry into the pleural space and not allowing it to escape. Occasionally, chest wall defects may result in a tension pneumothorax if the wound is completely covered by an occlusive dressing or if the wound itself acts as a ball-valve mechanism. More rarely, it may occur following markedly displaced fractures of the thoracic spine. In the past, based on studies using the canine model, the pathophysiology of this disease was considered to be associated primarily with a mechanical pressure-related phenomenon.[5] Air accumulated in the involved pleural space and caused an increasing intrapleural pressure. This pressure caused compression of the ipsilateral lung, displacement of the diaphragm caudally, movement of the mediastinum and heart toward the uninjured side, kinking of the great vessels, and compression of the contralateral lung. This anatomic shift of structures would result in impaired filling of the heart and a disastrous fall in cardiac output.[6] Unfortunately, the canine model is not as similar to the human as was once thought. The mediastinum in the dog is more mobile. It is fenestrated, so that air communicates from one hemithorax to the other. Therefore, elevations of intrapleural pressure in dogs would affect central structures and cause cardiovascular compromise more readily than in humans.

Recently, this pressure-related mechanism has come into question as the primary event. Experiments have been performed in goats, monkeys, sheep, and swine; all of which have a mediastinum that is more similar to that of the human than the dog.[7–10] These studies support the hypothesis that central hypoxemia is the primary factor in the lethality of a tension pneumothorax and occurs prior to the development of significant hypotension. In this hypothesis, the mechanical pressure-related phenomenon is a late event.

These mechanisms become more confusing and mixed in the ventilator-dependent patient. There is a lack of studies documenting hemodynamic changes in the human subject with a tension pneumothorax.[11–14] In one case report, three ventilated ICU patients demonstrated decreased cardiac output as the first sign of a tension pneumothorax.[12] The authors proposed that the absence of spontaneous breathing did not allow increased variations in negative

intrathoracic pressure to act as a compensatory mechanism to prevent hemodynamic compromise. In another similar case, decreased cardiac output and mixed venous oxygen saturation were the dominant signs of a tension pneumothorax.[13] Hemoglobin desaturation via pulse oximetry was shown to be the earliest sign in a ventilator-dependent patient with a tension pneumothorax.[14]

Electrocardiographic (ECG) changes may be seen in association with a tension pneumothorax. In a left-sided tension pneumothorax, the more commonly described ECG changes are a rightward shift of the mean frontal QRS axis, precordial T-wave inversions, reduced R-wave voltage, and decreased and/or alternating QRS amplitude.[15–17] Other unique changes include PR-segment elevation in the inferior leads and reciprocal PR-segment depression in lead aVR.[18] A case report cited transient bradycardia, hypotension, and precordial ST-segment elevation; all of which reversed after treatment of a right-sided tension pneumothorax.[19]

Numerous mechanisms have been proposed as the causes of these ECG changes. They include simple displacement of the heart, rotation of the heart around its anteroposterior or longitudinal axis, transient hypoxia, changes in coronary artery blood flow, changes in pleural pressure, pulmonary resistance, pericardial tension, acute ventricular dilatation, alterations in ventricular repolarization, pressure-induced atrial injury, and insulation of the chest wall from the associated air.[15–20] The vast majority of ECG changes have been noted with left-sided rather than right-sided tension pneumothoraces. **The degree of pneumothorax and the severity of symptoms do not seem to correlate with the magnitude of the ECG abnormalities. In summary, ECG changes are not uncommon in tension pneumothorax and should not distract from the true diagnosis.**

INDICATIONS

A tension pneumothorax must be considered in the differential diagnosis of any patient in extremis. If it is a possible etiology for the patient's cardiopulmonary collapse, needle decompression should be performed without delay. In every circumstance, and especially in the emergent setting, one may not be able to be 100% certain of the diagnosis. However, needle decompression is a relatively low-risk procedure with great lifesaving potential.

One setting that may be particularly confusing is in the dying patient with left precordial penetrating trauma. The immediate differential would be tension pneumothorax versus pericardial tamponade versus massive hemothorax. Physical examination findings are usually helpful but may also be confusing, mixed, or difficult to elicit in a chaotic and noisy resuscitation. **Needle decompression should be the first maneuver in this situation.** It may be lifesaving and will aid in the diagnosis. It is less invasive, quicker, and easier to perform than a pericardiocentesis or a thoracotomy. A tension pneumothorax is more common than pericardial tamponade in this setting. As for a massive hemothorax, a chest tube setup requires some time but should be requested at the time needle decompression is proceeding.

CONTRAINDICATIONS

There are no absolute contraindications to performing a needle thoracostomy to decompress a tension pneumothorax. It is imperative to identify the anatomic landmarks properly and perform this procedure carefully if the patient has a known or suspected coagulopathy.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- 12 to 16 gauge catheter-over-the-needle, 4.5 cm in length
- 5 or 10 mL syringe
- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Ultrasound machine (optional)
- Low frequency (2-5 MHz) ultrasound probe
- Sterile ultrasound probe cover
- Sterile ultrasound gel

PATIENT PREPARATION

Briefly describe the procedure to the patient if they are competent, able to understand, and cooperative. Place the patient supine. Some Emergency Physicians place the patient supine with the head of the bed elevated to 30°. This will allow the air to rise to the anterior upper chest. Unfortunately, this is not the most functional position. It is from the supine position that the patient can most easily be accessed and controlled by the greatest number of practitioners. The supine position is optimal to allow for other lifesaving maneuvers (e.g., airway management, cardiopulmonary resuscitation, etc.). Clean the skin of any dirt and debris in the area of the procedure. Apply povidone iodine or chlorhexidine to the skin.

Simultaneous with the performance of this procedure, other interventions should be requested: 100% face-mask oxygen (if the patient is not already intubated), pulse oximetry, cardiac monitoring, chest tube setup, intravenous access, and STAT chest radiography. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids. **While time is of the essence and this is an emergent procedure, aseptic technique should be followed.**

TECHNIQUE

The safest, easiest, and most reliable site for a needle thoracostomy to decompress a tension pneumothorax is the second intercostal space in the midclavicular line[1,2,6,21] (**Figure 38-1**). Apply a 12, 14, or 16 gauge catheter-over-the-needle onto a 5 or 10 mL syringe without the plunger. Identify the second intercostal space in the midclavicular line. Place the nondominant index finger over the needle insertion site. Grasp the syringe with the dominant hand. Insert the catheter-over-the-needle perpendicular to the skin and just above the superior border of the third rib (**Figure 38-2A**). This will avoid injury to the neurovascular bundle underlying the inferior

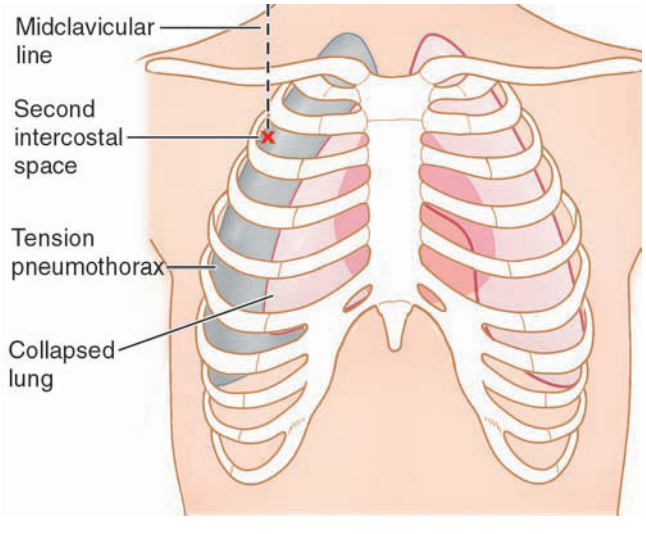


FIGURE 38-1. A right-sided tension pneumothorax. The preferred site for a needle thoracostomy is the second intercostal space in the midclavicular line.

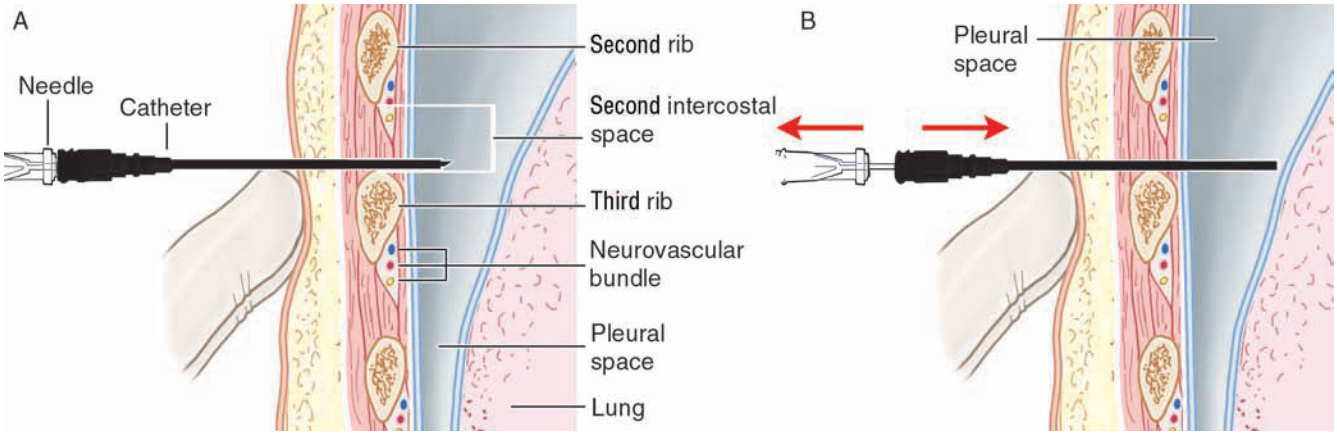


FIGURE 38-2. Decompression of a tension pneumothorax with a catheter-over-the-needle. **A.** The catheter-over-the-needle is inserted through the second intercostal space and into the pleural cavity. **B.** The catheter is advanced and the needle is removed.

border of the second rib. Some Emergency Physicians prefer to contact the upper portion of the third rib with the tip of the needle, walk it up the rib until it goes over the edge, and then advance it into the pleural space.

Advance the catheter-over-the-needle until a loss of resistance is felt as the tip of the needle penetrates the pleural space. A rush of air, with or without blood, will be heard escaping from the syringe. Stop advancing the catheter-over-the-needle. Advance the catheter until the hub is against the skin while simultaneously withdrawing the needle (**Figure 38-2B**).

ALTERNATIVE TECHNIQUES

Other sites have been described for performing a needle thoracostomy. These include the fourth or fifth intercostal space in the midaxillary line or the second intercostal space in the anterior axillary line.[22–25] There are several problems with these alternative sites. In the fourth or fifth intercostal space, the ribs are close together, with narrower interspaces making needle placement more difficult. There is more rib motion with breathing and arm movement can make catheter dislodgment more likely. In the supine patient, air will rise ventrally rather than laterally. Practically speaking, during the resuscitation of the unstable patient, the most important position for the Emergency Physician is at the patient's head. Insertion of a catheter in the second intercostal space in the midclavicular line is easier from this position than inserting a laterally placed catheter. The fourth or fifth intercostal space in the midaxillary line is the ideal space for a chest tube. Placement of the catheter in these alternative sites would mean having to penetrate more tissue, especially in the obese patient, making reaching the pleural space more difficult, and dislodgment of the catheter more likely. The major drawback to using the fourth or fifth intercostal space is the risk of inserting the catheter-over-the-needle below the diaphragm and into the liver (on the right) or the spleen (on the left).

If the first attempt at needle thoracostomy fails to decompress the pleural space, ultrasound can be used to measure chest wall thickness in order to determine the appropriate needle length and to confirm the presence or absence of a pneumothorax. Subcutaneous fat and tissue can be differentiated from air in the pleural space by the presence of the pleura seen deep to the pneumothorax and represented by a bright white line along with the absence of "lung slide."

If the patient is in extremis, a definitive chest tube should not be the primary therapy for a tension pneumothorax. The setup and performance of a tube thoracostomy take much longer than rapid decompression with a catheter-over-the-needle.

HANGING DROP TEST

A novel idea has been proposed to use the "hanging drop" test to identify the pleural space and determine if a tension pneumothorax is present.[26] It is quick, easy to perform, and uses supplies readily available in the Emergency Department. Be aware that gathering the supplies and performing this test can take a few minutes, thus delaying the needle decompression.

Using strict aseptic technique, insert a 4.5 cm long spinal needle into the second intercostal space in the midclavicular line and advance it until the tip is touching the upper border of the third rib. Remove the trocar. Place one to two drops of sterile saline or sterile water into the hub of the spinal needle. The fluid bubble will be elevated above the needle hub. Gently walk the needle up and over the edge of the third rib. Slowly advance the needle through the intercostal tissues while observing the fluid bubble. The negative intrathoracic pressure will suck the fluid bubble into the chest of there is no tension pneumothorax. The fluid bubble will be pushed out of the hub if a tension pneumothorax is present.

The author suggests using a spinal-type needle.[26] This cannot be recommended for two reasons. First, if a tension pneumothorax is present, the sharp needle should not be advanced or left in the pleural cavity to relieve a tension pneumothorax. It can puncture an organ or blood vessel. Second, the spinal needle would have to be removed and the procedure repeated with a catheter-over-the-needle. Consider using a catheter-over-the-needle to perform this procedure to avoid these issues.

PEDIATRIC CONSIDERATIONS

The basic technique is the same in pediatric patients. Use a smaller length and gauge catheter-over-the-needle in pediatric patients. A 20 or 22 gauge, 1 inch (in) or 2.5 cm catheter-over-the-needle should be used in preterm children and neonates. This same size can also be used in children up to approximately 1 to 2 years of age. Between the approximate ages of 2 and 6 years, consider using an 18 or 20 gauge, 1.5 in or 3.75 cm long catheter-over-the-needle. Over the age of 6 and into early adolescence, consider using a 16 or 18 gauge, 4.5 cm long catheter-over-the-needle. Use the adult size catheter-over-the-needle for older adolescents or obese children. These are just general recommendations. The individual child's size and body habitus need to be taken into consideration when choosing a catheter-over-the-needle size and length.

Some Physicians prefer to use a butterfly needle with attached tubing instead of a catheter-over-the-needle in preterm children,

neonates, and up to the first year of life. Select a butterfly needle size as described above. Place sterile water or sterile saline in a sterile specimen cup. Insert the distal hub end of the butterfly tubing into the bottom of the specimen container and submerged in the liquid. Tape the tubing onto the rim of the specimen container to secure it and ensure it does not pull out of the liquid in the specimen container. Insert the butterfly needle into the pleural space as described above. Air bubbles will move through the tubing and into the sterile liquid as the tension pneumothorax is decompressed. The specimen container also forms a water seal, preventing ingress of air into the pleural space, until a tube thoracostomy can be performed.

ASSESSMENT

Once the catheter has been placed into the pleural space, a gush of air should rush out of the syringe. **The procedure will have converted a tension pneumothorax into a simple pneumothorax requiring a tube thoracostomy.** The patient should improve hemodynamically and symptomatically. Saturations on pulse oximetry should rise after the decompression. If this does not occur, too short of a catheter-over-the-needle may have been used and the procedure should be repeated with a longer one. If a longer catheter-over-the-needle is not available, rapidly perform a tube thoracostomy. The other possibility is that the pleural space was entered appropriately but the diagnosis was incorrect. In this event, another cause of the patient's shock state should be sought and consideration should be given to "prophylactic" chest tube placement. This may prevent later sequelae from the iatrogenic catheter stab wound to the chest and simplify the further workup and monitoring of this unstable patient.

AFTERCARE

After insertion of the catheter and improvement in the patient's clinical status, the immediate life threat has been treated. Secure the catheter against the skin with a suture or an assistant holding it in place. **Continue to observe and monitor the patient closely for recurrence of the tension pneumothorax and procedural complications.** Establish intravenous access, cardiac monitoring, and pulse oximetry if not already done. Obtain baseline laboratory studies, an arterial blood gas, and a chest radiograph. Obtain a thorough history and physical examination to search for the etiology of the tension pneumothorax. **A definitive chest tube should be placed using sterile technique to prevent recurrence of the tension pneumothorax and to treat the simple pneumothorax.** Refer to Chapter 39 for the complete details regarding the placement of a chest tube. After a chest tube is inserted, remove the needle thoracostomy catheter and place a simple bandage over the puncture site.

COMPLICATIONS

An incorrect diagnosis of a tension pneumothorax in an unstable patient is always a possibility, even in the best of hands. If this is the case, the cause of the patient's shock state must still be aggressively sought and treated. A prophylactic chest tube should be considered for a presumed parenchymal lung injury and potential pneumothorax from the needle thoracostomy.[27–29] This is especially true if the patient is going to be transported out of the resuscitation area, will be given a general anesthetic, or is to be placed on positive-pressure ventilation.

Failure to reach and decompress the pleural space is the major argument against the use of needle thoracostomy. Depending on the patient's body habitus and the catheter length, the pleural space may not have been reached to be decompressed. In an initial study from the UK, the chest wall thickness was estimated to range from 1.3 to 5.2 cm by ultrasound in the second intercostal space.[30] A 3.0 cm cannula would fail to penetrate into the pleural cavity in 57% of the patients in this study. A 4.5 cm cannula would fail to penetrate into the pleural cavity in 4% of the patients. In this case, the procedure should be repeated with a longer catheter-over-the-needle. If one is not immediately available, a tube thoracostomy should be performed immediately.

Several studies have evaluated chest wall thickness using ultrasound and computed tomography (CT) scans in order to determine the needle length required to appropriately decompress the pleural space in the general adult population. Initial studies using ultrasound seemed to indicate that using needle lengths of 4.5 cm would be sufficient to reach the pleural space in most patients.[30] More recent studies using CT have shown that chest wall thickness varies significantly by gender and age. A study by Zengerink et al. found that chest wall thickness was greater than 4.5 cm 10% of the time in men younger than 40 and 19% of the time in men older than 40 years of age.[31] The same study found almost one-third of women less than 40 years had a chest wall thickness greater than 4.5 cm, falling to one-fourth for those over 40. Harcke et al. found a mean chest wall thickness of 5.36 cm in autopsy CT scan studies.[34] They recommended a 3.25 in or 8 cm long catheter-over-the-needle be used. It is important to note these variations. However, most authors still advocate a needle length of 4.5 cm as longer needle lengths increase the risk of vascular, pulmonary, or cardiac injury.

The second intercostal space in the midclavicular line is the recommended location for a needle thoracostomy. A prospective study of needle thoracostomy sites found that a more medial placement was often used.[35] A needle thoracostomy insertion point not in the midclavicular line is more likely to be associated with vascular injury and hemorrhage. This includes injury to the internal mammary artery medially, subclavian vessels superiorly, and the pulmonary trunk and heart inferiorly.

After the initial effective decompression of a tension pneumothorax, the catheter may become dislodged, clotted, kinked, or its tip may retract from the pleural space into the surrounding soft tissues. **If the tension pneumothorax recurs, immediately repeat the procedure.** Once needle decompression is reaccomplished, immediately perform a tube thoracostomy. If possible, a tube thoracostomy can be initiated by the Emergency Physician while other members of the resuscitation team continue with other interventions. This would hopefully prevent recurrence of the tension pneumothorax secondary to a delay in chest tube placement because other interventions (e.g., CPR, intubation, venous access, etc.) must also be performed.

There may be complications secondary to the catheter placement.[37–40] A local hematoma or underlying lung laceration may occur. Infectious agents may be introduced into the pleural cavity. If the catheter-over-the-needle is introduced too close to the sternum, the underlying mediastinal vessels or internal mammary artery may be penetrated or lacerated. If the catheter-over-the-needle is introduced under the inferior border of the second rib instead of over the superior border of the third rib, the intercostal vessels or nerve may be lacerated. **A proper technique in placing the catheter-over-the-needle should be observed to minimize preventable complications.**

The standard approach to relieving a tension pneumothorax is the placement of a large-bore needle in the ipsilateral second intercostal space. This works well in the standard patient where there are no adhesions or scarring in the pleural space. However, this may not be the proper needle location in the patient with prior pulmonary disease, pleural disease, or pleural adhesions. The classic hospital patient in this category is the patient with adult respiratory distress syndrome on positive end-expiratory pressure (PEEP) with high airway pressures who develops a loculated tension pneumothorax. The needle placed in the standard manner often fails to reach the

affected pleural area. Stat chest radiographs are often required to help guide placement of the needles and/or chest tubes in these more complex patients.[6] Bedside ultrasonography is also useful to help guide the procedure.

The needle thoracotomy procedure is not without its complications. This leads some to question the performance of a needle thoracostomy instead of just performing a tube thoracostomy. There are no clinical trials comparing needle versus tube thoracostomy to relieve a tension pneumothorax in human subjects. This study was recently undertaken in a swine model.[36] The authors demonstrated that a properly performed needle thoracostomy is as effective over a 4-hour period as a tube thoracostomy. While the authors did not record the time it took to perform the procedures, performing a needle thoracostomy is quicker, easier, and simpler and now just as effective when compared to a tube thoracostomy.

SUMMARY

Tension pneumothorax is a clinical diagnosis that is often made in an agonal patient with respiratory distress, absent (or decreased) breath sounds over a hemithorax, and severe cardiopulmonary compromise. Needle thoracostomy to decompress the tension pneumothorax should be performed immediately in the second intercostal space in the midclavicular line. This is a lifesaving procedure that is quick, simple to perform, easy to learn, and requires no special equipment. Needle thoracostomy should be followed as soon as feasible by a definitive tube thoracostomy.

39 Tube Thoracostomy

Kimberly T. Joseph

INTRODUCTION

A tube thoracostomy is the placement of a tube through the thoracic wall and into the pleural cavity. It is commonly referred to as a chest tube. It is placed in order to evacuate air, blood, or other fluid that collects within the pleural space. The etiology of the air or fluid collections can be due to iatrogenic complications, infection, lung disease, malignancy, or trauma.

Thoracic trauma continues to account for nearly one-quarter of all trauma-related mortality.[1,2] Although some injuries require surgical intervention, the majority may be treated nonoperatively. Injuries to the chest wall, lung, trachea, bronchi, or esophagus may lead to the presence of abnormal air and/or fluid in the pleural space. The use of a tube thoracostomy (chest tube) in these situations may be both diagnostic and therapeutic. Historically, closed-tube drainage of the pleura has been used for various indications for more than a century.[3] This chapter deals primarily with the use of tube thoracostomy following trauma. However, much of the information remains the same regardless if the patient is a trauma victim or a medical patient.

ANATOMY AND PATHOPHYSIOLOGY

On inspiration, the diaphragm and accessory muscles of respiration contract and generate negative pressure within the pleural space. Penetration of the visceral or parietal pleura due to injury disrupts this pressure gradient and allows air to enter the "potential space" between the parietal and visceral pleurae, resulting in a pneumothorax.[1,2] **A simple pneumothorax is the accumulation of air that is not under pressure within the pleural space.** It may cause the ipsilateral lung to collapse. As air continues to accumulate and if there are no adhesions, the increased pressure in the thoracic cavity may push the mediastinum toward the noninjured side. This can cause angulation of the atriocaval junction, impairment of atrial filling, and a subsequent decrease in cardiac output manifest by hypotension. **The presence of a pneumothorax under pressure accompanied by respiratory and/or circulatory compromise is termed a tension pneumothorax and is an immediate life threat**.

There are two important points to remember about a tension pneumothorax. First, it is a clinical diagnosis based on the patient's presenting signs and symptoms. Do not wait for a chest film to establish the diagnosis. Second, the initial treatment of this entity is needle decompression followed by tube thoracostomy. A large-bore needle is inserted in the second intercostal space (ICS) in the midclavicular line at the superior border of the rib. If the patient has a tension pneumothorax, a gush of air will ensue and the patient's symptoms will improve. Thus, the tension pneumothorax is converted to a simple pneumothorax and a chest tube is inserted for more definitive management. Refer to Chapter 38 for complete details regarding the needle thoracostomy procedure.

An open pneumothorax is caused by a traumatic chest wall injury that results in a defect that is greater than or equal to two-thirds the diameter of the patient's trachea. Air passes via the path of least resistance (i.e., the defect) and leads to equilibration of the intra- and extrathoracic pressures, thus compromising both oxygenation and ventilation. Like a tension pneumothorax, this is an immediate life threat. Initial treatment may consist of a nearly occlusive "three-sided" dressing creating a one-way valve for egress of air from the pleural cavity. Alternatively, the patient may be placed on positive-pressure ventilation. The chest tube can then be inserted at a site remote from the actual defect. Refer to Chapter 41 for complete details regarding the management of open chest wounds.

Injury to the chest may also result in laceration of vascular structures, including the lung parenchymal vessels, intercostal vessels, internal mammary arteries, great vessels, or the heart. Although the body can absorb small amounts of free blood from the pleural space, the presence of free blood over a prolonged period of time leads to increased risk of infection and fibrosis.[3,4] The body cannot effectively clear large quantities of blood or clot from the pleural cavity. Blood in the pleural space, otherwise known as a hemothorax, can in most cases be treated with the insertion of a chest tube. However, when a major systemic or pulmonary vessel has been injured, resulting in massive hemothorax (i.e., greater than 1500 mL of blood in the pleural space), tube thoracostomy is usually followed by urgent surgical intervention.

Penetrating wounds or blunt rupture of the thoracic esophagus may result in a pneumomediastinum, pneumothorax, hydrothorax, or some combination thereof. Esophageal injury should be suspected in any patient with a knife or ice pick wound in a suspicious location, a transmediastinal bullet trajectory, or a severe and sudden compression of the chest or abdomen.[2] If a pneumothorax or hydrothorax is a presenting finding, tube thoracostomy is used as part of the treatment. However, these patients require urgent surgical attention. Tube thoracostomy may also be used in the treatment of traumatic chylothorax resulting from injury to the thoracic duct.

One special circumstance deserves mention. Certain patients who have sustained significant blunt trauma to the torso may have a diaphragmatic rupture. Chest radiographs may reveal an air density in the hemithorax that could be mistaken for a pneumothorax. However, this may actually represent the presence of the stomach or colon in the thoracic cavity. When a chest tube is inserted in such a case, extra care must be taken when entering the pleural cavity so as not to injure a hollow viscus inadvertently.

INDICATIONS

The indications for a tube thoracostomy following blunt or penetrating trauma to the chest include the presence of a simple pneumothorax, hemothorax, hemopneumothorax, hydrothorax, or chylothorax. A chest tube is placed prophylactically in patients with penetrating injuries to the chest who do not have evidence of a pneumothorax on initial chest radiographs but are expected to undergo endotracheal intubation and general anesthesia. The medical indications for a tube thoracostomy include a pneumothorax, empyema, recurrent pleural effusion, pleurodesis, or a malignant pleural effusion. A tube thoracostomy should also be performed after the needle decompression of a tension pneumothorax into a simple pneumothorax.

OCCULT PNEUMOTHORAX

With the advent of computed tomography (CT), traumatic pneumothoraces and hemothoraces that are not evident on plain chest radiographs are being diagnosed more frequently. The question then arises as to whether or not these pneumothoraces should be treated. The management of these "occult pneumothoraces/hemothoraces" is somewhat controversial. One study looked at 40 patients who sustained chest trauma and were discovered by CT scan to have pneumothoraces.[5] The study concluded that patients undergoing positive-pressure ventilation should have placement of a chest tube. However, the study could not confirm that patients with small pneumothoraces who were not going to be ventilated could safely be observed. Plurad et al. reviewed 2326 CT scans, 80.5% after negative chest radiographs, in which 102 occult pneumothoraces and/or hemothoraces were noted.[6] Only 12 of these patients required tube thoracostomy. Similar results for small, isolated occult hemothoraces were seen by Stafford et al.[7] A smaller study by Enderson et al. noted a higher percentage of patients requiring tube thoracostomy, but these patients were undergoing positive-pressure ventilation.[8] As a general guideline, nonprogressive occult pneumothoraces can usually be managed without a tube thoracostomy.[9] However, close clinical observation and/or follow-up plain radiographs are recommended. An initially occult pneumothorax that is increasing in size or in a patient who develops respiratory distress requires a tube thoracostomy.[9] A patient with an occult pneumothorax and who also requires positive-pressure ventilation, endotracheal intubation, and/or general anesthesia is an indication for a tube thoracostomy.

CONTRAINDICATIONS

The only absolute contraindication to performing a tube thoracostomy is in the patient who requires an open thoracotomy. Although there are no firm contraindications to performing a tube thoracostomy in a trauma patient, there are some areas of controversy. It has been suggested that a patient with a small (<20%) pneumothorax without an associated hemothorax following trauma may be managed with close observation rather than a chest tube, especially in the case of blunt injuries. If observation is selected for such a patient, chest radiographs should be repeated within 3 to 6 hours to rule out an enlarging pneumothorax or the delayed manifestation of a hemothorax.[2,5]

There are several relative contraindications to performing a tube thoracostomy in the medical patient. These include the presence of a skin infection over the chest tube insertion site, a coagulopathy, large pulmonary blebs or bullae, pulmonary adhesions, loculated pleural effusions, tuberculosis, or previous tube thoracostomies. These patients may require CT or ultrasound guidance to place the chest tube. A coagulopathy should be corrected before the chest tube is inserted if such placement is not required emergently.

There has been some suggestion in the literature that there may be a role for the prehospital placement of chest tubes.[10,11] Although this has not gained widespread acceptance, aeromedical crews frequently perform tube thoracostomies in the field.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- 10 to 20 mL syringe
- Local anesthetic solution with epinephrine (1% lidocaine or 0.25% bupivacaine)
- 25 or 27 gauge needle
- #10 scalpel blade on a handle
- Kelly clamps, large and medium
- Chest tubes, sizes 12 to 42 French
- Sterile water
- Chest tube drainage apparatus with a water seal
- Christmas tree connector
- Suction source and tubing
- Needle driver
- Mayo scissors, large curved
- Size 0 or 1-0 suture, silk or nylon
- Petrolatum-impregnated gauze
- 4 × 4 gauze squares
- Adhesive tape, 3 to 4 in. wide
- Sterile drapes
- Sterile gloves and gown
- Face mask with a face shield or goggles
- Tincture of benzoin spray or swabs
- 0.25% bupivacaine

Most hospitals and Emergency Departments have prepared their own "chest tube trays" that contain all the equipment required to place a chest tube except the chest tubes, local anesthetic solution, and a collection system. These last three items will vary based on the etiology of the air and/or fluid in the pleural cavity, the age and size of the patient, and physician preference. Commercially produced chest tube kits are also available (e.g., Atrium Medical Corp., Hudson, NH and Centurion Medical Products, Howell, MI).

Chest tubes used in the Emergency Department are hollow, clear, straight plastic tubes (**Figure 39-1**). The distal end of the chest tube



FIGURE 39-1. The chest tube. The proximal end is beveled while the distal end is fenestrated.

has numerous fenestrations or holes that allow the passage of air and/or fluid into and through the tube. A radiopaque stripe allows for radiographic localization of the chest tube after it is inserted into the patient. The proximal end of the chest tube is beveled to allow it to fit better on a plastic connector.

Chest tubes are available in numerous sizes and from multiple manufacturers. The lower the number, the smaller the size of the chest tube. A spontaneous pneumothorax may be drained with an 18 to 26 French tube in adults, a 14 to 16 French tube in children, a 12 to 16 French tube in infants and small children, and an 8 to 12 French tube in neonates. Traumatic pneumothoraces are usually drained with a 32 to 36 French tube in adults and a 16 to 20 French tube in children. Traumatic hemothoraces, traumatic hemopneumothoraces, and empyemas require larger-size tubes. A 36 to 42 French tube in adults and a 20 to 24 French tube in children will provide adequate drainage without becoming occluded by blood clots or purulent material.

The procedure requires the use of a large Kelly clamp to bluntly dissect a subcutaneous tract as well as to puncture and dilate a tract through the intercostal muscles. The Kelly clamp requires the Emergency Physician to pull the ringed handles apart and in opposite directions to open the jaws of the clamp. Opening the jaws of the Kelly clamp when it is within the subcutaneous tissues or intercostal muscles can be quite difficult. A new clamp, the Centurion Blunt Dissector (**Figure 39-2**), was specifically designed to aid in the insertion of a chest tube (Centurion Medical Products, Howell, MI). The mechanical action of this new clamp is opposite that of the Kelly clamp. In the resting position, the jaws are closed and the ringed handles are held open with a spring mechanism. To open the jaws of the clamp, the ringed handles are squeezed together. This is a more natural, intuitive, and easier motion to perform. This chest tube clamp is disposable and available individually or incorporated into a chest tube insertion tray.

DRAINAGE SYSTEMS

It is important to know how to use the drainage system available at your institution to prevent any complications arising from the use of these devices. The classic glass bottle system with rubber corks is rarely, if ever, used in the United States today in the Emergency Department. Commercially available drainage systems are currently available in most hospitals (**Figure 39-3**). They are made of lightweight plastic, sterile, and intended for single-patient use. They are preassembled, disposable, and also may be used for autotransfusions. They have clear plastic covers to allow easy visualization of the fluid within the unit.



FIGURE 39-2. The Centurion Blunt Dissector (Photo courtesy of Centurion Medical Products, Howell, MI).



FIGURE 39-3. A commercially available chest tube drainage system.

The system is a single unit that consists of three or four chambers, depending on the manufacturer. The first chamber connects to the chest tube with flexible rubber tubing. It collects blood clots and/or other fluid expressed through the chest tube. The second chamber is the water seal. It allows one-way flow of air away from the patient and maintains a negative intrathoracic pressure gradient compared to the atmosphere. The third chamber is the suction regulator, which attaches to the wall suction. It draws in atmospheric air when needed to limit the negative pressure of the vacuum. Some manufacturers have included a fourth chamber to assess the patient's intrapleural pressure (e.g., Sentinel Seal, Sherwood Medical, Ireland).

PATIENT PREPARATION

Explain the risks, benefits, complications, and aftercare to the patient and/or their representative if time and the patient's clinical condition permit. Obtain an informed consent for a tube thoracostomy or document in the medical record the verbal discussion whenever possible. It should be understood that following trauma, a tube thoracostomy is often performed under urgent or emergent conditions. Lifesaving care should always proceed on the patient's

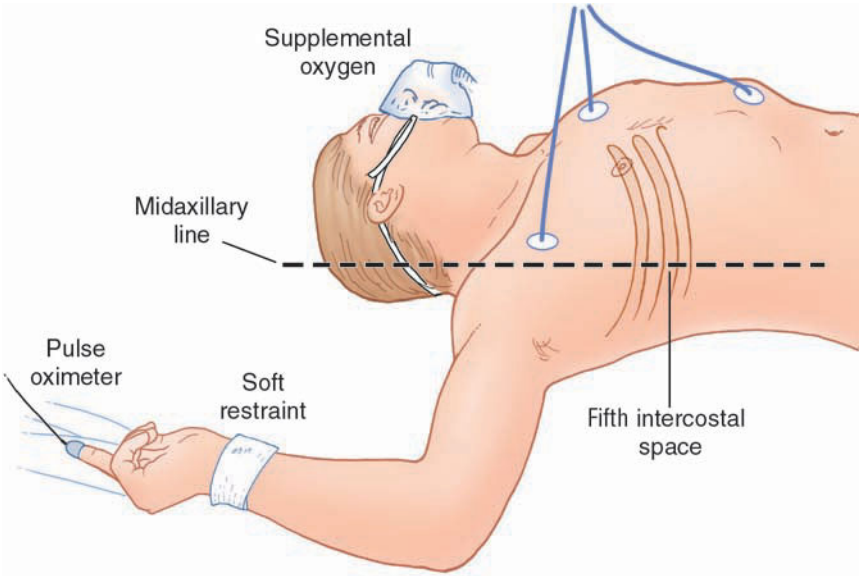


FIGURE 39-4. Patient positioning for a tube thoracostomy. Note the application of supplemental oxygen, pulse oximetry, cardiac monitoring leads, and a soft restraint.

behalf with the appropriate documentation in the medical record after the patient is resuscitated.

In recent years, there has been considerable discussion in the literature regarding the use of antibiotics in patients requiring a tube thoracostomy for trauma in the hope of preventing an empyema.[12–14] The Eastern Association for the Surgery of Trauma (EAST) practice management guidelines work group reviewed the literature regarding the use of antibiotics in conjunction with chest tube insertion. They found several trials, including four double-blinded, randomized trials that evaluated infectious complications after a tube thoracotomy using Centers for Disease Control (CDC) criteria. The studies each had their weaknesses. Despite these weaknesses, the working group recommended that there was sufficient class 1 and class 2 evidence to support a recommendation of administering a first-generation cephalosporin intravenously just before making the skin incision and continuing the intravenous antibiotic for 24 hours.[15]

If not contraindicated, the administration of parenteral analgesics, sedatives, and/or procedural sedation (Chapter 129) will be greatly appreciated by the patient, as the procedure is quite painful. Appropriate protocols for patient monitoring should be employed. At minimum, the patient should have supplemental oxygen applied, continuous pulse oximetry, and frequent checks of vital signs. Continuous cardiac monitoring should also be employed and monitored.

Place the patient supine or semierect with the arm on the involved side raised away from the chest (**Figure 39-4**). Identify the fifth ICS in the mid-to-anterior axillary line (**Figure 39-4**). Consider marking this point on the patient's skin with a pen or marking pen. A soft restraint may be placed around the wrist to prevent the arm from moving during the procedure. Apply povidone iodine or chlorhexidine solution to the chest wall and allow it to dry. Apply sterile drapes to demarcate a sterile field. **Sterile technique should be observed and followed by all involved personnel, who should be fully capped, gowned, masked, and gloved.**

Reidentify the fifth ICS in the mid-to-anterior axillary line (Figure 39-4). This is the preferred site for chest tube insertion. The reasons for this are twofold. The diaphragm rises during respiration to the level of the nipple. Chest tube insertion below the fifth ICS unnecessarily risks puncture of the diaphragm or abdominal organs. The area of the midaxillary line is the least muscular area of the chest wall and is thus an easier area from which to gain access to the pleural cavity.[1–3]

If the patient is awake and aware of their surroundings, infiltrate local anesthetic solution into the chest wall and pleural cavity. This should be performed regardless of whether the patient receives parenteral analgesics, sedatives, and/or procedural sedation. Approximately 10 to 20 mL of local anesthetic solution with epinephrine (e.g., lidocaine or bupivacaine) is required to provide adequate analgesia. Consider using bupivacaine as it provides longer analgesia than lidocaine. Be aware of the maximum weight based volume of local anesthetic solution to administer to prevent toxicity (Chapter 123). Raise a subcutaneous wheal of local anesthetic solution one interspace below the one to be used to insert the chest tube (i.e., the sixth ICS). Infiltrate local anesthetic solution subcutaneously and upward to a point above the fifth ICS. Redirect the needle to anesthetize the intercostal muscles and parietal pleura of the fifth ICS. Advance the needle into the pleural cavity and inject 2 to 3 mL of local anesthetic solution to adequately anesthetize the pleura (**Figure 39-5**).

TECHNIQUE

The technique described here is an "open" technique, as opposed to that employing the use of a trocar. Trocar-aided insertion of chest tubes is associated with a higher incidence of major complications

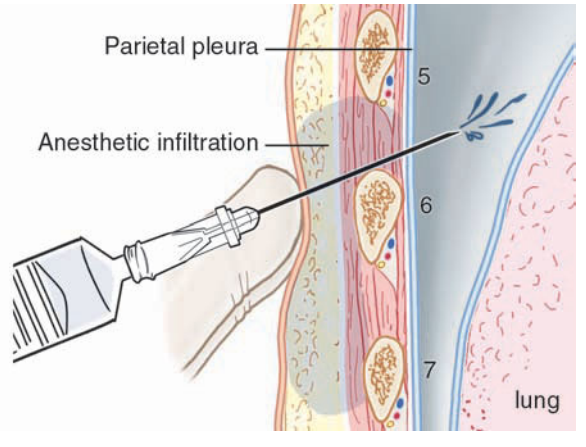


FIGURE 39-5. Infiltration of local anesthetic solution into the chest wall and pleural cavity.

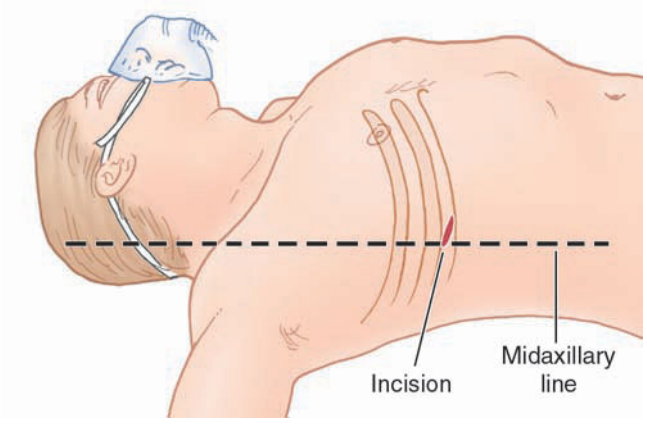


FIGURE 39-6. The initial skin incision is made over the rib one interspace below the desired chest tube insertion site.

and does not result in any significant saving of time.[1–3] **For these reasons, a trocar should never be used.**

Make a 3 to 5 cm incision with the #10 scalpel blade over the rib one ICS below (i.e., the sixth ICS) the desired ICS (**Figures 39-6 & 39-7A**). Bluntly dissect a tract or tunnel with the 6 in Kelly clamp in the subcutaneous tissue in a cephalic direction to the rib above. Orient the clamp with the tips curved toward the skin. Advance the closed tips of the clamp in 1 cm increments and open the jaws to dissect the tract (**Figure 39-7B**). The tract should terminate at the upper border of the fifth rib. **This will avoid injury to the neurovascular bundle lying under the inferior border of the rib.** Rotate the clamp 180° such that the tip is aimed just above the superior border of the fifth rib and toward the pleural cavity. Briskly push the closed tips of the clamp through the intercostal muscles and parietal pleura and into the pleural cavity (**Figure 39-7C**). **This maneuver requires a significant amount of force to enter the pleural cavity.** A twisting motion as the clamp is advanced may facilitate penetration into the pleural cavity. If the clamp is advanced slowly, the intercostal muscles will stretch and entering the pleural cavity will be difficult.

A loss of resistance associated with a rush of air or fluid should occur as the pleural cavity is entered with the closed tips of the clamp (**Figure 39-7C**). If under pressure, the fluid contained within the pleural cavity may exit the tract forcibly. **It is important not to plunge too deeply with the clamp as the pleural cavity is entered.** The tips of the clamp can injure the diaphragm, great vessels, heart, or lung. The forward motion of the clamp can be partially opposed by bracing the nondominant hand on the underside of the clamp and applying counterpressure away from the patient as the clamp enters the pleural cavity.

Spread the jaws of the clamp to enlarge the tract through the subcutaneous tissue, intercostal muscles, and parietal pleura. Insert a finger through the tract and into the pleural cavity (**Figure 39-7D**). The lung should be felt as it expands with inspiration and contracts with expiration. Rotate the finger to ascertain the presence or absence of adhesions. Gently break any loose adhesions between the lung and thoracic cage with the finger. Dense adhesions require the chest tube to be inserted at another site.

Prepare to insert the chest tube. Estimate the distance from the skin incision to the apex of the lung by laying the chest tube over the patient. Apply a clamp onto the chest tube at the estimated site at which it should exit the skin incision. This location should be 4 to 5 cm proximal to the fenestrations in the chest tube. Cut off the beveled proximal end of the chest tube just above the bevel.

Grasp and clamp the tips of the large Kelly clamp onto the distal end of the chest tube. Insert the tips of the clamp and chest tube

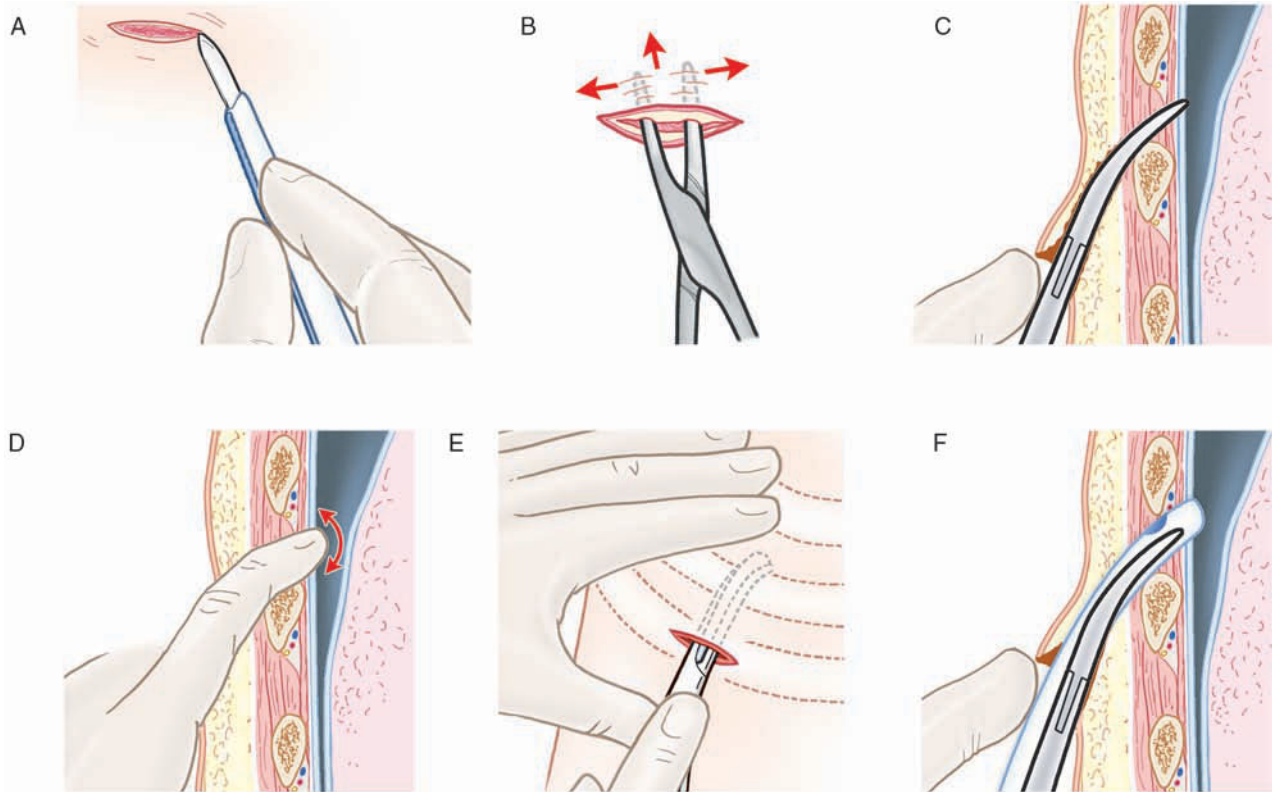


FIGURE 39-7. The tube thoracostomy. **A.** The skin incision is made. **B.** A tract is bluntly dissected in the subcutaneous tissues. **C.** The Kelly clamp is forced into the pleural cavity. **D.** A finger is inserted through the tract to feel for adhesions. **E.** The chest tube is held in the Kelly clamp and inserted through the tract. **F.** The chest tube is guided into the pleural cavity.

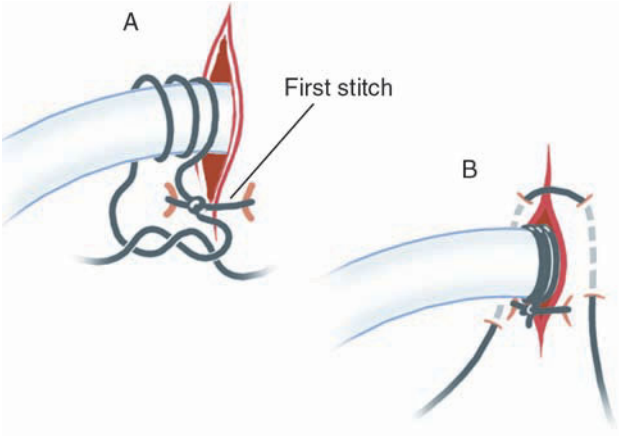


FIGURE 39-8. Securing the chest tube to the thoracic wall. **A.** The stay suture. **B.** The purse-string suture.

through the tract and into the pleural cavity (**Figures 39-7E & F**). Use the clamp to direct the tip of the chest tube posteriorly and superiorly. Alternatively, the dominant index finger can be placed through the tract to direct the chest tube. The use of the finger in the tract is the preferred method to guide the chest tube. The finger will be able to confirm the proper intrapleural placement of the chest tube. Release the Kelly clamp and advance the chest tube until all the fenestrations are within the pleural cavity and the preplaced clamp on the chest tube is at the skin incision. Hold the chest tube securely in place. Remove the Kelly clamp from the incision. Release the clamp on the chest tube.

Secure the chest tube with 0 or 1-0 silk or monofilament nylon suture (**Figure 39-8**). The many techniques that have been described for securing chest tubes are idiosyncratic and probably equivalent. Suffice it to say that the tube should be sewn in such a way that the incision is closed fairly tightly around the tube to assure a better seal and that routine movements of the patient should not dislodge it.

Place the first stitch as a simple interrupted stitch at one end of the skin incision (**Figure 39-8A**). Leave both ends of the suture long after tying the knot in the first stitch. Wrap the needle end of the suture firmly around the chest tube three or four times. Tie a knot in the suture to secure the chest tube to the skin (**Figures 39-8A & 9A**). Place the second stitch as a purse-string suture encompassing the chest tube (**Figure 39-8B**). Leave both ends of the suture long. Wrap both ends of the suture around the chest tube and tie a bow, not a knot. This stitch will be used later to close the skin incision after the chest tube is removed. Place simple interrupted or horizontal mattress sutures to close the remainder of the skin incision.

Apply an occlusive dressing over the incision site (**Figure 39-9B**). Apply petrolatum gauze over the incision site and around the chest tube as it exits the incision. Place gauge squares over the incision site. Apply tincture of benzoin to the chest wall surrounding the gauze squares. Tape the gauze and chest tube to the torso. The ends of the tape should be adherent to the tincture of benzoin. **Do not place tape over the patient's nipple. If the tape must cover the nipple, protect it with a piece of gauze.**

An alternative to the above dressing is a new product, the Centurion Chest Tube Anchor (Centurion Medical Products, Howell, MI). This is a sterile, adherent patch that surrounds the chest tube as it exits the skin (**Figure 39-10**). It forms an occlusive dressing. It has an attached cable tie to wrap around the chest tube and secure it in place. This cable tie replaces suturing the chest tube in place. The device can be trimmed to a smaller size for pediatric patients. The cable tie will secure all sizes of chest tubes.

Connect the chest tube to a drainage system (**Figure 39-11**), which is a self-contained multichamber device.[3] The first chamber is a collecting chamber that connects directly to the chest tube. The second chamber contains a small amount of saline or water and acts as a one-way valve. This assures flow only in the direction away from the patient. The third chamber controls suction, with a capability of at least 20 cm of water suction, and attaches to the wall suction system. Commercially available systems encompass all three chambers in one unit.

ASSESSMENT

Obtain an anteroposterior portable chest radiograph. Observe the position of the chest tube. Remove the chest tube and insert a new one if it is bent, kinked, or in the fissure of the lung. If its tip is against

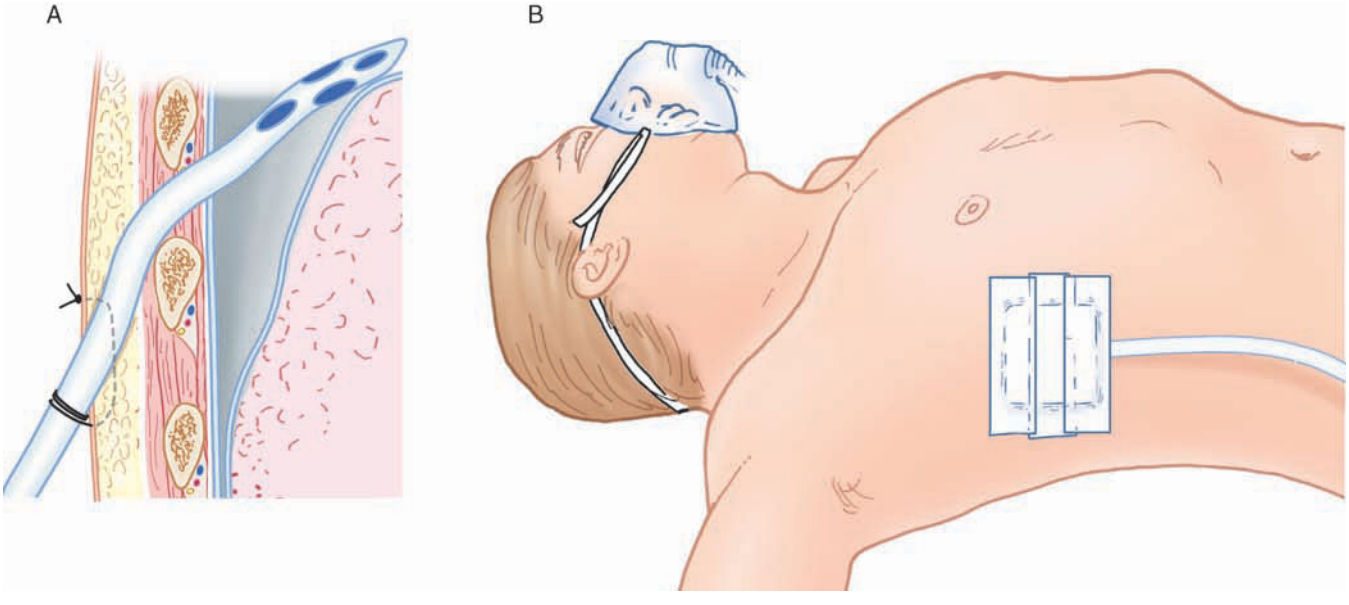


FIGURE 39-9. Securing the chest tube. **A.** The chest tube has been secured with suture to the chest wall. **B.** An occlusive dressing has been placed over the incision and taped to the chest wall.

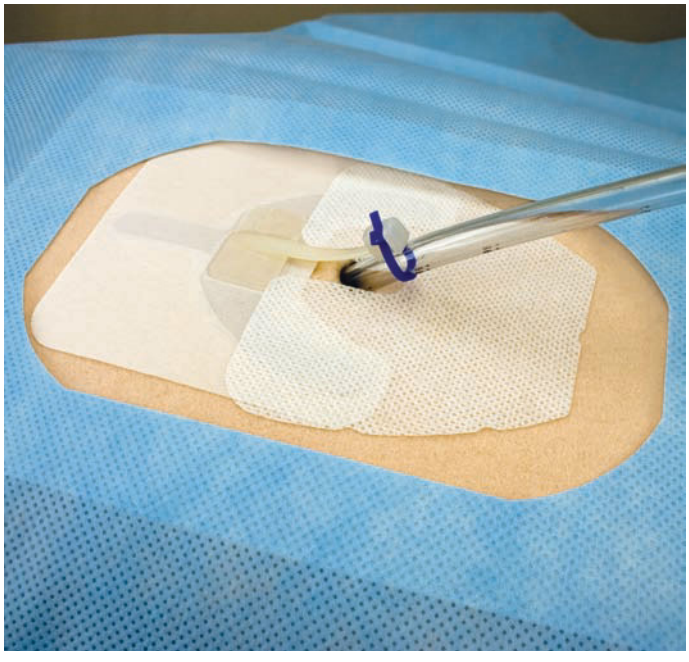


FIGURE 39-10. The Centurion Chest Tube Anchor (Photo courtesy of Centurion Medical Products, Howell, MI).

the mediastinum, unsecure the tube, withdraw it a few centimeters, resecure the tube, and obtain a repeat radiograph. If the chest tube is located in the subcutaneous tissue, remove it and insert a new one. Observe the fenestrations on the distal end of the chest tube in the radiograph. They all must be within the thoracic cavity. If not, remove the chest tube and insert a new one. **Never advance a chest tube further into the thoracic cavity after obtaining a chest radiograph, as this may track infectious material into the pleural cavity.**

Persistent bubbling in the system or failure of the lung to reexpand indicates a leak in the system. Check the system to ensure that all connections are secure. Place tape over the connections to eliminate leaks and prevent the components from becoming dislodged. Check the tubing for any holes or fissures. Examine the chest tube and the radiograph to confirm that all fenestrations are within the thoracic cavity. If not, replace the chest tube. An injury to the trachea, mainstem bronchus, a large bronchiole, or the esophagus can cause a persistent air leak. Insert a second chest tube to keep up with the leak and prepare the patient for bronchoscopy and/or esophagoscopy to diagnose the etiology of the persistent air leak.

AFTERCARE

Patients with chest tubes require close monitoring. If administered, continue prophylactic antibiotics for 24 hours. Obtain daily serial chest radiographs to monitor for resolution of the inciting process. The presence of air leaks from the chest tube indicates that the injury has not completely healed and the seal between the parietal and visceral pleurae has not yet been restored. Suction should be maintained until there is no evidence of an air leak. The acceptable minimal daily output from a chest tube as a criterion for removal varies according to the institution, the physician, and the reason for insertion. It is also unclear whether a trial period of water seal following suction is strictly necessary. There is literature to suggest that both suction and water seal protocols for removing chest tubes are effective and have similar incidences of recurrent pneumothoraces.[16] However, there is also literature supporting an abbreviated trial of water seal following suction, as it may allow time for occult pneumothoraces to manifest themselves and thus alleviate the need for reinsertion of a chest tube.[17] The chest tube insertion site should be monitored for signs of infection.

The chest tube and collection tubing should be checked periodically for blockage. If blocked, the tubing may be milked or stripped to alleviate the blockage and avoid the need to replace the chest tube. Milking refers to forcing air, fluid, or clots back into the chest. Stripping refers to creating negative pressure within the tubing to move fluid or clots distally and into the collecting chamber. To milk the tube, clamp or pinch the tubing shut distally while using the other hand to compress the tubing and move proximally to force the contents back into the thoracic cavity. To strip the tube, clamp or pinch the tubing shut proximally while using the other hand to compress the tubing and move distally followed by the sudden release of the proximal tubing.

CHEST TUBE REMOVAL

In planning to remove a chest tube, one must be prepared to replace it. All the necessary equipment and supplies should be readily available in case the patient urgently requires a new chest tube. The physician should wear gloves, a gown, a face mask with an eye shield

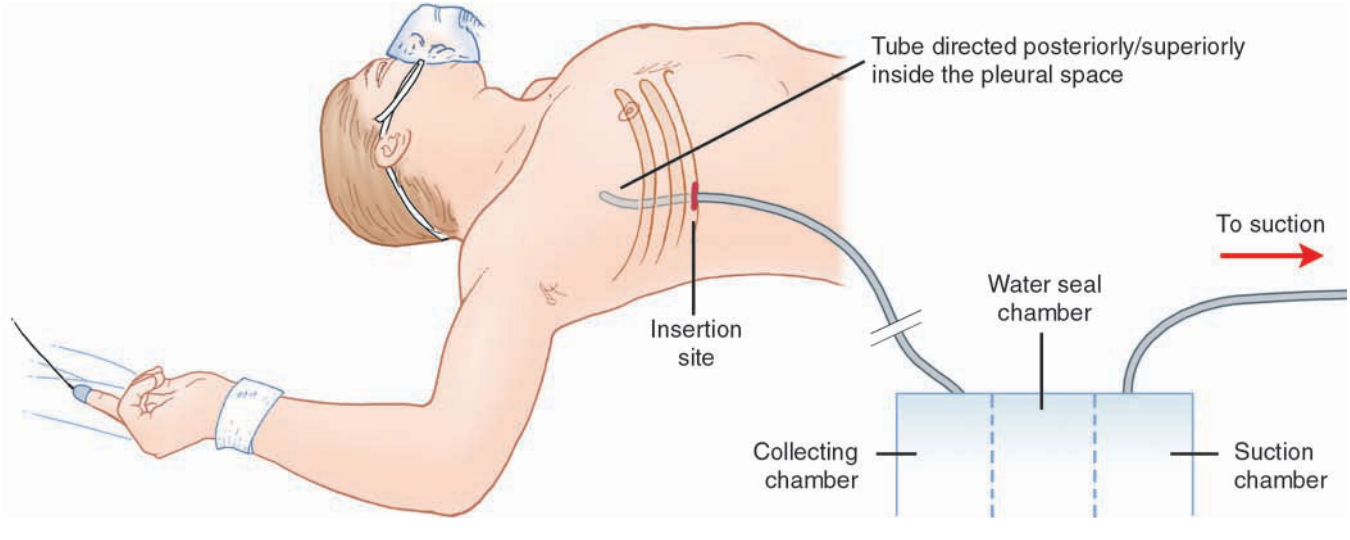


FIGURE 39-11. The chest tube is connected to a drainage system.

or goggles, and a cap to prevent becoming contaminated when the chest tube is removed.

Place the patient supine or semirecumbent. The use of parenteral sedation and soft restraints is rarely necessary when removing a chest tube. Carefully remove the tape securing the chest tube to the chest wall. Be cautious when removing the tape if it covers the patient's nipple, so as to prevent any injury. Remove the gauze squares and petrolatum gauze covering the incision site. Untie the bow securing the free ends of the purse-string suture that was previously placed. Cut the suture that is holding the chest tube to the chest wall. Remove this suture. Place the first half of a surgeon's knot in the free ends of the purse-string suture. Pass the ends of the suture to an assistant. **Instruct the patient to inhale or exhale fully and hold their breath.[18] This results in a Valsalva-type maneuver, and will prevent ambient air from being drawn through the chest wall and into the pleural cavity**. Quickly and smoothly remove the chest tube while the assistant cinches down the knot of the suture to seal the skin incision. Tie additional knots to secure the purse-string suture. Place petrolatum jelly or topical antibiotic ointment over the incision. Cover the site with gauze squares and tape it securely.

Observe the patient for 4 to 6 hours for any signs of cardiovascular or respiratory compromise. If the patient remains asymptomatic, obtain expiratory posteroanterior and lateral chest radiographs. Evaluate the radiograph for the recurrence of the pneumothorax, hemothorax, pyothorax, and/or hydrothorax. The dressing may be removed in 24 to 48 hours. Remove the chest wall sutures in 8 to 10 days.

COMPLICATIONS

Tube thoracostomy is often described as a simple procedure. But if it is not performed with care and attention, it can result in serious complications, including injuries to thoracic and abdominal organs.[1,2,19] An unusual occurrence of sudden death following chest tube insertion has been reported.[20] It was attributed to hemorrhage near the vagus nerve, causing irritation and stimulation of the vagus nerve and refractory bradycardia. Injury to the thoracic duct from the chest tube being inserted too deeply can result in a chylothorax.[21] Injury to the heart and great vessels can occur if the chest tube is placed anteriorly or a trocar was used to insert the chest tube. Lung injury can occur if the clamp plunges inward on entering the pleural cavity. **It is imperative that the Kelly clamp be controlled as it enters the pleural cavity.** If the lung is adherent to the chest wall, it may be penetrated by the Kelly clamp or the chest tube. **A trocar should never be used to insert a chest tube, as it can cause significant injury to the heart, lung, or other intrathoracic structures.**

Other complications associated with chest tube placement and removal include recurrent, residual, and loculated pneumothoraces. These may require the placement of additional chest tubes. A retained hemothorax may require decortication and may develop into an empyema.[4,22,23]

Posttraumatic empyema remains a serious complication of thoracic trauma with incidences ranging from 2% to 25%.[1,2,4,23] The etiology of the infection is not always clear. A break in sterile technique on chest tube insertion, nosocomial pneumonia, superinfected pulmonary contusion, and undrained hemothoraces have all been implicated. Empyemas that can be attributed to the chest tube insertion process are completely preventable complications that can be avoided by strict adherence to aseptic technique.

Bleeding can occur from several sites. Incision site bleeding is often due to superficial venules and arterioles. The application of pressure and the suturing of the incision closed will alleviate this bleeding in most cases. If the dissection or penetration into the pleural cavity occurs along the inferior surface of a rib, an intercostal artery or vein can be lacerated. Securing the chest tube against the inferior surface of the rib may tamponade the bleeding. If the bleeding continues, attempt to tamponade it with a Foley catheter. Insert the catheter into the pleural cavity, inflate the cuff, and withdraw the catheter to lodge the cuff against the posterior surface of the rib. Another option is to extend the incision to expose and ligate the bleeding vessel. Lung injury and bleeding from penetration into the pleural cavity are often self-limited and minor. Rarely will an injury be serious enough to warrant surgical intervention. **A trocar should never be used, as risk of injury to intrathoracic structures is significantly increased.** An anteriorly placed chest tube should be at least 3 cm from the lateral border of the sternum to prevent injury to the internal mammary artery.

The chest tube can become occluded and stop functioning. A large tube should always be inserted if its purpose it to drain blood, clots, or purulent material. Attempt to milk and/or strip the tubing, as described previously. Obtain a chest radiograph to determine if the chest tube is kinked. Twist the chest tube 180° and release it. If it spins back into its original position, it is kinked.[24] If the occlusion cannot be dislodged or the tube is kinked, the chest tube should be removed and a new one inserted.

Subcutaneous emphysema results from air from an inadequately decompressed pneumothorax that tracks into the subcutaneous tissues. Ensure that the chest tube, drainage system, and suction source are functioning properly. Replace any component that is not functioning. Verify that the chest tube is within the pleural cavity and not within the subcutaneous tissues using either plain chest radiography or ultrasound.[25] Evaluate the chest radiograph to ensure that all of the drainage holes are within the pleural cavity and not in the subcutaneous tissues.

Reexpansion pulmonary edema occurs from the rapid expansion of a lung that has been collapsed for over 48 to 72 hours or from the removal of a large pleural effusion.[26,27] Patients will begin to experience increasing shortness of breath and hypoxemia within a few hours of the procedure. Repeat chest radiographs will show an expanded lung with pulmonary edema. The exact etiology of this complication is unknown. This complication may be prevented by the slow expansion of a lung and the removal of pleural fluid in increments. Treatment includes supportive care, supplemental oxygenation, and positive-pressure ventilation (i.e., BiPAP, CPAP, and/or intubation). Diuretics have no role in relieving the edema. Reexpansion pulmonary edema has an associated mortality rate of up to 20%.[27]

The sources of pain for a patient with a tube thoracostomy are numerous. These include the skin incision, subcutaneous dissection, intercostal muscle transection, the chest tube, and the underlying injury. Pain can often be managed with parenteral analgesics and sedation. Intrapleural bupivacaine has been found to be effective in reducing pain.[28,29] Administer 20 to 40 mL of 0.25% bupivacaine through the chest tube and into the pleural cavity. Clamp the chest tube or the tubing for up to 10 minutes to allow the bupivacaine to thoroughly coat the pleural cavity. **Carefully monitor and observe the patient to ensure that they do not develop a tension pneumothorax while the chest tube is clamped.** Unclamp the chest tube and allow the excess anesthetic to drain into the collection system. This can provide several hours of pain relief to a patient who may have limits on or contraindications to parenteral analgesics.

SUMMARY

Tube thoracostomy is useful in the treatment of thoracic injuries resulting in pneumothoraces, hemothoraces, hydrothoraces, and chylothoraces. Attention must be paid to observe sterile technique, choose the proper insertion site, carefully enter the pleura, and verify entry via digital exam. Appropriate drainage systems should be employed to assure maintenance of a closed, water-tight system.

Monitor the patient regularly while the chest tube is in place. Emergency Physicians performing this procedure should be cognizant of the serious complications that may be associated with tube thoracostomies, some of which are directly related to the insertion technique. Adherence to the principles described above will assist in avoiding many of these complications and provide optimal care for victims of thoracic trauma.

40 Thoracentesis

Eric F. Reichman, Cristal R. Cristia, and Jehangir Meer

INTRODUCTION

Thoracentesis is a term derived from the Greek meaning "to pierce the chest." It is used today to refer to the removal of air or fluid from the thoracic cavity. Accumulation of pleural fluid is not a specific diagnosis but rather a reflection of an underlying process. In almost all newly discovered pleural effusions, thoracentesis should be performed to aid in the diagnosis and management of the underlying etiology.

Hippocrates first described thoracentesis in the management of an empyema.[1] Thoracentesis was used widely in World War II and the Korean conflict in lieu of a thoracotomy for chest drainage. By the time of the Vietnam War, this practice was replaced by tube thoracostomy. Today, thoracentesis is used in the diagnosis and therapy of pleural effusions, emergent and temporizing treatment of a tension pneumothorax, and the management of small, nontraumatic pneumothoraces.[1–4]

A pleural effusion can be identified clinically and radiologically. Clinically, the patient may develop pain related to irritation of the parietal pleura, compromised pulmonary mechanics, or interference with gas exchange.[3] The pain may be located in the chest, abdomen, or ipsilateral shoulder. Another common symptom is a cough; its mechanism is unclear. Dyspnea occurs secondary to the space-occupying effect of the fluid and alterations in gas exchange. In extreme cases, pleural effusions can reduce cardiac output. On physical examination, tactile fremitus is absent or attenuated and there is dullness to percussion. Auscultation reveals decreased breath sounds on the involved hemithorax.

Radiographically, on a posteroanterior (PA) chest radiograph, an effusion can be diagnosed when there is homogeneous opacification in the hemithorax, absent air bronchograms, and clouded vesicular vascular markings. In a cadaveric study, the minimum fluid volume needed to blunt the costophrenic angle was 175 mL.[5] More than 500 mL had to be injected into some cadavers to blunt the costophrenic angle.[5] In a study on mechanically ventilated patients, ultrasound consistently identified nonloculated pleural effusions when the effusion was at least 500 mL.[6] A lateral decubitus film is often necessary and will determine whether the fluid is loculated or free-flowing. It will also be helpful if one of the following signs is present on the PA chest radiograph: a clear costophrenic angle, an elevated hemidiaphragm, a blurred contour of the diaphragmatic dome, or the gastric bubble seen more than 2 cm from the lung border in patients with left-sided pleural effusions.[2] If the fluid collection is 10 mm thick on the lateral decubitus film, thoracentesis can most likely be performed using clinical skills to locate the fluid.[7] If it is less than 10 mm thick, ultrasound may be needed for localization.[3]

The use of ultrasound is no longer limited to Radiologists. With proper training, Emergency Physicians can utilize ultrasound for thoracentesis procedural guidance. The portable AP (anteroposterior) radiograph cannot always reliably distinguish between a pleural effusion, a pneumonia, or atelectasis.[8] In these indeterminate cases, ultrasound can be clinically useful. Pleural fluid can be identified as a black hypoechoic area, which appears darker than the surrounding lung, diaphragm, and liver. Ultrasound can aid in the identification of small effusions. Thoracentesis performed blindly has an associated complication rate of up to 30%.[9] Ultrasound allows the Emergency Physician to map the pleural effusion and choose the best site for thoracentesis, thereby reducing the rate of pneumothoraces to less than 3%.[10–14] Ultrasound guidance has been shown to be very safe in assisting with thoracentesis in intubated and mechanically ventilated patients, both high-risk populations for complications.[12,15]

A pneumothorax may be simple or under pressure (also known as tension). A simple pneumothorax may present clinically with chest pain, dyspnea, hypoxia, and tachycardia. Physical examination may reveal, on auscultation, decreased breath sounds on the affected side. Performance of a thoracentesis to relieve a tension pneumothorax is based on the mechanism of lung injury, the patient's symptoms, and physical examination findings. Mechanisms of injury to the lung include mechanical ventilation, chest trauma, instrumentation of the chest, and spontaneous lung rupture. Classically, the patient has a clinical presentation of hypotension, tachycardia, and absent breath sounds on the affected side. Other symptoms may include a deviated trachea, acute change in mental status, air hunger, chest pain, cyanosis, diaphoresis, hypoxia, and cardiorespiratory arrest.[1,4] Sometimes a patient with a tension pneumothorax may have a normal physical examination due to subtle auscultation findings often missed in a noisy Emergency Department. Tactile fremitus may be absent and percussion is typically hyperresonant over the hemithorax with the tension pneumothorax.

There are two major indications for performing a thoracentesis.[1–3,6] The first is for the evacuation of air. This includes a simple pneumothorax and the emergent diagnosis and temporizing treatment of a tension pneumothorax. The second is for the evacuation of fluid. This may be done to help diagnose the etiology of pleural effusion or for the treatment of a symptomatic pleural effusion.

PLEURAL EFFUSIONS

ANATOMY AND PATHOPHYSIOLOGY

The pleura is a serous membrane that covers the lungs, mediastinum, diaphragm, and thoracic cavity. The pleural space is a potential space between the lung and the thoracic cavity. A thin layer of fluid normally exists between the visceral pleura covering the organs and the parietal pleura covering the chest wall. This fluid acts as a lubricant.[3] Pleural fluid originates from three sources: parietal capillaries, visceral capillaries, and the interstitium. Hydrostatic and oncotic forces govern the flow of fluid in the pleural space. These forces are summarized in **Figure 40-1**. In a healthy person, protein-free fluid enters the pleural space from the parietal pleura and is absorbed by the visceral pleura. Small amounts of protein then leak into the pleural space. Approximately 10% of the pleural fluid and large proteins are removed by the lymphatics at a rate of up to 20 mL/h for each hemithorax.[2] Ventilation and muscular activity facilitate the action of the lymphatics.[3]

Alterations in pleural fluid homeostasis will lead to a pleural effusion: a pathologic collection of excess fluid, located between the visceral and parietal pleura. Hydrostatic changes result in protein-free effusions (transudates). Changes in oncotic pressure (abnormality in the lung or pleura) lead to effusions. The differential diagnosis of transudates and exudates is listed in **Table 40-1**.

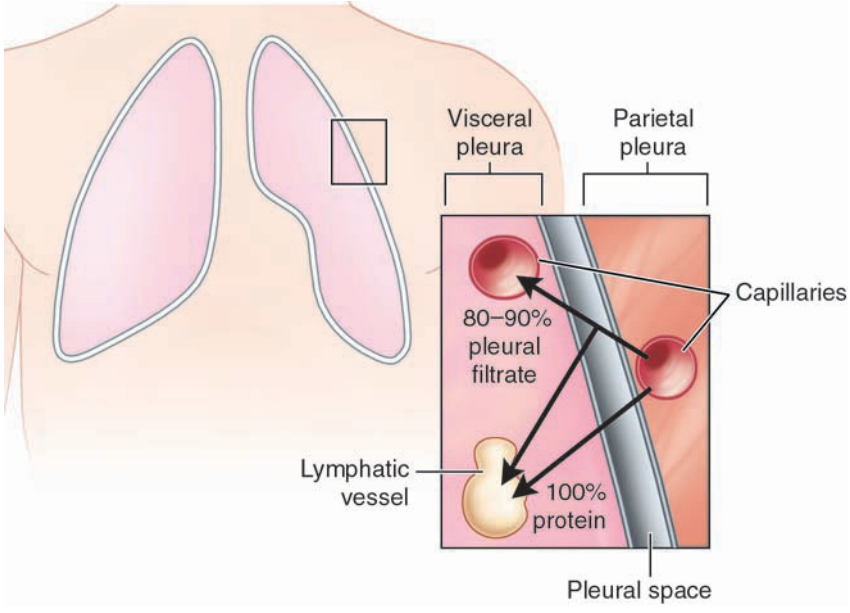


FIGURE 40-1. Schematic of pleural fluid homeostasis in a normal lung.

INDICATIONS

A thoracentesis may be performed to remove pleural fluid for analysis to diagnose the etiology of the fluid (e.g., malignancy, infection). It may also be performed to relieve the patient's symptom of dyspnea when a large pleural effusion interferes with normal respiration or results in respiratory compromise.

CONTRAINDICATIONS

The only absolute contraindications are an uncooperative patient or a patient who refuses to give informed consent for the procedure.[16] Uncooperative patients or patients with altered levels of consciousness may require sedation for the procedure.

There are numerous relative contraindications to performing a thoracentesis. Patients receiving anticoagulants, with a bleeding diathesis (whether known or suspected), or thrombocytopenia have a significant risk of bleeding.[2,16] Consider reversing the anticoagulant or the bleeding disorder prior to performing the thoracentesis. A small volume of pleural fluid may make the procedure difficult to perform and increase the risk of complications.[16] Patients undergoing positive-pressure ventilation (i.e., mechanical ventilator, BiPAP, or CPAP) are at an increased risk of developing a pneumothorax and a tension pneumothorax.[1] Although, one study has shown that a thoracentesis can be done as safely in a ventilator-dependent patient as in patients not being mechanically ventilated.[17] Pleural adhesions may limit the amount of fluid obtained or require multiple thoracenteses to drain the fluid.[1] Loculated pleural adhesions should be drained under ultrasound guidance. Areas of cellulitis or other infection on the chest wall should be avoided unless no alternate site can be identified for the procedure.[1,3] Unsupervised physicians with little or no experience should not perform this procedure, as the risk of complications is increased.[7] Patients with chronic obstructive pulmonary disease are at increased risk for complications.

TABLE 40-1 Differential Diagnosis of Fluid Exudates and Fluid Transudates in the Pleural Space

Exudates	Transudates
Asbestos exposure	Atelectasis
Collagen vascular disease	Cirrhosis of the liver with ascites
Drug-induced	Congestive heart failure
Empyema	Nephrotic syndrome
Esophageal rupture	Peritoneal dialysis
Idiopathic	Pulmonary embolism
Malignancy	
Pancreatitis	
Parapneumonic	
Pulmonary embolism	
Rheumatoid arthritis	
Systemic lupus erythematosus	
Thoracic duct exposure	
Trauma	
Tuberculosis	
Viral	

EQUIPMENT

Diagnostic Thoracentesis for Pleural Effusions

- Sterile gloves and gown
- Face mask with a face shield or goggles
- Local anesthetic solution, 1% to 2% lidocaine
- Heparin, 1000 U/mL
- Atropine, 1 mg
- Alcohol pads
- Povidone iodine or chlorhexidine solution
- Gauze 4 × 4 squares
- Sterile drapes
- Sterile towels
- Sterile gloves
- Band-aids
- 25 or 27 gauge needle
- 21 and 22 gauge needles, 1.5 in. long
- 10 mL syringes
- 50 mL syringe
- 18 or 20 gauge needle

Ultrasound Guidance

- Ultrasound machine
- 3.5 to 5.0 MHz phased-array ultrasound probe
- Sterile ultrasound gel
- Sterile ultrasound probe cover

Therapeutic Thoracentesis for Pleural Effusions

- The supplies listed above
- 16 to 18 gauge catheter-over-the-needle
- 14 to 18 gauge catheter-through-the-needle
- Three-way stopcock
- Connector tubing (connects to three-way stopcock and sterile container)
- Sterile container for pleural fluid
- 50 mL syringe
- Intravenous extension tubing

Commercial kits have been developed and are available to provide the equipment needed to perform a thoracentesis. The kits are disposable, intended for single-patient use, and contain the required equipment. They save time in that the equipment does not have to be found and set up. Disadvantages include potential increased cost and limited equipment in the kit.[18] Common kits include the Pharmaseal, distributed by Baxter (Jacksonville, TX); the Arrow Clark Thoracentesis Kit, distributed by Arrow (Reading, PA); the Argyle Turkel Safety Thoracentesis Kit, distributed by Boston Scientific (Miami, FL), and the Turkel Thoracentesis Kit, distributed by Tyco Healthcare (Mansfield, MA).[3]

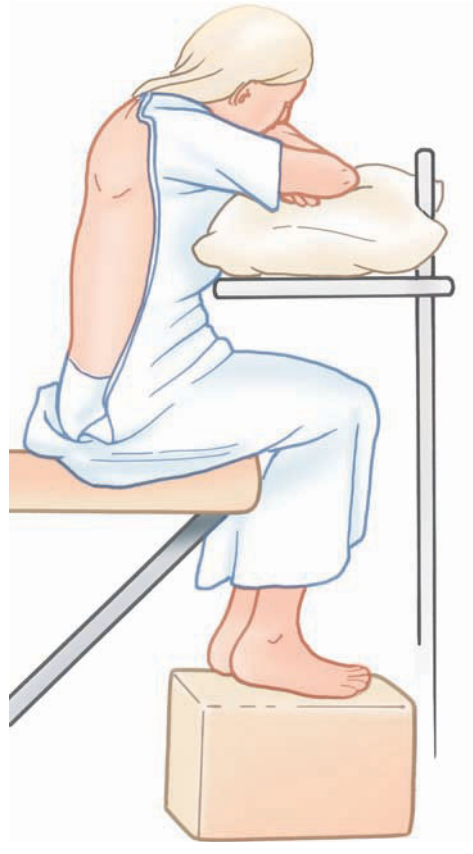


FIGURE 40-2. Recommended positioning of an ambulatory patient for a diagnostic or therapeutic thoracentesis for the evacuation of fluid.[2]

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative and obtain a signed consent form.[1] The position of the patient can vary depending on their clinical condition. Patients who are ambulatory and cooperative should sit up at the edge of a bed with their feet on the floor or a stool (**Figure 40-2**). Place the patient's head and arms on an elevated bedside tray. The patient's back should be as vertical as possible so that the lowest part of the hemithorax is posterior. This will ensure that the free-flowing fluid remains posteriorly.[1–3,16]

In debilitated patients, one of three other positions is recommended. Place the patient in the lateral decubitus position, lying on the side of the pleural effusion. The patient's back should be along the edge of the bed. The procedure would then be performed in the midscapular line or the posterior axillary line. Place a ventilator-dependent patient into the lateral decubitus position, lying on the side with the pleural effusion.[17] Second, place the patient supine and elevate the head of the bed as much as maximally possible. The patient would then be sitting with the assistance of the bed, and the procedure would be performed in midaxillary or posterior axillary line.[3] Finally, the patient can be placed supine. The procedure would then be performed at the posterior or midaxillary line. With the patient supine, ultrasonography may be required to locate the pleural fluid. Sedation or paralysis may be needed for optimal positioning depending on the patients clinical condition.

After positioning the patient, clean any dirt or debris from the skin. Identify the anatomic landmarks required to perform the procedure. After viewing the chest radiograph and estimating the amount of pleural fluid, percuss from superior to inferior starting at the midscapular or posterior axillary line. **The site chosen for aspiration should be a single interspace below the top of the dullness to percussion.**

If the fluid thickness is less than 10 mm on radiographs, ultrasound may be used to locate the fluid.[5,16] Alternatively, ultrasound can be routinely used to locate pleural fluid. Ultrasound has been shown to be comparable to CT for diagnosing and managing a pleural effusion.[19]

Although not required, some Emergency Physicians place the patient on the cardiac monitor, noninvasive blood pressure cuff, pulse oximetry, and supplemental oxygen to monitor them during and after the procedure. Apply povidone iodine or chlorhexidine solution to the skin surface and allow it to dry. Apply sterile drapes around the site of the procedure. If using an ultrasound-guided technique, be sure to fit the transducer with a sterile glove or probe cover before exposing the probe to the sterile skin. Use sterile ultrasound gel. Atropine should be at the bedside. It can be administered (1.0 mg subcutaneously or intramuscularly or 0.5 mg intravenously) to patients who develop symptomatic bradycardia during the procedure. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids as well as protect the patient from infection.

Place a skin wheal of local anesthetic solution over the thoracentesis site using a 25 or 27 gauge needle on a 10 mL syringe containing the local anesthetic solution. Remove the 25 or 27 gauge needle from the syringe. Apply a 21 or 22 gauge, 1.5 to 3.0 in needle to the syringe containing the local anesthetic solution. Anesthetize the subcutaneous tissues and the periosteum of the rib (**Figure 40-3**). Walk the needle up the rib while simultaneously injecting local anesthetic solution. Gently aspirate prior to injecting each time the needle is advanced to ensure that the needle is not within a blood vessel. When the superior border of the rib is located, slowly and

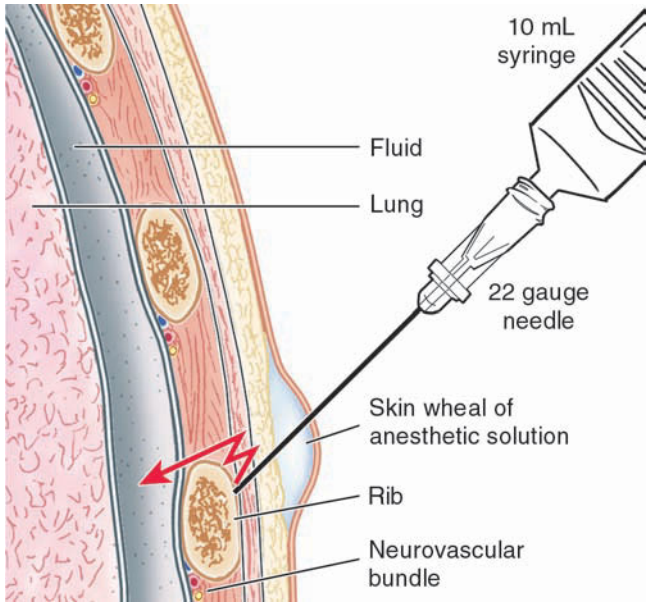


FIGURE 40-3. Administration of local anesthesia. A skin wheal is made. The needle is inserted through the skin wheal while local anesthetic solution is injected to anesthetize the subcutaneous tissues and the periosteum of the rib. The needle is "walked" above the upper border of the rib (red jagged line) to avoid the neurovascular bundle inferior to the rib. The intercostal muscles, parietal pleura, and pleural space are then infiltrated with local anesthetic solution.

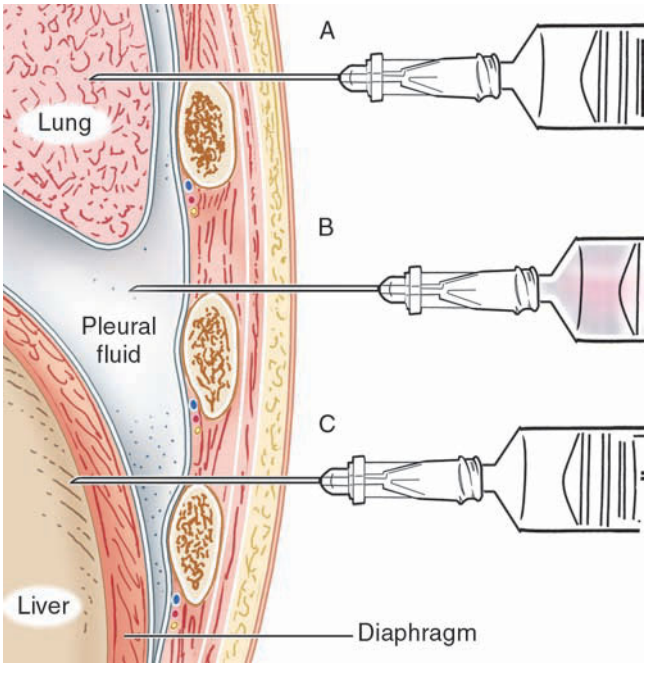


FIGURE 40-4. Needle positioning for a diagnostic thoracentesis. **A.** The pleural space is entered above the effusion (too high). **B.** The pleural space is entered properly, over the rib and into the fluid. **C.** The needle is too low and enters the abdominal cavity below the diaphragm.

carefully advance the needle over the rib while applying negative pressure on the syringe. Be sure not to insert the needle below the rib to avoid injury to the neurovascular bundle inferior to the rib. When the pleural space has been entered, fluid will flow into the syringe. Inject and aspirate small volumes (1 to 2 mL) while the needle is within the pleural cavity. This will distribute the local anesthetic solution into the pleural fluid and ensure anesthesia of the pleura. Withdraw the needle from the pleural cavity and out the skin.

DIAGNOSTIC THORACENTESIS TECHNIQUE FOR PLEURAL EFFUSIONS

Attach an 18 gauge needle to a 50 mL syringe containing 1 mL of heparin. The heparin will ensure accurate pH and cell counts as it prevents the fluid from clotting. Introduce the needle through the anesthetized track and into the pleural cavity (**Figure 40-4B**). Aspirate up to 50 mL of fluid. Withdraw the needle and place the fluid into the appropriate sterile containers. **Use proper techniques when transferring the fluid into containers or specimen tubes to prevent a needlestick injury.**

If pleural fluid cannot be aspirated, also known as a dry tap, four possibilities must be considered. The needle may be too short, positioned too high to reach the fluid (**Figure 40-4A**), positioned too low to reach the fluid (**Figure 40-4C**), or there may not actually be an effusion. Repeat the physical examination and review the chest radiograph to reconfirm the presence of a pleural effusion. Use ultrasound, if available, to assess the presence of a pleural effusion. Penetration of the lung with the needle is rarely catastrophic but can result in a pneumothorax.[3]

For debilitated patients, the principles are the same with the exception of the site for the procedure. If the patient is supine, use the midaxillary line or the posterior axillary line. Be cautious of the diaphragm, as it can be as high as the fifth interspace on expiration at the anterior axillary line. If the patient is in the lateral decubitus position, use the midscapular line or the posterior axillary line for the procedure.

THERAPEUTIC THORACENTESIS TECHNIQUES FOR PLEURAL EFFUSIONS

The same sterile preparation, location of fluid, positioning, and anesthesia considerations apply for therapeutic thoracentesis as with the diagnostic procedures. However, there is one difference between a diagnostic and a therapeutic thoracentesis—that is, the quantity of fluid removed. Up to 1.5 L is removed in a therapeutic thoracentesis. A diagnostic thoracentesis requires approximately 10 to 20 mL of pleural fluid.

CATHETER-OVER-THE-NEEDLE TECHNIQUE

Two types of catheters can be used to perform this procedure. They are the catheter-over-the-needle and the catheter-through-the-needle (**Figures 40-5 & 40-6**). The catheter-over-the-needle technique

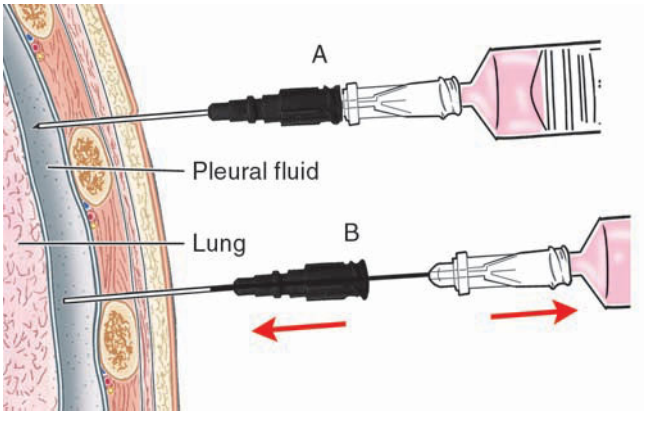


FIGURE 40-5. The catheter-over-the-needle technique. **A.** The needle and catheter are inserted over the rib and aimed slightly caudally into the pleural cavity. **B.** The catheter is advanced into the pleural cavity and the needle is removed.

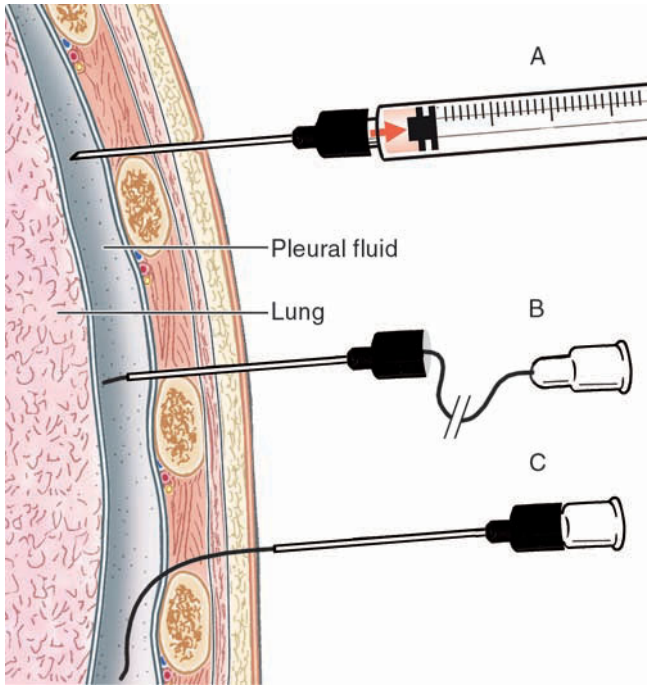


FIGURE 40-6. The catheter-through-the-needle technique. **A.** The needle is inserted over the rib and aimed slightly caudally into the pleural space. **B.** The catheter is inserted through the needle and into the pleural cavity. **C.** The needle is removed and the catheter remains within the pleural cavity.

is most commonly used (**Figure 40-5**). Make a small "nick" in the skin with a #11 surgical blade at the needle insertion site. Attach a 14 to 18 gauge catheter-over-the-needle to a 10 mL syringe as a handle. Insert the catheter-over-the-needle into the nick and advance it, reproducing the original anesthetized tract (**Figure 40-5A**). Apply negative pressure to the syringe as the catheter-over-the-needle is advanced. Stop advancing the catheter-over-the-needle when fluid is aspirated. Angle the catheter-over-the-needle caudally. Securely hold the syringe and needle so they do not move. Advance the catheter until the hub is against the skin. Withdraw the needle and syringe as a unit while the catheter remains in the pleural cavity (**Figure 40-5B**). **When the needle is removed, quickly cover the catheter with a gloved finger. This will prevent ambient air from entering the pleural cavity.** Attach intravenous catheter extension tubing to the hub of the catheter. Place a three-way stopcock attached to a 50 mL syringe onto the extension tubing. Hold the catheter hub against the skin securely. Aspirate fluid into the syringe and then advance the fluid into the sterile container by adjusting the three-way stopcock.

An alternative option is to set up a siphon through the three-way stopcock. Prime the tubing with pleural fluid. Place the end of the tubing into a sterile container that is located below the site of the catheter. This allows the fluid to flow freely into the sterile container. Fluid can be removed in 50 mL aliquots up to 1.5 L. As a general rule, this is the limit, due to the risk of postevacuation pulmonary edema and excessive protein loss.[1]

CATHETER-THROUGH-THE-NEEDLE TECHNIQUE

The second option is to utilize the catheter-through-the-needle system (**Figure 40-6**), known as the Bardig Intracath system. It is not as popular as the catheter-over-the-needle systems. Place the needle on a tuberculin syringe. Insert the needle and advance it through the anesthetized tissues (**Figure 40-6A**). A small "nick" in the skin with a #11 surgical blade will facilitate needle entry. Apply negative pressure to the syringe as the needle is advanced along the anesthetized tract and into the pleural cavity (**Figure 40-6A**). Stop advancing the needle when fluid is aspirated. Securely hold the needle so it does not move. **Remove the syringe and cover the needle hub with a gloved finger. This will prevent ambient air from entering the pleural cavity.** Angle the needle slightly caudally and advance the catheter through the needle (**Figure 40-6B**). Withdraw the needle, leaving the catheter within the pleural cavity (**Figure 40-6C**). **Once the needle is removed, do not readvance the needle, as the catheter may shear off and fall into the pleural cavity.** Place a three-way stopcock or a large syringe onto the hub of the catheter. Place the needle guard on the needle. Secure the catheter by taping it to the skin. Withdraw fluid as previously described. Fluid can be removed in 50 mL aliquots up to 1.5 L. As a general rule, this is the limit, due to the risk of postevacuation pulmonary edema and excessive protein loss.[1]

SELDINGER TECHNIQUE

An alternative approach is to use the Seldinger technique to insert a small bore catheter into the pleural cavity. The major disadvantages to this technique include the time it takes to insert the catheter, the cost of the catheter kit versus a catheter-over-the-needle, and catheter blockage (from cells, debris, and protein) requiring insertion of a second catheter. Another option is to use a central venous catheter kit.[20,21] The larger catheter opening may not become obstructed as easily.

ULTRASOUND-GUIDED TECHNIQUE FOR PLEURAL EFFUSIONS

Ultrasound can be used to map the location and the extent of pleural effusion, and to help identify the appropriate site of needle entry. Real-time guidance is usually not required. A 3.5 to 5.0 MHz phased-array probe is recommended for ultrasound-guided examination of the pleural space.[22] In general, orientation of the probe follows the convention that the probe marker should correlate to the reference point in the left upper corner of the screen.

With the patient in an upright sitting position, percuss and auscultate the posterior thorax to estimate the location of pleural fluid. Apply sterile ultrasound gel onto the ultrasound probe cover. Place the probe at the intercostal space of the estimated level of pleural fluid in the posterior axillary line, usually at the level of ribs 9 to 11. Sweep the probe superiorly and inferiorly, as well as transversely, to assess the location and size of the fluid collection. Identify the liver on the right, the spleen on the left, and the diaphragm.

In a debilitated patient in the lateral decubitus position, place the ultrasound probe in the midscapular line or, if possible, the posterior axillary to locate the fluid. A ventilator-dependent patient should be placed in the lateral decubitus position. If the patient is supine, place the probe in the posterior or midaxillary line. The real-time movement of the diaphragm can be used as a key reference point when examining the pleural space.[23] The liver may also be used as a echogenic reference point for the identification of adjacent hyperechoic or hypoechoic structures. Keep in mind that the best window to view the intrathoracic contents is through the intercostal space, as ultrasound penetration through the soft tissue is superior to that of bone.

The ultrasound waves will initially penetrate the skin, subcutaneous tissue, and muscle to produce multiple layers of varying echogenicity. The echogenic ribs cast an acoustic shadow (**Figure 40-7**). The parietal and visceral pleura are encountered posterior to the rib as two hyperechoic lines, each <2 mm thick.[23,24] The diaphragm can be identified as a hyperechoic transverse structure at the base of the chest wall. The lung is visualized as a bright, hyperechoic structure just cephalad to the diaphragm. The lung should become more



FIGURE 40-7. Ultrasound image of a normal lung. Visualized from top to bottom are the subcutaneous tissues, muscle (M), rib shadow (*arrowhead*), and pleural line (*arrows*).

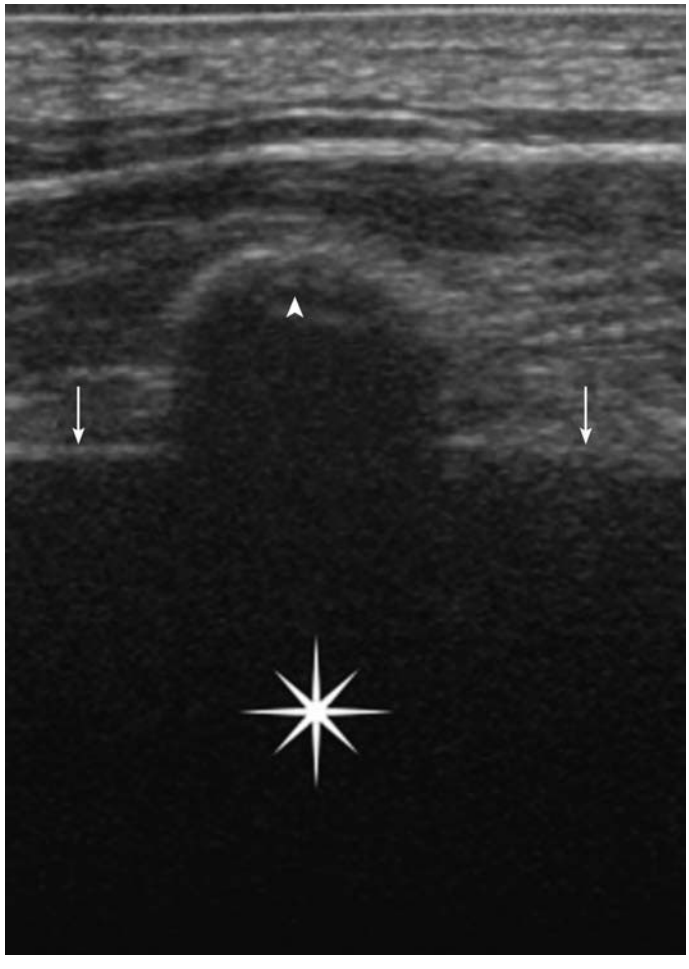


FIGURE 40-8. Ultrasound image of a pleural effusion. The pleural effusion appears black or anechoic (*asterisk*). The pleura is not brightly echogenic (*arrows*) due to the separation of the two layers. Note the rib shadow (*arrowhead*) in the upper part of the image.

intensely hyperechoic, or brighter in the inspiration phase. A pleural effusion can be identified as an anechoic to a hypoechoic image above the diaphragm that decreases in size with inspiration.

Two additional ultrasound findings should be identified on exam: "lung slide" and "comet tail" artifact. The movement of the lung in reference to the surrounding parietal pleura with inspiration and expiration produces an artifact referred to as "lung slide." Normal inspiration should produce a "slide" with each breath, representing movement between the visceral and parietal pleural interface. The thin, hyperechoic sliding line is located approximately 0.5 cm below the surface of the rib, and should move back and forth with each inspiration.[25] A "comet tail artifact" is another normal finding that can be readily identified in a healthy patient. The comet tail artifact is identified as a hyperechoic vertical artifact that slides transversely and is oriented perpendicular to the transverse "lung slide" previously mentioned.[25]

A pleural effusion is easily visualized using ultrasound (**Figure 40-8**). It appears black or anechoic. A distinct hyperechoic pleural line is not seen as the parietal and visceral pleura are separated by the effusion. Lung tissue appears hyperechogenic compared with the anechoic effusion (**Figure 40-9**). The pleural effusion can be seen moving during the respiratory cycle.

The posterior approach is the preferred choice in the stable, cooperative patient who is able to sit up and lean over a table (**Figure 40-10**). To survey the lung anatomy and map the effusion, scan the posterior hemithorax from the inferior border of the scapula to the upper lumbar region and from the paravertebral area to the posterior axillary line. Note the minimum depth of the effusion and the location of other vital structures (i.e., diaphragm, liver, spleen, and lung). Scan with the probe parallel to and perpendicular to the ribs, and observe the structures during the full respiratory phase. The diaphragm can go as low as the 12th rib posteriorly and as high as the 8th rib laterally. Determine the location of the skin entry site. Mark the site with a pen, surgical marker, or by indenting the skin with the cap of a needle. The ideal site should have a large area of pleural effusion and be free of any internal structures (i.e., liver, spleen, or diaphragm) along the needle path.

The lateral approach is used for mechanically ventilated patients and for those who are unable to sit up for the procedure. Abduct the ipsilateral arm and place the hand behind the patient's head, as one would in preparation for the placement of a chest tube (**Figure 40-11**). Survey the anterior and lateral thorax from the midclavicular line to the posterior axillary line. Note the depth of the effusion and the location of any vital structures to be avoided. Determine and mark the skin entry site.

The lateral decubitus approach is an alternative for patients unable to sit upright. Place the patient on their side with the pleural effusion side down. Use ultrasound to map the effusion. Note the distance from the skin to the effusion, the depth of the effusion, as well as the presence of any important structures to be



FIGURE 40-9. Ultrasound image of a pleural effusion (*asterisk*) with the underlying hyperechoic lung tissue (L). Note the rib shadow (*arrowhead*) in the upper left of the image.



FIGURE 40-10. Posterior approach in the sitting patient. A linear ultrasound probe is seen here, although a phased-array probe is often preferred to visualize deeper structures.

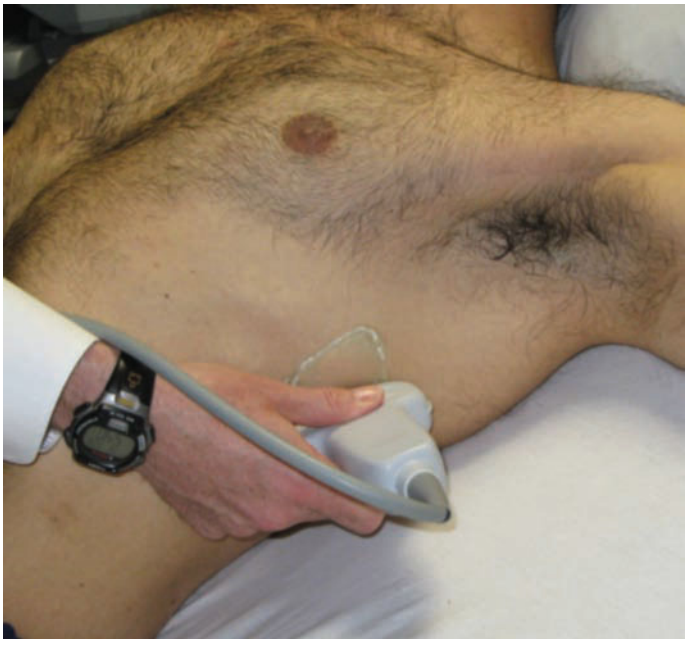


FIGURE 40-11. Lateral approach in the supine patient. A curvilinear probe is positioned in the midaxillary line. Note the coronal plane of the probe.

avoided. Determine and mark the skin entry site, usually at the posterior axillary line.

Regardless of the patient position or approach, do not allow the patient to move once they have been scanned and the skin entry site marked. Prep and drape the patient similar to that for the blind thoracentesis approach. Use local anesthetic to anesthetize the skin, rib, and pleura. The catheter-over-the-needle can be inserted blindly, as described previously, at the skin insertion site or using real-time ultrasound guidance.

The use of ultrasound guidance can be helpful. Place a sterile cover over the ultrasound probe. Apply sterile ultrasound gel over the cover. Rescan the patient in the area previously identified the skin entry site (**Figure 40-12**). Verify that no structures are along

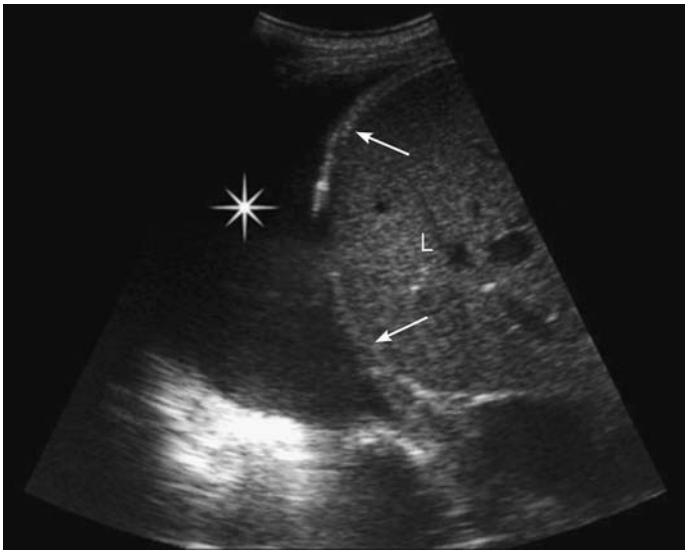


FIGURE 40-12. The pleural effusion (*asterisk*) is visible above the diaphragm (*arrows*). The liver (L) is seen below the diaphragm.

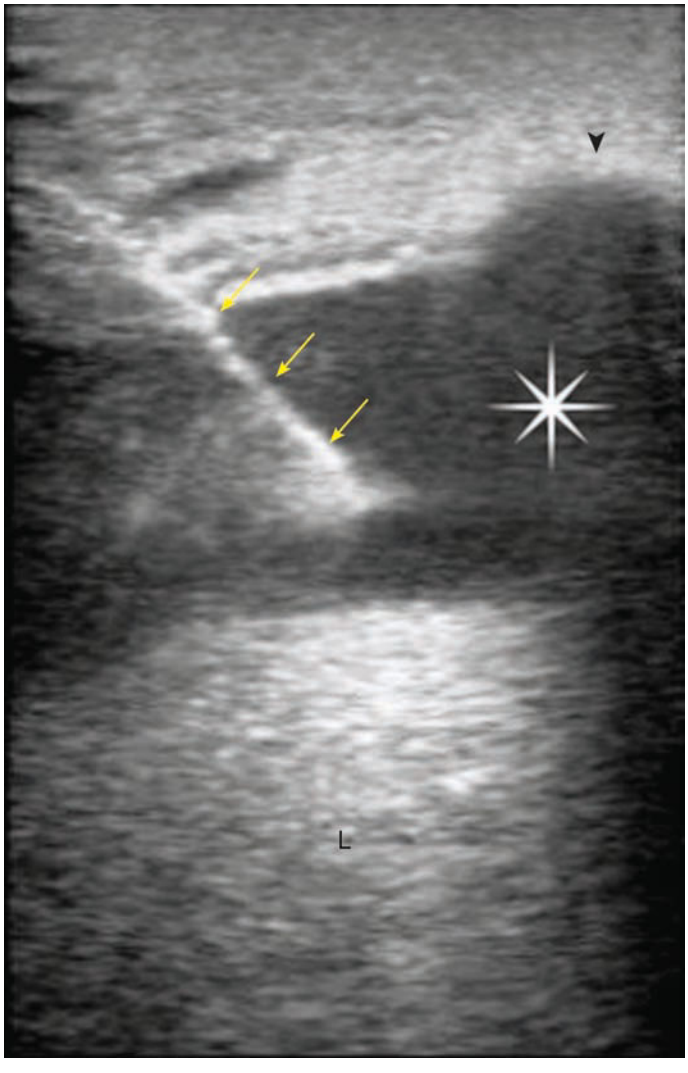


FIGURE 40-13. Long-axis view of a thoracentesis needle (*arrows*) being placed into a pleural effusion (*asterisk*) under ultrasound guidance. The rib shadow is denoted by an arrowhead.

the needle path between the skin and the pleural effusion. Insert an 18 gauge catheter-over-the-needle into the pleural space using the technique already described while using ultrasound for real-time visualization of the needle entering the pleural cavity. The needle will appear as a thin, bright, hyperechoic structure moving through the skin, subcutaneous tissue, parietal pleura, visceral pleura, and finally reaching the hypoechoic pleural effusion (**Figure 40-13**). Aspirate to confirm that the catheter-over-the-needle is within the pleural effusion. Place the ultrasound probe aside. Continue the remainder of the procedure as described previously.

ASSESSMENT

Numerous analyses of the pleural effusion fluid are required to determine its etiology (**Table 40-2**). Large pleural effusions are more commonly associated with infections and malignancy.[26] Fluid analysis criteria have been established to separate transudates and exudates.[10,27] If the fluid fits one of the criteria in **Table 40-3**, it is an exudate. These parameters have been confirmed to have 98% sensitivity and 83% specificity in detecting exudates.[28] Color and odor can be helpful. If the fluid has a putrid odor, consider an infection. White or yellow fluid suggests an empyema or chylothorax. The fluid's white blood cell count is of limited benefit. If it is >10,000, the fluid likely represents a parapneumonic effusion. A pleural fluid hemoglobin and hematocrit can be compared to that of the blood. Bloody pleural effusions are usually associated with malignancy, pneumonia, pulmonary embolism with a lung infarction, or trauma.[29] If the fluid is grossly bloody, consider a hemothorax. If the pleural fluid's hematocrit is >50% of the serum hematocrit, a hemothorax is likely and chest tube placement should be considered. Other helpful tests include a fluid pH. If the pH is below 7.25 to 7.30, consider it the result of a parapneumonic process, rheumatologic process, esophageal rupture, or malignancy. An elevated amylase level suggests esophageal rupture, malignancy, or pancreatic disease.[30] Elevated triglyceride levels suggest a chylothorax. Cytology is important to search for an underlying malignancy. Up to 50% of patients with a pulmonic malignancy will have neoplastic cells in the pleural fluid.[3] Bacteriologic information such as Gram's stain, acid-fast, and fungal preparations are also important, although the yield can be below 30%.[16] Fluid should always be sent for aerobic and anaerobic cultures to rule out an infectious etiology for the pleural effusion. The appearance of pleural fluid on ultrasound may help identify whether the pleural fluid is a transudate or an exudate. Transudates are consistently seen as anechoic, whereas exudates may range from an anechoic to a hyperechoic.[31,32]

TABLE 40-2 Laboratory Analysis of Pleural Effusions

Acid-fast stain
Amylase
Cell count and differential
Color
Cultures
Acid-fast
Aerobic
Anaerobic
Fungal
Glucose
Gram stain
Hemoglobin and hematocrit
pH
Triglycerides

AFTERCARE

When done aspiring fluid, remove the catheter and apply a bandage to the puncture site. Several authors have suggested that a postprocedure chest radiograph may not be necessary.[33,34] These were small studies with methodologic errors. Omitting the postprocedure chest radiograph cannot be recommended at this time. Obtain a plain chest radiograph upon completion of the procedure to assess for a pneumothorax. An expiratory film is the best film to look for a pneumothorax, especially if it is small. Repeat a chest radiograph in 4 to 6 hours to look for a delayed pneumothorax. If no pneumothorax is present and if appropriate for the clinical condition, the patient may be discharged with good instructions and close follow-up.

TABLE 40-3 Laboratory Features of a Pleural Fluid Exudate

Fluid/serum lactate dehydrogenase (LDH) > 0.6
Fluid/serum protein > 0.5
Pleural fluid LDH > 200 IU/mL
Pleural fluid LDH > 2/3 upper limit of normal for serum

TABLE 40-4 Potential Complications Associated with a Thoracentesis

Cough
Hemothorax
Hypovolemia
Hypoxemia
Inadequate yield
Intrapleural infection
Laceration of an intercostal nerve or vessel
Laceration of the liver or spleen
Pain at the procedure site
Pneumothorax
Reexpansion pulmonary edema
Shortness of breath
Tension pneumothorax
Vasovagal reactions

The procedure site should be evaluated two to three times a day for signs of infection. These patients should be educated about the signs, symptoms, and significance of an infection. They should return to their primary physician or the Emergency Department immediately if they develop fever, chills, shortness of breath, redness or pus at the puncture site, or if any concerns arise.

COMPLICATIONS

The potential complications of a thoracentesis are listed in **Table 40-4**.[1,3,16,28,35] Complication rates range from 20% to 50%. The major complications are a 5% to 19% incidence of pneumothorax and a 1% to 7% incidence of pneumothorax requiring a chest tube.[11,36] One author recommends ultrasound-guided thoracentesis for all patients as the safest approach, although this is disputed by others.[9,36] The majority of studies report lower rates of postprocedural pneumothoraces with ultrasound-guided thoracentesis performed by an experienced operator.[9–11,15,37–41] However, others have not shown a significant difference in the incidence of postprocedural pneumothoraces with the use of ultrasound.[42,43]

The use of the proper technique and the Emergency Physician's experience are important in reducing the rate of complications.[44–46] Despite this, it is difficult to predict which patients may be at risk of developing a postprocedural pneumothorax.[47] Drainage of large volumes of fluid, greater than 1.5 to 2 L, may increase the risk of developing a pneumothorax.[48] Improper technique or tortuosity of the intercostal artery can result in intercostal artery injury.[49] Qureshi compiled methods to reduce the incidence of pneumothorax.[16] They are direct supervision of inexperienced operators, removal of small amounts of fluid, use of small-gauge needles, use of ultrasound for small effusions, and use of a needle-catheter system for a therapeutic procedure.

PNEUMOTHORAX

ANATOMY AND PATHOPHYSIOLOGY

A thoracentesis can be performed to relieve a simple pneumothorax or a tension pneumothorax. A pneumothorax can be defined by the presence of air between the visceral and parietal pleura.[25] Primary spontaneous pneumothoraces occur in otherwise healthy people without antecedent trauma. Secondary spontaneous pneumothoraces occur as a complication of underlying lung disease, most commonly chronic obstructive pulmonary disease.[1,3] A traumatic pneumothorax occurs as a result of penetrating or blunt trauma to the thoracic cavity. An iatrogenic pneumothorax is a subcategory of the traumatic pneumothorax, with the three most common etiologies being pleural biopsy, subclavian vein catheterization, and thoracentesis.

The pressure in the pleural space is negative in reference to the atmosphere. This is due to the tendency of the lung to collapse and the chest wall to expand. The alveolar pressure is greater than the pleural space pressure due to the elastic recoil of the lung. As a result, if a communication occurs between the alveolar and pleural space, the air will preferentially move into the pleural space until the pressure equalizes. The physiologic consequence is a decrease in vital capacity and PaO_2. This may be well tolerated in otherwise healthy people but not in patients with underlying cardiac and/or pulmonary disease. If a one-way valve develops such that air can only enter the pleural space from the alveolus but not return, the intrapleural pressure will eventually exceed atmospheric pressure, with a progressive increase in air occupying the pleural space. Clinical deterioration may occur due to a decreasing PaO_2 and cardiac output.[50–52] Other data point to hypoxia and hypercarbia as the cause of clinical deterioration.[18]

Ultrasound guidance may aid in locating a pneumothorax, with the best viewing window being the intercostal space. Zhang et al. showed a sensitivity and specificity of ultrasound in diagnosing a pneumothorax of 86% and 97%, respectively; whereas conventional radiography was 28% and 100%, respectively.[53] In addition, ultrasound diagnosed a pneumothorax within only 2 to 5 minutes, compared to 20 to 30 minutes for chest radiography.[53] In a similar study, ultrasound showed a sensitivity and specificity of 100% and 94% for detection of pneumothoraces, compared to 36% and 100% for chest radiography.[54]

Controversy exists to the exact management of a spontaneous pneumothorax.[55–60] Options include simple aspiration, tube thoracostomy, and simple aspiration followed by a tube thoracostomy if aspiration fails. Simple aspiration is more likely to fail with larger pneumothoraces.[58,59] Several recent reviews, including a Cochrane Collaboration, came to similar conclusions regarding simple aspiration.[55–57] These conclusions, while not definitive, were that simple aspiration is associated with a reduction in the percentage of patients requiring hospitalization compared to tube thoracostomy. There were no differences between the two procedures in early failures, immediate success rate, duration of hospitalization, one-year success rates, and the number of patients requiring a subsequent pleurodesis. Advantages of simple aspiration compared to tube thoracostomy include less equipment costs, easier to perform, simpler to perform, quicker to perform, and the potential to avoid hospitalization.

INDICATIONS

All tension pneumothoraces require needle drainage followed by tube thoracostomy. Patients usually present with respiratory distress, tachycardia, unilateral absence of breath sounds, hypotension, and neck vein engorgement. Although difficult to assess, these patients have tracheal deviation that is often limited to the thoracic cavity.

Not all simple pneumothoraces require drainage, as they may resolve spontaneously. Conservative management has shown a spontaneous resorption rate of 1.25% per day.[46] A pneumothorax should be drained if the patient complains of dyspnea, dyspnea on exertion, pain, or if the pneumothorax is estimated to be 15% or greater.

CONTRAINDICATIONS

There are no absolute or relative contraindications to relieving a tension pneumothorax, as it is a life-threatening emergency.

Contraindications to thoracentesis to relieve a simple pneumothorax are few. These include infection at the site of the procedure,

in which case an alternate site should be selected.[3] A traumatic pneumothorax or a pneumothorax associated with a hemothorax or pyothorax requires tube thoracostomy. Any pneumothorax that is expanding or expanding despite thoracentesis also requires a tube thoracostomy. Any patient on anticoagulation or with a suspected bleeding diathesis, whether known or suspected, may require reversal of the condition before the procedure.[1] A patient with minimal symptoms and a small pneumothorax may be observed before deciding to evacuate the pneumothorax.

EQUIPMENT

Pneumothorax—Tension

- Alcohol swab, povidone iodine solution, or chlorhexidine solution
- 12 to 16 gauge catheter-over-the-needle, 2 in. long

Pneumothorax—Stable

- Sterile gloves and gown
- Face mask with a face shield or goggles
- Povidone iodine or chlorhexidine solution
- Sterile gauze sponge
- Sterile towels
- Sterile basin
- Syringes for anesthesia infiltration, 5 and 10 mL
- 25 gauge needle for anesthesia infiltration of the skin
- 21 or 23 gauge needle for infiltration of subcutaneous tissue, periosteum, and pleura
- 16 or 18 gauge catheter-over-the-needle
- 14 to 18 gauge catheter-through-the-needle
- Pigtail or straight catheter kit
- Three-way stopcock
- 50 mL syringe
- Intravenous extension tubing
- Heimlich valve

Ultrasound Guidance

- Ultrasound machine
- 3.5 to 5.0 MHz phased-array ultrasound probe
- Sterile ultrasound gel
- Sterile ultrasound probe cover

Commercial kits have been developed and are available to provide the equipment needed to perform a thoracentesis. These kits are disposable, single-patient use, and contain all the required equipment. They save time in that the equipment does not have to be found and set up. Disadvantages include potentially increased cost and limited equipment in the kit.[18] Common kits include the Pharmaseal, distributed by Baxter (Jacksonville, TX); the Arrow Clark Thoracentesis Kit, distributed by Arrow (Reading, PA); and the Argyle Turkel Safety Thoracentesis Kit, distributed by Boston Scientific (Miami, FL).[3]

The TRU-CLOSE Thoracic Vent (UreSil, Skokie, IL) is an alternative device to the pigtail catheter and Heimlich valve combination. It is a one-piece unit that combines an intrapleural catheter and an external one-way antireflux valve that attaches to the chest wall by an adhesive pad. Its insertion is quicker, easier, and simpler than a traditional catheter. The low profile makes ambulation and outpatient management easier for the patient. These devices are rarely available in the Emergency Department.

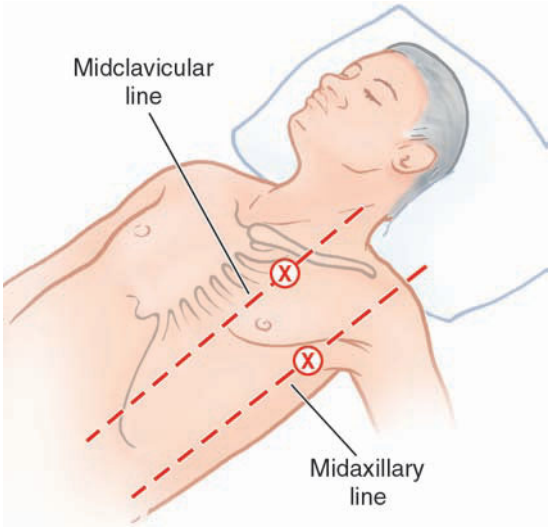


FIGURE 40-14. Relief of a tension pneumothorax. The patient should be in the supine position, with the head of the bed elevated 30° if not contraindicated. The second intercostal space in the midclavicular line is the recommended site. For pleural effusions or a debilitated patient, the midaxillary line or posterior axillary line may be used at the level of the fourth or fifth intercostal space.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative and have a consent form signed.[1] Place the patient supine on the bed. Alternatively, the patient may be supine with the head of the bed elevated to 30° (**Figure 40-14**). Clean any dirt or debris from the skin. Identify the anatomic landmarks required to perform the procedure. Although not required, it is recommended to place the patient on the cardiac monitor, noninvasive blood pressure cuff, pulse oximetry, and supplemental oxygen. Apply povidone iodine or chlorhexidine solution to the skin surface and allow it to dry. Apply sterile drapes around the site of the procedure. Atropine should be at the bedside. It may be administered (1.0 mg subcutaneously or intramuscularly or 0.5 mg intravenously) to patients who develop symptomatic bradycardia during the procedure. The most common approach is the second intercostal space in the midclavicular line (**Figure 40-14**). An alternate site is the fourth or fifth intercostal space in the midaxillary line. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids as well as protect the patient from infection.

TENSION PNEUMOTHORAX TECHNIQUE

If the patient has a tension pneumothorax, thoracentesis is both a diagnostic and therapeutic procedure. A tension pneumothorax is a true life threat. Identify the needle insertion site by palpating the second intercostal space in the midclavicular line. If a tension pneumothorax is clinically evident, ultrasound guidance is not necessary prior to needle decompression and should not delay treatment. **Insert the catheter-over-the-needle over the superior border of the third rib to avoid the neurovascular bundle, which is located on the inferior border of the second rib.** Advance the catheter-over-the-needle into the pleural space. If time permits, a 5 to 10 mL syringe without the plunger can be attached to the catheter-over-the-needle. The syringe barrel can be used as a handle to advance the catheter-over-the-needle.

When the pleural cavity is entered, a release of pressure and a small "pop" may be felt. Stop advancing the needle. Securely hold the needle so it does not move. Advance the catheter until the hub is against the skin. Remove the needle. If the patient has a tension pneumothorax, a continuous rush of air will be heard or felt. **Needle thoracentesis for a tension pneumothorax is a temporizing measure; therefore, a tube thoracostomy should be performed immediately after this life-saving procedure.** Refer to Chapter 39 for complete details regarding this procedure.

SIMPLE PNEUMOTHORAX TECHNIQUES

A primary spontaneous pneumothorax occupying over 15% of the hemithorax is the indication for simple aspiration via a thoracentesis.[3] The same sterile preparation, location of fluid, positioning, anesthesia considerations, and ultrasound-guided technique apply to the evacuation of a simple pneumothorax as to a diagnostic thoracentesis.

Spontaneous pneumothoraces used to be drained by tube thoracostomy. Simple aspiration may be just as effective as a tube thoracostomy.[55–60] If a tube thoracostomy is required, a small bore straight or pigtail catheter can be just as effective to manage a spontaneous pneumothorax.[61–65] While an initial study recommends using small bore tubes in patients with chest trauma, further clinical information is required before this becomes standard of care.[66] The advantages of a small bore catheter include: less pain on insertion, decreased need for analgesics and sedation, and the potential to discharge the patient with outpatient management.

CATHETER-OVER-THE-NEEDLE TECHNIQUE

Two types of catheters can be used to perform this procedure. They are the catheter-over-the-needle and the catheter-through-the-needle (**Figures 40-5 & 40-6**). The catheter-over-the-needle technique is most commonly used (**Figure 40-5**). Make a small "nick" in the skin with a #11 surgical blade at the needle insertion site. Attach a 14 to 18 gauge catheter-over-the-needle to a 10 mL syringe as a handle. Insert the catheter-over-the-needle into the nick and advance it, reproducing the original anesthetized tract (**Figure 40-5A**). Apply negative pressure to the syringe as the catheter-over-the-needle is advanced. Stop advancing the catheter-over-the-needle when air is aspirated. Angle the catheter-over-the-needle superiorly. Securely hold the syringe and needle so they do not move. Advance the catheter until the hub is against the skin. Withdraw the needle and syringe as a unit while the catheter remains within the pleural cavity (**Figure 40-5B**). **When the needle is removed, quickly cover the catheter with a gloved finger. This will prevent ambient air from entering the pleural cavity.** Attach intravenous catheter extension tubing to the hub of the catheter. Place a three-way stopcock attached to a 50 mL syringe onto the extension tubing. Hold the catheter hub against the skin securely. Aspirate air into the syringe and then advance the air into the room by adjusting the three-way stopcock. Air is then withdrawn manually. This process should be continued until resistance is felt. **If no resistance is felt after 4 L of aspiration, it is presumed that expansion has not occurred and a continual leak of air exists from the lung into the pleural cavity; therefore a tube thoracostomy should be performed.** After no more air is aspirated, close the stopcock and secure it to the chest wall. The success rate for the aspiration of a pneumothorax is 64%.[67,68]

CATHETER-THROUGH-THE-NEEDLE TECHNIQUE

The second option utilizes the catheter-through-the-needle system (**Figure 40-6**), which is known as the Bardig Intracath system. It is not as popular as the catheter-over-the-needle systems. Place the needle on a tuberculin syringe. Insert the needle and advance it through the anesthetized tissues (**Figure 40-6A**). A small "nick" in the skin with a #11 surgical blade will facilitate the needle entry. Apply negative pressure to the syringe as the needle is advanced along the anesthetized tract and into the pleural cavity (**Figure 40-6A**). Stop advancing the needle when air is aspirated. Securely hold the needle so it does not move. **Remove the syringe and cover the needle hub with a gloved finger. This will prevent ambient air from entering the pleural cavity.** Angle the needle slightly superiorly and advance the catheter through the needle (**Figure 40-6B**). Withdraw the needle, leaving the catheter within the pleural cavity (**Figure 40-6C**). **Once the needle is removed, do not readvance the needle, as the catheter may shear off and fall into the pleural cavity.** Place a three-way stopcock attached to a 50 mL syringe onto the hub of the catheter. Place the needle guard on the needle. Secure the catheter by taping it to the skin. Withdraw air as previously described.

SELDINGER TECHNIQUE

Drainage can also be accomplished using a pigtail or straight catheter and the Seldinger technique (**Figure 40-15**). An alternative is to use a central venous catheter if a pigtail catheter is not available.[18,19] Attach a 16 gauge, 2 in catheter-over-the-needle to a 5 or 10 mL syringe. Insert the catheter, as described above, aimed superiorly. Securely hold the needle and syringe so it does not move. Advance the catheter to the hub. Remove the needle and syringe. **Quickly cover the catheter hub with a gloved finger.** Insert the guidewire through the catheter (**Figure 40-15A**). **Hold the guidewire securely to prevent it from falling completely into the pleural cavity.** Remove the catheter over the guidewire, leaving the guidewire in place (**Figure 40-15B**). Extend the skin incision with a #11 scalpel blade by 3 to 5 mm to allow the catheter to enter into the pleural space without "crumpling" (**Figure 40-15C**). Advance the dilator over the guidewire and into the pleural cavity to dilate the tract (**Figures 40-15C & D**). A gentle twisting motion of the dilator as it is advanced will aid in its insertion into the pleural cavity (**Figure 40-15D**). Hold the guidewire securely. Remove the dilator while leaving the guidewire in place. Insert the catheter over the guidewire and into the pleural cavity (**Figure 40-15E**). Remove the guidewire and attach a three-way stopcock to the catheter. Aspirate the air as described previously.

DRAINAGE SYSTEMS

Drainage systems for a pneumothorax vary in style but function with the same "one-way valve" principle. The simplest method is a flutter valve. It is best illustrated by the following noncommercial method. Cut a premoistened finger from a sterile glove. Tie the proximal end to the thoracentesis catheter with a silk suture and cut the distal end so that it is open to the air[1] (**Figure 40-16**). This creates a flutter valve and allows air to escape with coughing or expiration and prevents air from reentering the pleural space on inspiration.

A commercial kit often contains a Heimlich flutter valve[1] (**Figure 40-17**). **The arrow on the clear protective tube covering the Heimlich valve must point away from the patient.** Suction is usually not needed. Stable patients can be sent home with this setup. This includes patients with a primary spontaneous pneumothorax and a small apical pneumothorax with initial reexpansion and good apposition of the lung with the lateral chest wall. Up to 30% of patients with a secondary pneumothorax can be treated on an ambulatory basis. Additional requirements include good residual lung function, normal oxygen saturation, and an air leak adequately treated by thoracentesis.[35] **A contraindication to using the flutter valve is a hemothorax.** A closed underwater seal system is recommended in these cases. Refer to Chapter 39 for details regarding the use of a closed underwater seal system and the other indications for its use.

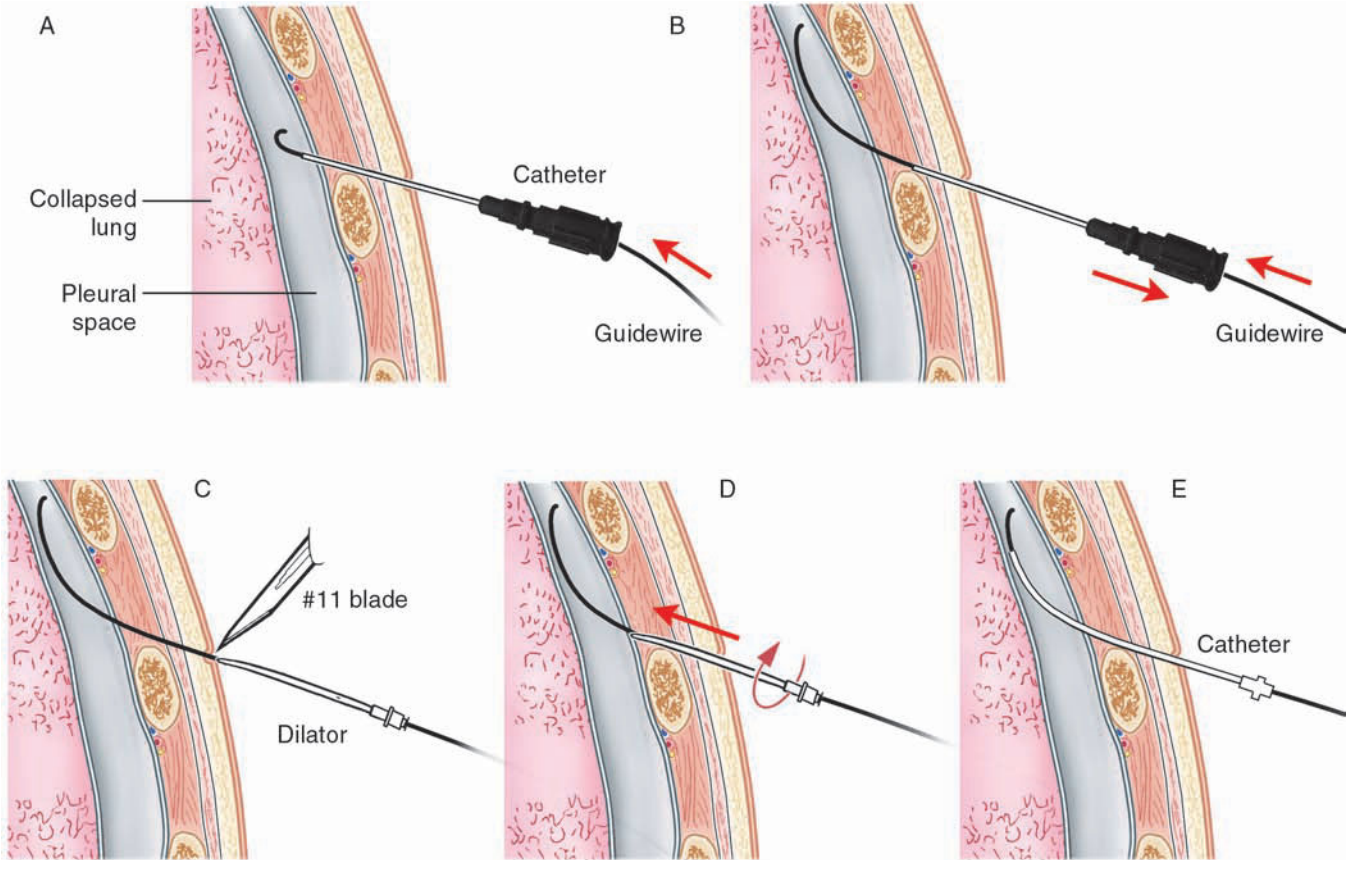


FIGURE 40-15. The Seldinger technique for inserting a catheter to aspirate a pneumothorax. A catheter-over-the-needle has been placed into the pleural cavity and aimed superiorly. The needle has been removed while the catheter remains in the pleural cavity. **A.** A guidewire is inserted through the catheter. **B.** The catheter is removed while the guidewire remains in the pleural cavity. **C.** The skin incision is enlarged with a #11 scalpel blade. A dilator is placed over the guidewire. **D.** The dilator is advanced over the guidewire and into the pleural cavity. A gentle twisting motion will help guide the dilator through the tract. **E.** The dilator has been removed while the guidewire remains inside the pleural cavity. The catheter is advanced over the guidewire and into the pleural cavity. The guidewire is then removed while the catheter remains inside the pleural cavity.

ULTRASOUND-GUIDED TECHNIQUE FOR A PNEUMOTHORAX

The same sterile preparation applies to ultrasound evaluation of a pneumothorax as for evaluation of a pleural effusion. However, a pneumothorax may be more readily identified with the patient positioned supine rather than upright. A 3.5 to 5.0 MHz phased-array probe is recommended for ultrasound-guided examination of the pleural space.[22] In general, the orientation of the probe follows the convention that the probe marker should correlate to the reference point in the left upper corner of the screen.

The key ultrasound features of a pneumothorax include: absence of inspiration–expiration related "lung slide," loss of "comet tail" artifact, and broadening of the pleural line to a thick band.[24] In the case of a unilateral pneumothorax, the hemithorax suspected of

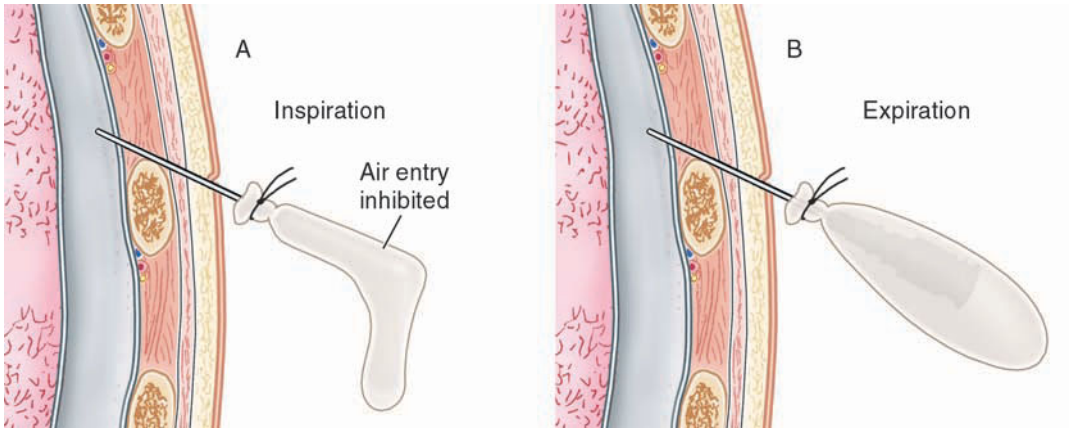


FIGURE 40-16. Use of a finger from a sterile glove as a one-way valve. Place the proximal end of the finger on the drainage system and cut the distal tip. It will act as a one-way valve.

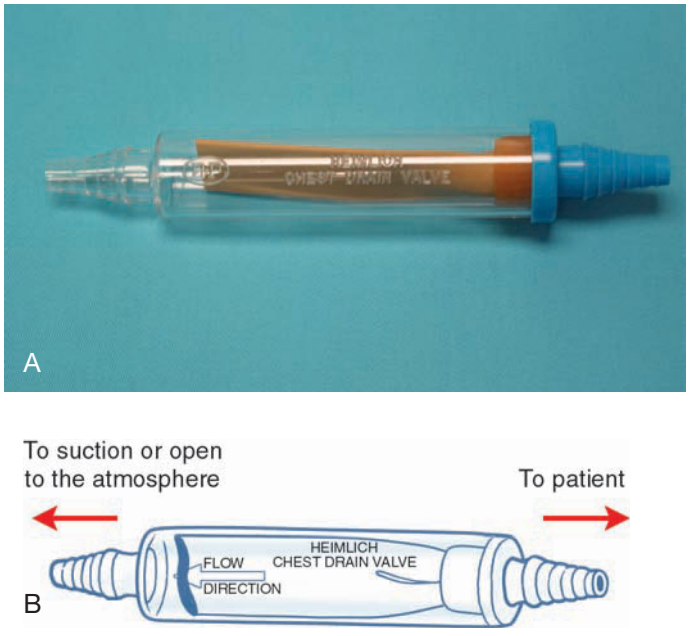


FIGURE 40-17. The Heimlich valve.

having a pneumothorax should be compared to the unaffected side, with the unaffected side showing normal "lung slide," "comet tail" artifact, and pleural line <2 mm thick.

ASSESSMENT

Relief of a tension pneumothorax will equalize the pressure between the atmosphere and the pleural space. The patient will now have a simple pneumothorax. The vital signs should begin to normalize, the pulse oximetry improves, and the respiratory distress improves. If the patient had a tension pneumothorax, they will need a tube thoracostomy followed by a chest radiograph. The patient may begin to cough when the lung reexpands. Breath sounds should be present bilaterally upon reexpansion.

If the patient does not improve clinically after needle decompression for a tension pneumothorax, there are two possibilities. First, the pleural space may not have been entered with the needle. This occurs when the patient is obese or very muscular. The procedure may then be repeated with a longer needle. Second, the patient may not have had a tension pneumothorax. Reevaluate the patient by physical examination, bedside ultrasonography, and review the chest radiograph to determine if a tension pneumothorax is present.

Obtain a chest radiograph after the relief of a simple pneumothorax. It will allow the Emergency Physician to determine the success, or lack thereof, of the procedure. Perform a tube thoracotomy if at any point the pneumothorax is not improving with a thoracentesis or if the patient's symptoms worsen.

AFTERCARE

Obtain a follow-up chest radiograph upon completion of the procedure to assess for a pneumothorax. An expiratory film should be obtained, especially if the pneumothorax was small. A chest radiograph should be repeated 4 to 6 hours after the procedure to look for a delayed pneumothorax. If no pneumothorax is present and if appropriate for their clinical condition, the patient may be discharged with good instructions and close follow-up. An alternative is placement in an observation unit and discharge within 24 hours.[69]

The procedure site should be evaluated two to three times a day for signs of infection. These patients should be educated about the signs, symptoms, and significance of an infection. They should return to their primary physician or Emergency Department immediately if they develop fever, chills, shortness of breath, redness or pus at the puncture site, or if any concerns arise.

A patient may be a candidate for outpatient management with a Heimlich valve under the following conditions: a stable primary spontaneous pneumothorax, close apposition of the lung to the lateral chest wall with initial thoracentesis or aspiration and drainage procedures, Emergency Physician satisfaction with the position of the catheter, and an air leak that is manageable with one thoracentesis. A small study has confirmed this outpatient management, whereas many Emergency Physicians have been managing patients like this for years.[70] Contraindications for outpatient management include traumatic pneumothoraces, secondary pneumothoraces, a patient with poor residual function, a large air leak requiring tube thoracostomy, a hemothorax, unacceptable residual collapse defined as poor apposition of the lateral lung to the lateral chest wall, or if the patient is not reliable.[6]

Instructions to the patient should include the following: clean the thoracentesis site with mild soap daily; apply a split dressing around the catheter and tape it to the skin; make sure that the tubing is taped firmly to the valve to prevent accidental dislodgment; the arrow on the valve should point away from the patient; the sound of air exiting the valve is expected; and showers are permitted but not a bath or swimming. If these patients experience shortness of breath, chest pain, or difficulty breathing, they should call 911 and immediately return to the Emergency Department. Instruct the patient on the removal of the Heimlich valve from the catheter if significant shortness of breath develops as they may have developed a tension pneumothorax. They should also be instructed on the signs of an infection at the chest wall insertion site.

The patient should follow-up daily for radiographic evaluation. Upon complete inflation of the lung, the thoracentesis catheter can be removed. The patient should be observed for 4 to 6 hours after catheter removal and a repeat chest radiograph obtained. The patient can be discharged if the lung is completely expanded. If not, a thoracostomy tube should be reinserted and the patient admitted.

COMPLICATIONS

Complications associated with this procedure can be numerous. Clinically, a pneumothorax can become worse. Causes include lacerating the lung with the needle, inadequate coverage of the hub of the needle or catheter with a gloved finger after entering the pleural space, and an air leak in the drainage system. It may also occur from a lung parenchymal-pleural fistula that can develop from poor lung expansion during large-volume pneumothorax drainage.[71] A tension pneumothorax can occur from a lung laceration along with inadvertent plugging of the drainage system (e.g., fluid in tube, kinking). A hemothorax is possible if the lung, intercostal artery, or mammary artery is lacerated with the needle. Less common complications include cardiac or great vessel perforation due to poor positioning of the needle upon insertion. Infection occurs about 2% of the time if sterile technique is observed. Catheter shearing is possible with the catheter-through-the-needle system if the needle guard is not placed on the needle or the catheter is withdrawn through the needle. Many of these complications can be prevented by the use of proper and careful technique.

Reexpansion hypotension has been reported following rapid evacuation of persistent unilateral pneumothoraces of at least

1 week duration. The mechanism is unclear. It is associated with reexpansion pulmonary edema that precipitates intravascular volume depletion, myocardial depletion, or large volume aspiration.[1] Reexpansion pulmonary edema may be precipitated by pneumothoraces over a few days duration before reexpansion or large volume aspiration.[72–74]

SUMMARY

A thoracentesis can help differentiate between transudates and exudates. Together with the clinical presentation, the information can be useful in diagnosing the patient's condition. It can be lifesaving if the patient has a tension pneumothorax. It offers an alternative to tube thoracostomy for patients with stable spontaneous primary pneumothoraces. Outpatient management can be considered in some cases with the addition of a Heimlich valve. Regardless of what method is used, physicians in training should be supervised until competency with this procedure is demonstrated.

41 Open Chest Wound Management

Eric F. Reichman

INTRODUCTION

Open chest wounds come in a variety of shapes and sizes. Their one commonality is an open communication between the pleural space and the external environment. The wounds have often been sealed by the soft tissues of the chest wall in the vast majority of patients with penetrating injuries to the chest. The primary concern with these patients is the diagnosis and treatment of underlying thoracic, cervical, and/or abdominal injuries. **Rarely, small perforations may produce a valve-like entry into the pleural space, enabling air to be "sucked in" during inspiration but blocking air egress during expiration. Thus air will continue to accumulate, leading to a tension pneumothorax requiring needle decompression followed by a tube thoracostomy.** Larger, more destructive wounds of the chest may also occur. These are most common in combat injuries. In civilian practice, they are often secondary to shotgun injuries. The larger wounds are also caused by high-velocity weapons, explosions, on-the-job injuries, propeller injuries, or fencepost impalements, to name a few. Clothing, wadding, shell fragments, and pieces of the chest wall may all be driven into the thoracic cavity. Such injuries are associated with physical loss of a portion of the chest wall itself, making adequate ventilation impossible.[1] These wounds are known by numerous names including open chest wounds, open pneumothoraces, sucking chest wounds, and communicating pneumothoraces. These specific open chest wounds are the focus of this chapter.

Wounds of the chest are described in the earliest of medical documents, the Edwin Smith papyrus. This document dates from the time of Imhotep (3000 B.C.). It contains descriptions of 58 cases, three of which involved chest injuries per se. One was actually an open chest wound, case number 40. The patient sustained a penetrating injury to the anterior thorax through the manubrium. Treatment consisted of binding the wound with fresh meat on the first day and, later, with grease, honey, and lint.

During Greco-Roman times, open chest wounds were universally fatal. In 362 B.C., Epaminondas was wounded by a spear to the chest at the battle of Mantinea. Once he discovered that the Thebans had been victorious, he pulled the spear out, knowing that he would die.

Galen cared for chest wounds in gladiators. Treatment consisted of a poultice and leaving the wound open. This treatment did not change until the time of Theodoric, who advised the closing of chest wounds. In 1267, he was quoted as saying, "The stitches should be placed in accordance with the size of the wound so that the natural heat cannot escape in any way nor the air outside be able to enter." His advice was not accepted by all. The Master Military Surgeon Paré left these wounds open for 2 to 3 days to allow drainage of blood, after which he would close them.

During the Battle of Crecy in 1346, firearms and firearm injuries were first introduced. In 1382, small guns were used against the Venetians. Injuries from these weapons were documented in the chronicles of these battles.

Techniques for managing chest wounds have improved with each subsequent war. The most important treatable aspect of these chest wounds was the associated open pneumothorax. The question of whether to manage such injuries open or closed remained controversial. In Rome in 1514, John de Vigo was the first surgeon to present his views on gunshot wounds of the chest. He thought them to be universally fatal and, for the most part, untreatable. William Hewson, in 1767, observed that a patient with a large open chest wound was not able to breathe but could do so easily once the injury was closed.

It took another 40 years for Baron Larrey, Napoleon's Surgeon, to confirm Hewson's observation in a wounded soldier. He gave one of the best descriptions of an open pneumothorax, shock, and air hunger in his memoirs of the Napoleonic wars:

"A soldier was brought to the hospital at the Fortress of Ibrahym Bey, immediately after a wound penetrated the thorax between the fifth and sixth true ribs. It was 8 cm in extent. A large quantity of frothy and vermillion blood escaped from it with a hissing noise at each inspiration. His extremities were cold, pulse scarcely perceptible, countenance discolored, and respiration short and laborious. In short he was every moment threatened with a fatal suffocation. After having examined the wound, the divided edges of the part, I immediately approximated the two lips of the wound and retained them by means of adhesive plaster, and a suitable bandage around the body. In adopting this plan I intended only to hide from the sight of the patient and his comrades, the distressing spectacle of the hemorrhage, which would soon prove fatal; and I therefore thought that the effusional blood into the cavity of the thorax could not increase the danger. But the wound was scarcely closed, when he breathed more freely, and felt easier. The heat of the body soon returned, and the pulse rose. In a few hours he became quite calm, and to my great surprise, grew better. He was cured in a very few days, and without difficulty."

Another famous accounting of an open chest wound was by William Beaumont in 1825. He attended Alexis St. Martin in 1822, who was shot in the lower chest. Beaumont arrived within one-half hour of the injury and noted that the wound had been caused by a short-range blast, within a yard of St. Martin's chest: "fracturing and carrying away the anterior half of the sixth rib, fracturing the fifth, lacerating the lower portion of the left lobe of the lungs, the diaphragm and perforating the stomach. The whole mass of materials forced from the musket, together with fragments of clothing and pieces of fractured ribs, were driven into the muscles and cavity of the chest."

Upon Beaumont's arrival, he found lung and stomach herniating from the wound. "After cleaning the wound from the discharges and other extraneous matter, and replacing the stomach, and the lung as far as practicable, I applied the carbonated fermenting poultice and kept the surrounding parts constantly wet with a lotion of muriate of

ammonia and vinegar." After an hour, Beaumont returned expecting to find his patient dead. To his pleasure and surprise, the patient was, in fact, improved. He had saved his life by closing his chest wound.

By the final years of World War I, the controversy of "to close or not to close" was resolved in favor of immediate wound closure. However, when closing these wounds it was important to understand the physiology of negative intrathoracic pressure. The German internist Buelau introduced closed underwater seal drainage of an empyema in 1875. In 1889, T. Holmes, a consulting Surgeon at St. George's Hospital in London, introduced intercostal drainage for large chest wounds. However, he did not advocate an underwater seal. It was not until World War II that closed tube drainage was added to the treatment of an open pneumothorax as a routine measure. Positive-pressure ventilation was introduced in the early 1900s. The most recent advancement in the treatment of these injuries came from the Scandinavians, who invented respirators in the early 1950s. Mortality from chest wounds steadily decreased in each war. It was 79% in the Crimean War, 62.5% in the Civil War, 55.7% in the Franco-Prussian War, 24.6% in World War I, 12% in World War II, and in recent civilian experience is now 4% to 7%.[2]

ANATOMY AND PATHOPHYSIOLOGY

The pathophysiology of an open pneumothorax has not much been improved upon since the days of Hewson and Larrey. The pathophysiologic changes of a sucking chest wound depend on the size of the wound and the intactness of the pleural space and lung. A defect in the chest wall is usually of no major clinical significance if the pleural space is obliterated.[3] However, most commonly, the pleural space is free and the air and/or blood moves in and out through the chest wall defect, making a "sucking" sound.

A sucking chest wound or open pneumothorax results in a mostly unidirectional flow of air through the wound and into the pleural space. During inspiration, the intrathoracic pressure is negative compared to the extrathoracic pressure. This allows air to flow through the wound and into the pleural space. During expiration, the tissues surrounding the wound come into apposition and decrease the wound diameter. This results in air becoming trapped within the pleural space. As breathing continues, this process progresses and air increasingly accumulates in the pleural space, compresses the lung, and prevents lung expansion during inspiration. The open pneumothorax can become large enough to exert tension on the hemithorax contents and the mediastinal structures.

In larger injuries, this air movement causes the ipsilateral lung to move inward and collapse on inspiration (**Figure 41-1A**). The lung may expand slightly or remain completely collapsed upon expiration, depending on the size of the chest wall defect (**Figure 41-1B**). There may also be mediastinal motion toward the noninjured lung during inspiration and toward the injured lung during expiration. This to-and-fro motion compromises the function of the healthy lung as well as the injured lung because it prevents its full expansion during inspiration. During expiration, some of the air from the noninjured lung may shift to the injured lung, and the reverse may happen during inspiration (an element of the "pendelluft" phenomenon). This entire mechanism results in a large functional dead space in the noninjured lung and loss of ventilation of the injured lung, causing severe ventilatory derangement, asphyxia, hypoxemia, and hypercarbia.[2–4]

The patient with an open pneumothorax may manifest a spectrum of presentations, ranging from asymptomatic and stable to severely dyspneic and agonal. The presentation depends on the size of the chest wall defect, the extensiveness of the injuries to the lung and other structures, the preinjury pulmonary status, and whether the pleural space is free or has adhesions. The patient may present with progressive respiratory insufficiency leading to a rapid demise if not treated. **The critical diameter of the chest wall wound has been described as two-thirds (or greater) the diameter of the trachea.[5] It is thought that at this size, air moves preferentially through the chest wall rather than through the trachea.**

Two additional "open chest wounds" deserve mention. First is the wound that fully penetrates the chest wall but seals itself and closes. It can seal from apposition if adjacent chest wall soft tissues, a hematoma, underlying pleural adhesions that do not allow air into the pleural space, or from a combination of these. This type of injury prevents air from entering the pleural space and does not significantly alter respiratory physiology except for the pain of breathing. This type of wound does not indicate that there is no underlying cardiac, intrathoracic, lung, or mediastinal injury. These types of wounds require management of hemorrhage, the application of a simple dressing, and a Surgeon for management of the wound, continued hemorrhage, and any internal injuries.

The final type of open chest wound is one that allows bidirectional airflow. Breathing results in bidirectional airflow through both the trachea and the chest wound, thus decreasing airflow through the trachea. This results in hypoventilation and hypoxemia. These patients require positive-pressure ventilation with either a bag-valve-mask device, CPAP or BiPAP machine through a face mask, or endotracheal intubation. The wound must be covered with a three-sided dressing, or an occlusive dressing after the placement

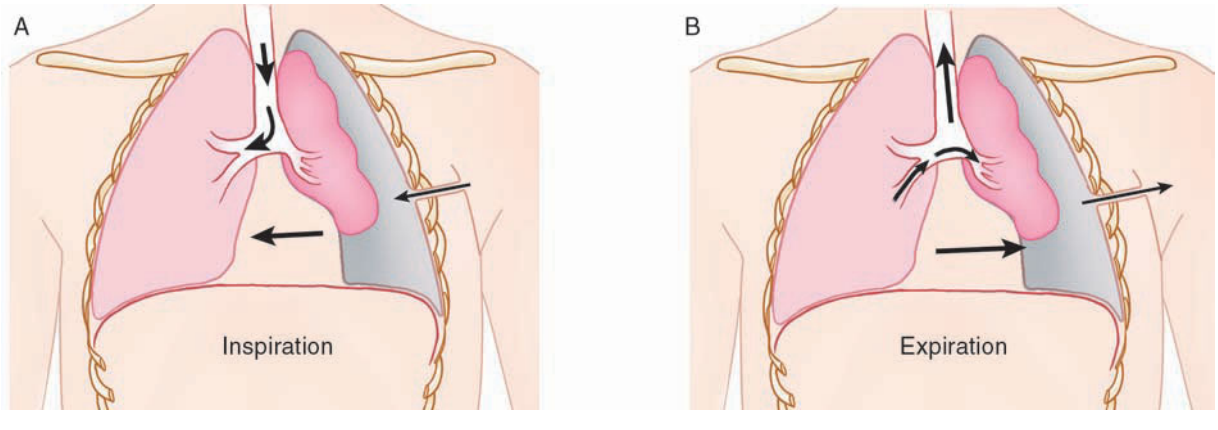


FIGURE 41-1. The effects of an open chest wound. **A.** Air moves into the pleural cavity and the lung collapses with inspiration. **B.** Air exits the pleural cavity and the lung expands slightly with expiration. The arrows represent the direction of airflow.

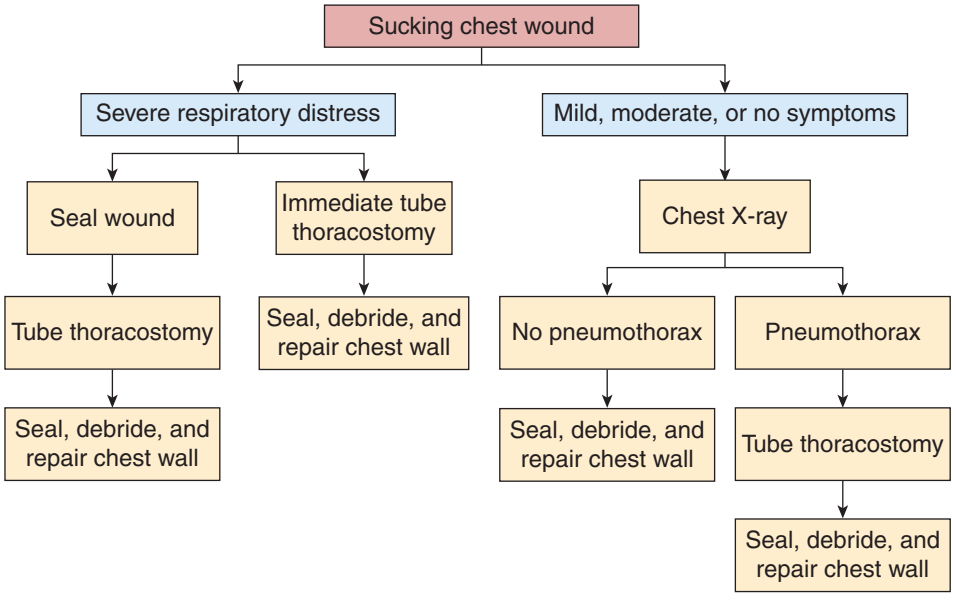


FIGURE 41-2. Algorithm for the diagnosis and treatment of an open pneumothorax. (Modified from Symbas.[3])

of a chest tube, and a Surgeon for management of the wound, continued hemorrhage, and any internal injuries.

INDICATIONS

Diagnosis of these injuries can be made easily based upon the obvious presence of the chest wall defect and the noise produced as the air moves in and out through the wound. In the symptomatic patient, all open chest wounds should be treated immediately.[3,6] Treatment techniques should be selected based on the patient's clinical condition and stability (**Figure 41-2**). **The three-sided dressing is only a temporary measure and it must be followed with the placement of a chest tube.**

Most experts agree that only the symptomatic patients should be treated in the field. An occlusive dressing should be placed over the wound and taped on only three sides. **The three-sided dressing allows air within the pleural cavity to be expelled into the atmosphere while preventing atmospheric air from entering the pleural cavity. If the wound is taped on all four sides, an open pneumothorax may quickly be converted into a tension pneumothorax.**[4,5,7–10]

In the Emergency Department, the very symptomatic patient should be treated as in the field. However, a completely occlusive dressing may be placed over the wound if a chest tube is subsequently to be placed. Continuously and closely monitor the patient for the development of a tension pneumothorax if the wound is completely sealed prior to the tube thoracostomy. **If a tension pneumothorax occurs, remove the occlusive dressing on at least one side or perform a needle thoracostomy (Chapter 39) to relieve it.**

Obtain a rapid, portable anteroposterior chest radiograph if the patient is asymptomatic, mildly symptomatic, or moderately symptomatic. If a pneumothorax is present, perform a tube thoracostomy and seal the wound. If the patient becomes severely symptomatic, the Emergency Physician should default to the other limb of the algorithm (**Figure 41-2**).

CONTRAINDICATIONS

There are no contraindications to the placement of a three-sided occlusive dressing, as this is a treatment for a life-threatening emergency. It must be properly placed to prevent the accidental conversion to a totally occlusive dressing and the progression of an open pneumothorax to a tension pneumothorax.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Petrolatum gauze
- Gauze 4 × 4 squares
- Reinforcing sterile dressings
- Tincture of benzoin
- Adhesive tape
- Sterile gloves and gown
- Face mask with an eye shield or goggles

The supplies for an occlusive dressing (i.e., petrolatum gauze) may not be readily available within or outside of the Emergency Department. Numerous substitutes for the petrolatum gauze are available. This includes a defibrillator pad. These gel-like pads are large, can be cut to size, and adhere to both dry and wet skin. Other alternatives include coating a water-soluble lubricant onto one side of a piece of aluminum foil, plastic food wrap, plastic from the packaging of sterile procedure packs, a piece cut from a plastic trash bag, or a zippered sandwich bag.

PATIENT PREPARATION

The amount and timing of patient preparation will be dictated by the location of the patient and his or her physiologic status. An informed consent is not required, as this is a noninvasive and lifesaving procedure. Such procedures should occur emergently with minimal patient preparation. If time permits, place the patient on the cardiac monitor and pulse oximeter and provide supplemental oxygen by face mask. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids.

If the patient has severe respiratory insufficiency, consider performing orotracheal intubation before or simultaneously with the application of the three-sided occlusive dressing. Positive-pressure ventilation through the endotracheal tube will expand the collapsed lung and force the intrapleural air out the wound and into the atmosphere.

Prepare the chest wall if the patient is asymptomatic, mildly symptomatic, or moderately symptomatic. Clean the wound and surrounding chest wall of any dirt and debris. Apply povidone iodine

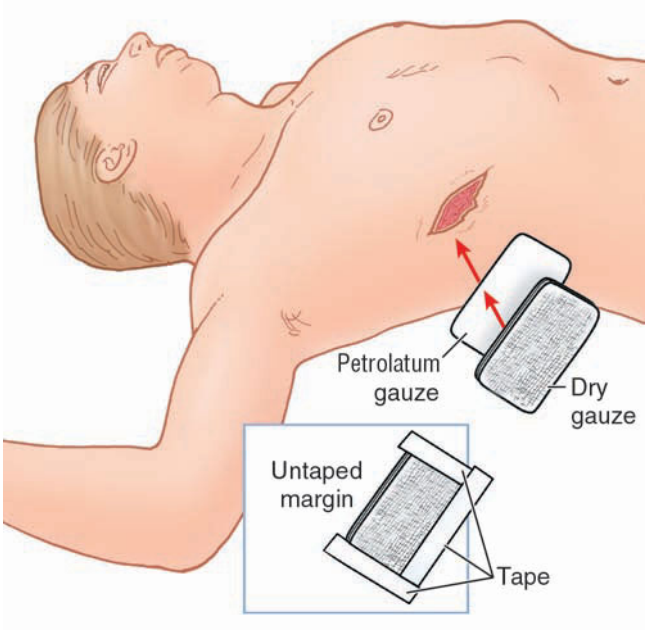


FIGURE 41-3. The three-sided occlusive dressing.

or chlorhexidine solution to the skin surrounding the wound and allow it to dry. Do not place the povidone iodine or chlorhexidine into the wound, as this has been shown to inhibit wound healing. Apply the three-sided occlusive bandage as described below. **If the patient is moderately to severely symptomatic, no preparation is required, as this wastes valuable time. Immediately apply the three-sided occlusive bandage.**

TECHNIQUE

The safest initial therapy for symptomatic sucking chest wounds is the careful application of a petrolatum gauze-based dressing taped on three sides (**Figure 41-3**). Apply three or four layers of petrolatum gauze over the wound. The dressing should extend 6 to 8 cm beyond the margins of the wound so that it will not be sucked into the pleural cavity in the spontaneously breathing patient. Cover the petrolatum gauze with dry 4 × 4 gauze squares. Apply tincture of benzoin around three sides of the dressing. Apply tape to secure the three sides of the dressing to the chest wall.

ALTERNATIVE TECHNIQUE

An alternative to the three-sided dressing is one that is totally occlusive or a four-sided dressing. There is little to no clinical evidence that a three-sided dressing is superior to a four-sided dressing. **The four-sided dressing should be placed only in the setting where rapid placement of a chest tube will be undertaken.** This occurs most commonly in the Emergency Department. It may be considered in the field when a tube thoracostomy is included in the prehospital standing medical orders.[23]

ASSESSMENT

Once the three-sided dressing has been placed, continue to closely monitor the patient for associated complications and evaluate them for underlying injuries. **Paramount among the complications is conversion of a simple pneumothorax to a tension pneumothorax. Do not be led into a false sense of security after placing the three-sided dressing. A patient can still develop a tension pneumothorax.** Periodically evaluate the three-sided dressing to ensure it is not covered with another dressing or blankets, not positioned between the patient and the bed or another object, and that it has not become occluded on all four sides. **If a tension pneumothorax occurs, remove the occlusive dressing on at least one side or perform a needle thoracostomy (Chapter 38) to relieve it.** Patients with an open chest wound have typically sustained an injury comprising great kinetic energy, whether from a blunt or penetrating event. Associated injuries will be very common. A head-to-toe secondary survey is imperative.

AFTERCARE

The aftercare of these patients consists of a tube thoracostomy (i.e., chest tube) followed by aggressive wound care, pain management, pulmonary toilet, continued monitoring, and investigation for other underlying injuries. **Once the wound is closed, the underlying pneumothorax or hemopneumothorax should be treated with the placement of a chest tube placed through an incision away from the injury site and not through the open chest wound.**

Pain will be a major problem for these patients. Trauma to the parietal pleura, bony structures, and intercostal nerves is very painful. It is imperative that these patients be able to make adequate ventilatory efforts, cough, deep breathe, perform incentive spirometry, and have aggressive pulmonary toilet. These are all necessary to prevent atelectasis, retained secretions, and pneumonia.[11] Various pain-relieving techniques may be utilized. Infiltration of long-acting local anesthetic solution may give initial relief, especially during wound debridement. Parenteral analgesics are the initial treatment modality. Advanced techniques to consider include regional nerve blocks, intercostal nerve blocks, and indwelling intrapleural or epidural catheters.

More definitive wound care should be considered once the patient is stabilized. Small, clean wounds may be managed simply with routine wound care and changes of the occlusive dressing. Local irrigation and debridement may be added if there is a limited amount of contamination. Large, grossly contaminated, and/or complex wounds are best managed in the operating room. Optimally, these wounds should be debrided and closed primarily. However, some wounds may be contaminated or complex, such that closure is not possible initially. In such cases, the wound should be debrided and left open. Large, occlusive dressings are placed along with chest tubes for removal of air, fluid, and blood. Multiple operative debridements may be required. When the wound is clean and the patient is optimized, secondary closure may be performed.[11]

Closure of large wounds may require a combination of complex techniques. These may include various skin, subcutaneous tissue, and muscle flaps.[12] Free rib grafts, pectoral muscle flaps, latissimus dorsi muscle flaps, abdominal muscle flaps, omentum flaps, skin grafts, or a myocutaneous flap can be utilized.[12–19] If using these are not possible, closure may be accomplished with a prosthetic material such as Prolene or Marlex, either temporarily or definitively.[20–22] In wounds of the lower chest, detachment of the diaphragm with reattachment at a higher level may be utilized. This converts an open chest wound to an intraabdominal wound and alleviates the ventilatory problems.

COMPLICATIONS

Complications may occur acutely or may be delayed. **Occlusion of the chest wall defect and decompensation of the patient from a simple pneumothorax being converted to a tension pneumothorax is the primary early complication. The patient must be closely monitored until a chest tube can be inserted.** A tension pneumothorax can result if the wound is completely occluded by

a blood clot, a dressing that has been sucked into the wound, soft tissue, or a bandage that is adherent on all four sides. **Immediately remove the bandage to relieve a tension pneumothorax.** Some physicians and authors remove only one side of the occlusive bandage to relieve the pneumothorax. The choice to remove part or all of the bandage is physician-dependent. If the patient is still symptomatic, ensure that the wound is not occluded by a blood clot or soft tissue.

Other complications would ensue from the failure to seek, diagnose, and treat other underlying, potentially life-threatening injuries. The patient may develop respiratory insufficiency secondary to multiple causes, some of which may be preventable with optimal care. These causes include inadequate pulmonary toilet, inadequate pain management, pulmonary contusion, pneumonia, and/or adult respiratory distress syndrome. Wound complications may include infection, fasciitis, osteomyelitis, empyema, hemothorax, and loculated hemothoraces or pneumothoraces. These wounds require frequent evaluation and aggressive care to prevent these sequelae.

SUMMARY

Open chest wounds are easily diagnosed by the evident chest wall defect and the auscultation of air moving into and out of the pleural cavity. This is a true life-threatening emergency. Treatment is dictated by the patient's clinical presentation. Lifesaving therapy should be undertaken with the simple application of a three-sided petrolatum gauze dressing. The three-sided dressing allows air within the pleural cavity to be expelled into the atmosphere while preventing atmospheric air from entering the pleural cavity. This converts the open pneumothorax to a closed pneumothorax and eliminates the major physiologic derangement. Once the patient is stabilized, more definitive care should be carried out with chest tube placement and appropriate wound care.

42 Emergency Department Thoracotomy

Kenny Banh

INTRODUCTION

An increase in urban violence combined with better triage and transport systems has resulted in the arrival of sicker trauma patients at the Emergency Department (ED). Previously, these patients might not have survived long enough to make it to the ED.[1] The majority of individuals with penetrating chest injuries arrive in the ED in stable condition and are managed without major operative procedures.[2] A subset of individuals, however, arrive in extremis and may require a thoracotomy. The purpose of the ED thoracotomy may be to control hemorrhage within the chest, to relieve a pericardial tamponade surgically or one that cannot be decompressed by a needle thoracotomy, to redistribute cardiac output to the brain and the heart, or to provide more effective cardiac massage.[3]

ANATOMY AND PATHOPHYSIOLOGY

The structures within the chest include the heart, esophagus, lungs, bronchi, pulmonary hilar vessels, and numerous other vascular structures. The heart is located in the anterior mediastinum. The aorta and esophagus are located in the posterior mediastinum. The internal mammary arteries course along the posterior aspect of the anterior chest wall just lateral to the sternum. The intercostal vessels run along the inferior aspect of the ribs. The subclavian vessels are at the very superior aspect of the thorax. They course directly under the clavicles and can be very difficult to visualize via an anterolateral thoracotomy. The azygos vein can be found coursing along the posterior right hemithorax and emptying into the superior vena cava.

The heart is covered by the tough pericardial sac. **The phrenic nerves run superiorly to inferiorly on each side of the pericardiac sac.** They can be visualized as white or yellow strands on either side of the pericardium. Once the pericardial sac is opened, the left anterior descending coronary artery can be visualized on the anterior surface of the heart. It overlies the interventricular septum. Injuries to the left of this artery usually denote left ventricular damage while injuries to the right usually denote right ventricular damage. The majority of the anterior surface of the heart is occupied by the right ventricle.

The posterior mediastinum contains the aorta. It is located posterior to the esophagus and runs lateral to the vertebral bodies. The thoracic aorta gives off the intercostal vessels. If torn during the mobilization of the aorta, the intercostal vessels can cause troublesome bleeding.

Beall et al. originally introduced the ED thoracotomy for penetrating chest wounds.[4] This procedure was subsequently used for patients with penetrating abdominal wounds and victims of blunt trauma. **In recent years, several studies have shown an abysmal survival rate associated with an ED thoracotomy in victims of blunt trauma.** When vital signs are present in the field, the survival rates for such individuals range from 0.6% to 6.0%.[5–7] Patients who undergo an ED thoracotomy for penetrating abdominal injuries have survival rates of approximately 5%.[8] In these cases, the ED thoracotomy is performed for resuscitation purposes.

Patients presenting to the ED with penetrating chest trauma who present without signs of life in the field have a poor prognosis. Survival for these patients ranges from 0% to 9%.[9,10] If the patient sustains penetrating chest trauma and has signs of life in the field, survival averages 14%, with a range of 0% to 36%.[1] The reason for the wide range probably lies in the small numbers of patients in the studies and the varying definitions of "signs of life."

The best survival for penetrating chest injury and an ED thoracotomy is in patients with stab wounds resulting in cardiac tamponade. The use of bedside ED ultrasonography allows better identification of these patients. The survival for this entity ranges from 21% to 71%, averaging 31%.[6,11–14] It should be noted that 90% of patients who survive an ED thoracotomy for penetrating chest injuries have good neurologic outcomes.[11] This must be contrasted with a 50% incidence of good neurologic outcome in survivors of blunt trauma who receive a thoracotomy.[15]

INDICATIONS

Signs of life, if present at the scene or at any time during the transport or resuscitation and a short transport time, should prompt an ED thoracotomy in patients with penetrating chest trauma.[13,16] These signs include a palpable pulse, a blood pressure, pupil reactivity, any purposeful movement, an organized cardiac rhythm, or any respiratory effort. **Thus, the patient must have signs of life on presentation or have lost them en route to the ED if a thoracotomy is to be considered.** A thoracotomy should be performed to control hemorrhage within the thoracic cavity, to decompress a pericardial tamponade, to cross-clamp the aorta and redistribute the cardiac output to the brain and heart, and to provide open cardiac massage. Patients who are in shock or rapidly deteriorating clinically after penetrating chest trauma and are not responding to aggressive fluid resuscitation are also candidates

for an ED thoracotomy. It is also indicated to cross-clamp the aorta when the patient is exsanguinating from injuries below the level of the diaphragm.[17]

CONTRAINDICATIONS

There are a few well-supported contraindications to performing an ED thoracotomy. **A thoracotomy should not be performed in patients with penetrating chest trauma who have no vital signs in the field.**[18,19] In the absence of field vitals, the survival rates are at the lower end of the range. The few that survive have severe neurologic impairment. Outside of patients that collapse in the ED, **victims of blunt trauma with or without field vitals should not routinely undergo an ED thoracotomy.**[20] It is also contraindicated when prehospital CPR exceeds 10 minutes without a return of spontaneous circulation after blunt trauma, when prehospital CPR exceeds 15 minutes without a return of spontaneous circulation after penetrating trauma, and when the patient presents to the ED in asystole without a pericardial tamponade.[18,19] **An ED thoracotomy should not be performed regardless of the indications if a Trauma Surgeon, or other qualified Surgeon, is not immediately available to take the patient to the Operating Room for definitive management.** Do not perform an ED thoracotomy with the anticipation of transferring the patient to another facility if they can be resuscitated.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile towels
- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Sandbags or towels
- #3 scalpel handle
- #10 scalpel blade
- US Army retractors, 1 set
- Curved Mayo scissors, 8¾ and 6¾ in.
- Curved Metzenbaum scissors, 5½ in.
- Toothed forceps
- Satinsky vascular clamp
- Finochietto rib retractor, 12 in spread
- Suction source
- Suction tubing
- Yankauer suction catheter
- 2-0 silk suture on a large curved needle
- Hemostats, needle driver, 10 in
- Gauze 4 × 4 squares
- Sternal saw, hand-operated
- Lebsche knife (sternal osteotome) and mallet

All hospitals and EDs have preprepared, prepackaged, and sterile thoracotomy trays. Review the equipment available on the trays at your institution to become familiar with their contents before the tray is required emergently.

PATIENT PREPARATION

The patient should already be supine, intubated, and ventilated. Abduct the left upper extremity 180° (**Figure 42-1**). The extremity should be held in position by an assistant or with the use of a soft restraint. Place sandbags or towels under the patient's left scapula. This will elevate the torso off the bed to allow for more complete access. Apply povidone iodine or chlorhexidine solution to the patient's left chest. Apply sterile drapes over the chest to demarcate a surgical field.

An ED thoracotomy is primarily performed on patients who are unresponsive. As such, there is no immediate need for analgesics, sedatives, or local anesthetic solution. If the patient is resuscitated, they will experience significant postprocedural pain. **Parenteral analgesics and sedatives should be available and administered if the patient survives and there are no contraindications.**

Set up the required equipment. Open the prepackaged, sterile thoracotomy tray on a bedside table. The tray should contain all the equipment required for the procedure. Sterile technique should be observed and followed by all involved personnel, who should be fully capped, gowned, masked, and gloved. This will protect the healthcare personnel from exposure to the patient's blood and body fluids as well as minimizing the risk of infection if the patient survives.

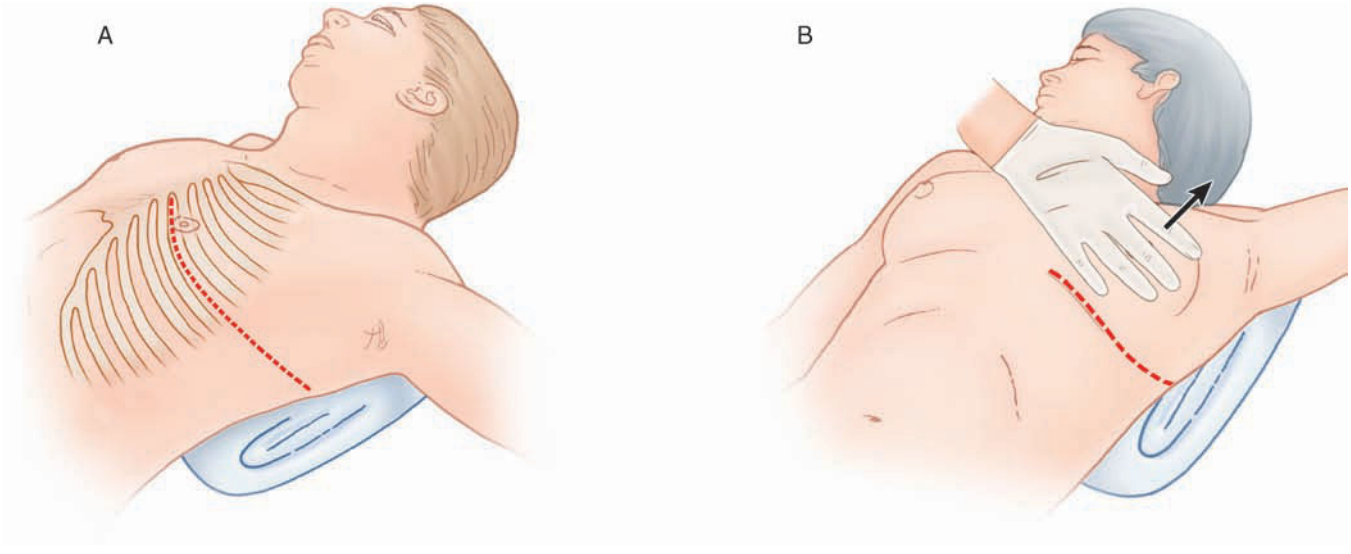


FIGURE 42-1. Patient positioning. Place a sandbag or towel under the left shoulder and abduct the left arm 180°. Identify the fifth intercostal space in the male (**A**) or the inframammary line in the female (**B**).

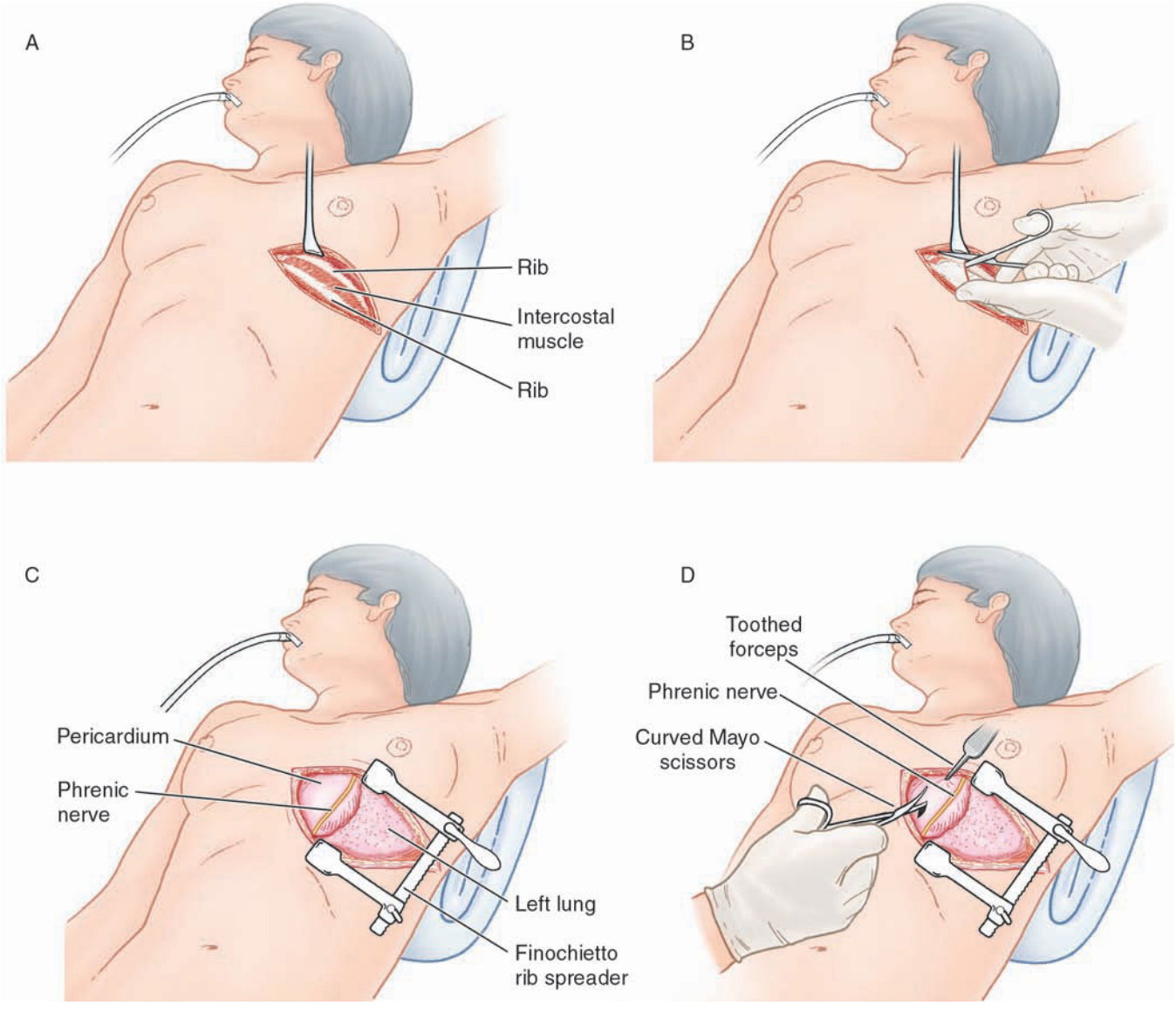


FIGURE 42-2. ED thoracotomy. **A.** The initial incision is made through the skin, subcutaneous tissue, and superficial muscles. **B.** The intercostal muscles are incised with Mayo scissors. **C.** The Finochietto rib spreader is inserted and opened. **D.** The pericardium is grasped and opened.

TECHNIQUES

LEFT-SIDED THORACOTOMY

Apply the scalpel blade to the handle. Identify the site to be used to make the initial skin incision. This is the left fourth or fifth intercostal space, corresponding to the intercostal space below the nipple in a male and below the inframammary fold in a female (**Figure 42-1**). **Using one stroke of the scalpel, make an incision extending from the sternum to the posterior axillary line or the gurney (Figure 42-2A).** Carry the incision through the skin, subcutaneous tissues, and superficial chest musculature down to and through most of the intercostal muscles (**Figure 42-2A**). An Army retractor may be used to open and separate the edges of the incision. This step is based on physician preference and is not required.

Discontinue mechanical ventilation. Consider advancing the endotracheal tube into the right mainstem bronchus. This will allow the left lung to deflate and minimize injury upon entering the left thoracic cavity while still ventilating the right lung. Alternatively, temporarily discontinue mechanical ventilation. Puncture through the intercostal muscles in the anterior axillary line with the curved Mayo scissors. Carefully extend the puncture 2 to 3 cm using the curved Mayo scissors. Insert the nondominant index and middle fingers through the incision and separate the lung from the chest wall. Advance the fingers and Mayo scissors simultaneously, superiorly then inferiorly to cut the intercostal muscles along the entire inner space (**Figure 42-2B**). Resume mechanical ventilation.

Insert the Finochietto retractor with the arm and crank positioned near the gurney (**Figure 42-2C**). Turn the crank to open the arms of the rib spreader. Clear any blood from the left hemithorax and inspect for any brisk bleeding. If extensive bleeding is observed, it must be controlled. Use digital pressure or hemostats to initially control intercostal artery or other bleeding vessels. Subsequently place 2-0 silk stitches to tie off the bleeding vessels. For subclavian vessels, digital control must be followed by rapid transport to the operating room, since these vessels are difficult to control through an anterolateral thoracotomy.

OPENING THE PERICARDIUM

Move the left lung superiorly and laterally to expose the pericardial sac. **A pericardiotomy should be routinely performed if blood is seen within the pericardial sac, if the heart cannot be visualized through the pericardium, or if there is no other obvious injury within the chest and a potential cardiac injury may exist. Many Emergency Physicians and Trauma Surgeons will routinely open the pericardium when they are performing a thoracotomy, as a pericardial tamponade is difficult to detect visually and a potential cardiac injury may exist.**

Open the pericardial sac anterior to the phrenic nerve. Grasp and elevate the pericardium with a toothed forceps anterior to the phrenic nerve, which appears as a white or yellow strand along the lateral aspect of the pericardium (Figure 42-2D). Make an incision in the pericardium near the apex of the heart using a curved Mayo scissors. Note the color of the fluid that is expressed from the pericardial sac. It should normally be straw-colored without any hint of red. Carefully insert one of the jaws of the Mayo scissors into the pericardial sac. **Extend the incision with the Mayo scissors parallel to the phrenic nerve, from the apex of the heart to the root of the aorta.** Deliver the heart from the pericardium and inspect it for any injury. Internal cardiac massage may be performed for asystole, bradycardia, and/or hypotension. The technique is described in Chapter 43. Any cardiac wounds identified should be temporarily plugged or closed as described in Chapter 44.

RIGHT-SIDED THORACOTOMY

If there is a high index of suspicion of injury in the right hemithorax with minimal or no injury found in the left hemithorax, the thoracotomy must be extended to the right side. If possible, extend the incision through the sternum using a curved Mayo scissors and continue it to the right posterior axillary line (**Figure 42-3**). Remove the Finochietto rib spreaders from the left side and apply them to the patient's right fifth intercostal space. Examine the right hemithorax for injury. When the sternum is cut, the internal mammary arteries on both sides will be lacerated. Apply hemostats to the transected vessels to obtain hemostasis. They may later be tied off if the patient is resuscitated.

Occasionally, the large curved Mayo scissors cannot transect the calcified sternum. Perform a right-sided thoracotomy similar to that on the left. If further access is required, cut the sternum with a hand-held sternal saw or a Lebsche knife (**Figure 42-4**). Pass one end of the sternal saw from the left fifth intercostal space, behind the sternum, and out of the right fifth intercostal space (**Figure 42-4A**). Place an index finger through the loop on each end of the sternal saw. Move the hands toward and away from the patient in a to-and-fro motion until the sternum is transected. Alternatively, a Lebsche knife can be used to transect the sternum. Place the hooked portion of the knife under the sternum with the sharp blade against the lateral border of the sternum (**Figure 42-4B**). Lift up the handle of the Lebsche knife to lock it against the posterior surface of the sternum. This will prevent the tip of the Lebsche knife from cutting the heart. Hit the flat knob on the back of the Lebsche knife with a mallet to drive the knife through the sternum (**Figure 42-4B**).

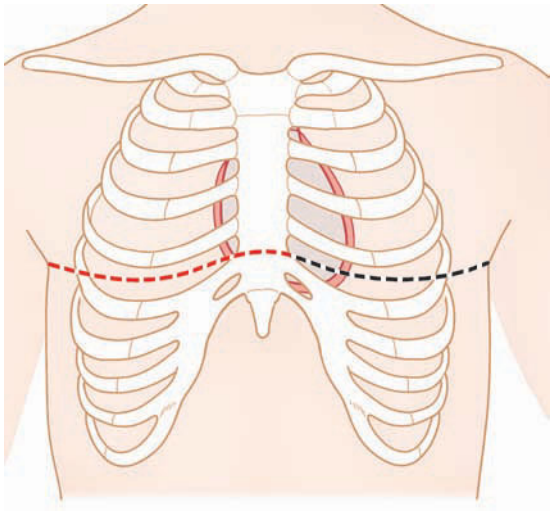


FIGURE 42-3. The left-sided incision is continued across the sternum and the right fifth intercostal space to perform a right-sided thoracotomy.

ASSESSMENT

Any bleeding should be controlled with the application of pressure, hemostats, and/or sutures. Any injuries to the heart (Chapter 44) or the hilum and great vessels (Chapter 45) should be managed. Cross-clamping of the proximal aorta will prevent further exsanguination from more distal injuries (Chapter 46). Open cardiac massage can be performed while the resuscitative efforts continue (Chapter 43).

AFTERCARE

If the patient is resuscitated in the ED, they should be immediately transported to the Operating Room for definitive care as soon as the Anesthesiologist and Surgeon are available. Continue the administration of fluids, packed red blood cells, platelets, plasma, and inotropic agents as necessary until the patient is hemodynamically stable. Administer broad spectrum antibiotics intravenously if the patient is resuscitated and survives. Administer parenteral analgesics and/or sedation if not contraindicated.

COMPLICATIONS

The ED thoracotomy has many potential and serious complications. Fortunately, this procedure is often being performed as a last effort at resuscitation of a "dead patient." The complications are, therefore, not significant when the alternative to this procedure is death.

The ED thoracotomy is rarely ever performed under truly sterile conditions. Time is often of the essence in performing this procedure. Povidone iodine or chlorhexidine solution and sterile drapes are rarely applied before an emergent ED thoracotomy. If applied, the povidone iodine or chlorhexidine solution does not have time to dry before the skin incision is made. Parenteral antibiotics should be administered if the patient is resuscitated.

The complications of the thoracotomy include vascular and organ injury. Lacerations of the internal mammary or intercostal arteries can be ligated with silk suture. There is also the possibility of inadvertent laceration of the lung or the myocardium during the initial incision. By temporarily halting mechanical ventilation while performing the thoracotomy, injury to the underlying lung can often be prevented. These injuries will need repair at the appropriate time.

A pericardiotomy can result in significant complications. The left phrenic nerve may be transected. The myocardium or a coronary artery can be lacerated. The heart may be fixed by adhesions to the pericardium from prior pericardial disease or pericarditis. Attempting to remove the heart from the pericardium can result in avulsion of the atrial or ventricular myocardium. Performance of the pericardiotomy adds another delay in initiating cardiac compressions.

Care should be taken to prevent injury to any of the healthcare providers. Universal precautions should be followed by all

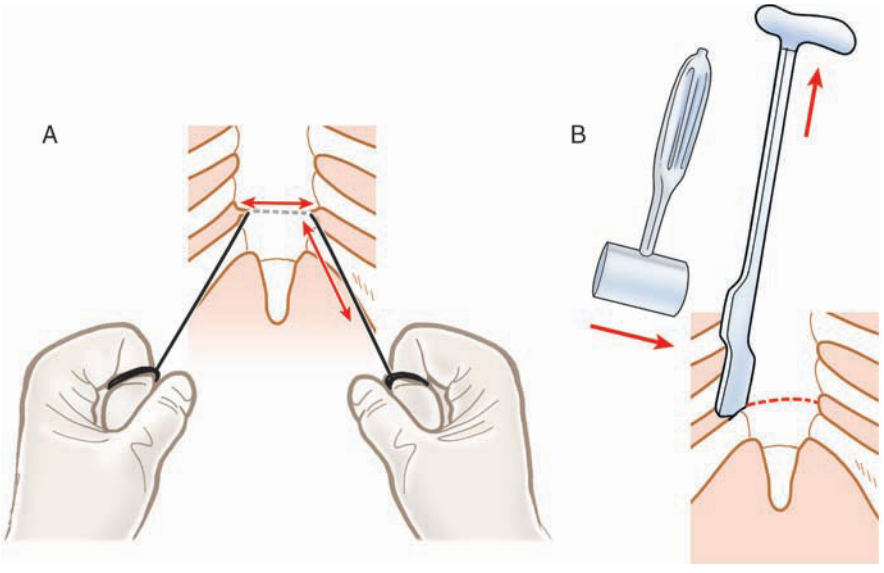


FIGURE 42-4. Cutting the sternum. **A.** The sternal saw is moved to-and-fro while maintaining upward pressure. **B.** The Lebsche knife is hooked under the sternum and lifted upward to secure it in place. The mallet strikes the Lebsche knife and drives it through the sternum.

personnel. The use of gloves, goggles, masks, and gowns will protect against exposure to the patient's blood. All needles, scalpels, and scissors should be returned to the bedside tray immediately after use and not left on the patient or the bed. Use extreme caution when placing your hands inside the patient's hemithorax. Fractured ribs from the trauma or the Finochietto rib spreader can easily penetrate gloves and skin. The costs associated with an occupational exposure associated with an ED thoracotomy are quire significant.[21] This is especially true if the healthcare provider develops hepatitis C or HIV.[21]

SUMMARY

An ED thoracotomy is a lifesaving procedure when used on patients in extremis secondary to penetrating chest or abdominal trauma. To be considered for this procedure, the patient must have signs of life when brought to the ED, must have lost them en route, or have lost them on the scene. This procedure should rarely be used in patients with blunt trauma. The Emergency Physician must have the appropriate surgical backup before performing a thoracotomy, since this procedure does not provide definitive therapy.

43 Open Cardiac Massage

Eric F. Reichman

INTRODUCTION

The purpose of cardiopulmonary resuscitation (CPR) during cardiac arrest or hypovolemic shock is to provide adequate cardiac output. This can be done using either closed or open chest cardiac massage. Open cardiac massage may on rare occasions be performed in the Emergency Department. It is performed on patients who have had an emergent thoracotomy after penetrating chest trauma and have inadequate cardiac activity. It may also be performed, in rare instances, after a thoracotomy to decompress a pericardial tamponade in a medical patient. Open cardiac massage is considered a heroic procedure in the Emergency Department that can be lifesaving if performed on the appropriate patient.[1–11]

Open cardiac massage was routinely performed before the introduction of closed chest CPR. This technique was primarily performed in hospitals by Surgeons. Most of the patients were surgical and open cardiac massage had a high success rate. After the development of closed chest CPR in the early 1960s, there was a dramatic decline in open cardiac massage in the mid-to-late 1960s and 1970s. The exceptions were cardiac arrests due to trauma or in the Operating Room.

ANATOMY AND PATHOPHYSIOLOGY

The efficacy of cardiac massage can be established by measuring the cardiac output, coronary perfusion pressure, and cerebral perfusion pressure. Del Guercio et al. showed that a higher cardiac index can be achieved with open than with closed cardiac massage.[1] A minimal coronary perfusion pressure of 15 mmHg must be maintained for return of spontaneous circulation. While not all patients with this pressure will have a return of spontaneous circulation, a pressure of less than 15 mmHg predicts a uniformly fatal outcome.[2] While closed chest CPR generated only 1 to 9 mmHg of pressure, Boczar et al. found that their patients all had a coronary perfusion pressure of almost 20 mmHg throughout open chest massage.[3] Open chest CPR produces improved cerebral perfusion and better neurologic recovery.[4,10] Open cardiac massage can generate near normal cerebral blood flow and improve cardiac perfusion pressure.

INDICATIONS

Open cardiac massage is indicated if absent or inadequate cardiac activity is noted after a thoracotomy for penetrating trauma, a thoracotomy to decompress pericardial tamponade (spontaneous, postsurgical, or from an aortic dissection), or a cardiac arrest after recent chest surgery.[7,9,11] Other possible indications include abnormal chest wall anatomy that prevents closed chest CPR, hypothermic cardiac arrest, refractory ventricular fibrillation, massive air embolism, and if standard CPR is not effective.

CONTRAINDICATIONS

The only absolute contraindication to performing open cardiac massage is the presence of a palpable pulse. Open cardiac massage is ineffective if the patient has a pericardial tamponade. Perform a pericardiotomy and remove any clots from the pericardial sac. The

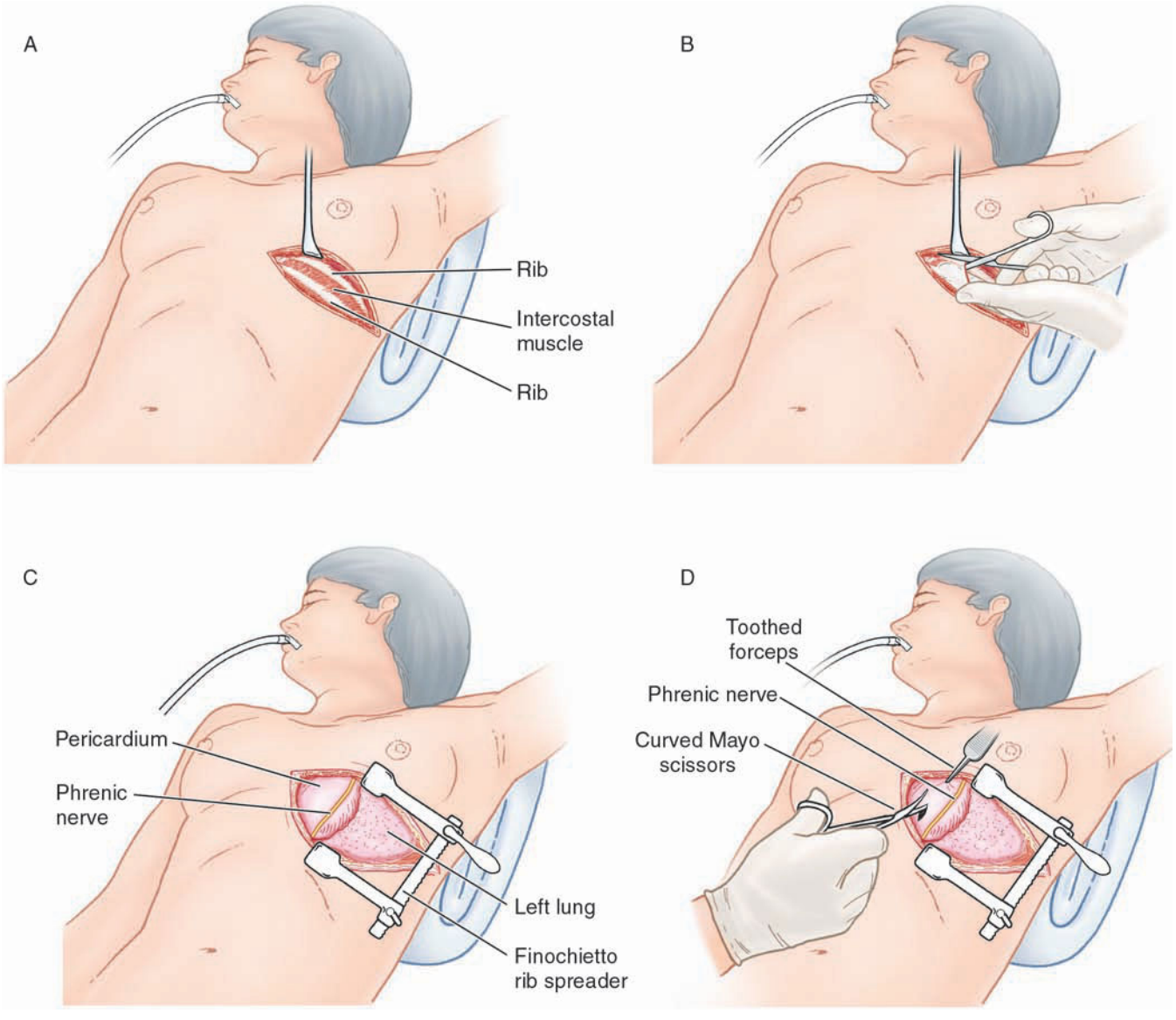


FIGURE 43-1. The anterolateral thoracotomy.

heart may then begin to beat spontaneously. If not, repair any lacerations to the myocardium prior to performing cardiac compressions.

EQUIPMENT

No equipment is required to perform open cardiac massage other than that needed to perform the thoracotomy and pericardiotomy (Chapter 42).

PATIENT PREPARATION

The preparation and positioning of the patient is exactly the same as that for a thoracotomy. A thoracotomy must first be performed (**Figure 43-1**). Refer to Chapter 42 for the complete details of a thoracotomy. A pericardiotomy should be performed only if absolutely necessary—that is, if blood is seen within the pericardial sac or cardiac tamponade is suspected. Remove any blood and clots from the pericardial sac, deliver the heart from the pericardial sac, and repair any myocardial lacerations.

An intact pericardium is preferable if open cardiac massage is to be performed. It prevents the fingertips from inadvertently rupturing the atria or ventricles should the heart be grasped incorrectly. The pressure from open cardiac massage is distributed over a larger area if the pericardium remains intact. The heart will move within the pericardial sac, prevent the fingers from compressing one spot for a prolonged time, and may decrease the chance of myocardial rupture.

TECHNIQUES

Several important principles must be kept in mind prior to performing open cardiac massage. The heart must be angled not more than 20° to 30° into the left hemithorax (Figure 43-2A). Angulation of more than 30° may crimp the pulmonary veins and vena cava closed and thus minimize cardiac output. The compressive forces should be applied perpendicular to the interventricular septum. Your hands should be placed directly behind and in front of the heart. The left anterior descending artery can be used as a landmark, as it runs above the interventricular septum. Do not place the fingers over the coronary arteries so that their flow is occluded. The fingertips should never be used to compress the heart, as they may rupture the

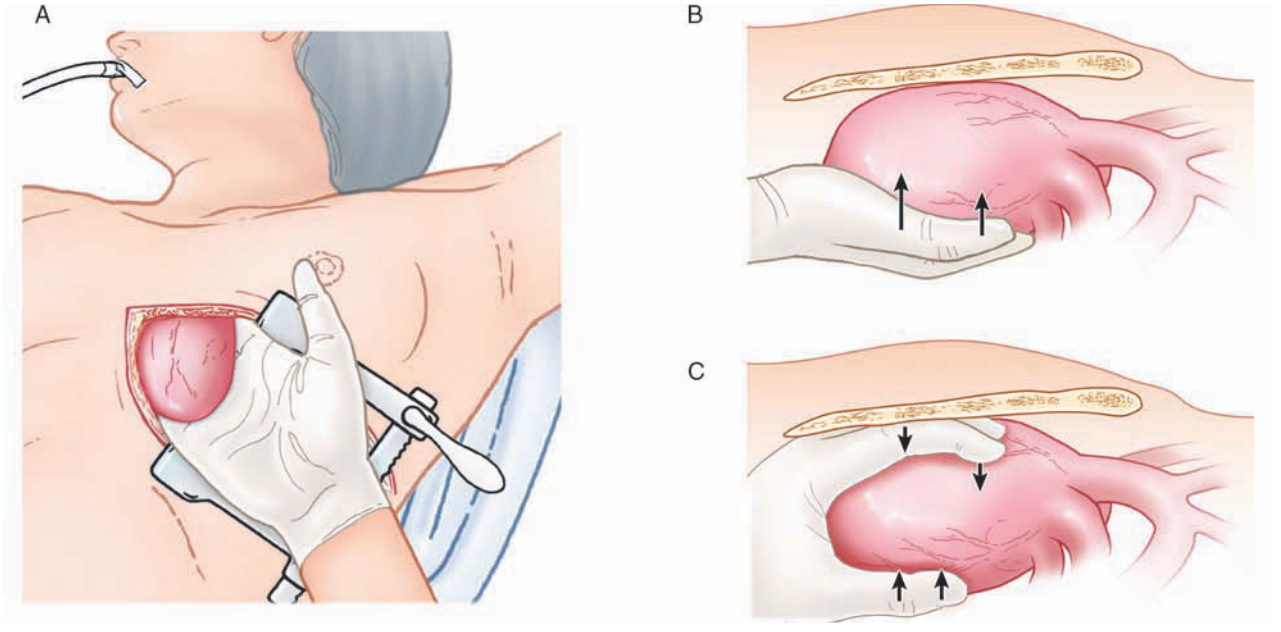


FIGURE 43-2. One-handed open cardiac massage. **A.** The dominant hand angles the heart 20° to 30° into the left hemithorax. **B.** One-handed cardiac massage with sternal compression. **C.** The one-handed compression technique.

myocardium. Use only the palm, volar surfaces of the fingers, and pads of the fingers to perform cardiac compressions. The fingers should always be held tightly together to form a flat surface. This allows the force of compression to be spread out and not concentrated over one finger. Each compression of the heart must be followed by complete relaxation of the heart. It is during this relaxation phase (i.e., diastole) that the cardiac chambers fill with blood and the coronary arteries perfuse the myocardium.

Three techniques have been described to perform open cardiac massage (**Figures 43-2 & 43-3**). These include one-handed massage with sternal compression, one-handed compression, and two-handed compression. Two-handed compression has been shown to be consistently superior to the other two techniques in generating cardiac output.[5]

ONE-HANDED MASSAGE WITH STERNAL COMPRESSIONS

Tightly adduct the fingers of the dominant hand to make a flat surface. Insert the hand into the thoracotomy incision and against the posterior surface of the heart (**Figures 43-2A & B**). Angle the heart 20° to 30° into the left hemithorax. Compress the heart against the sternum, beginning with the heel of the hand, then the palm, then fingers in sequence. This method is difficult to perform in children because of the plasticity of the sternum.[6]

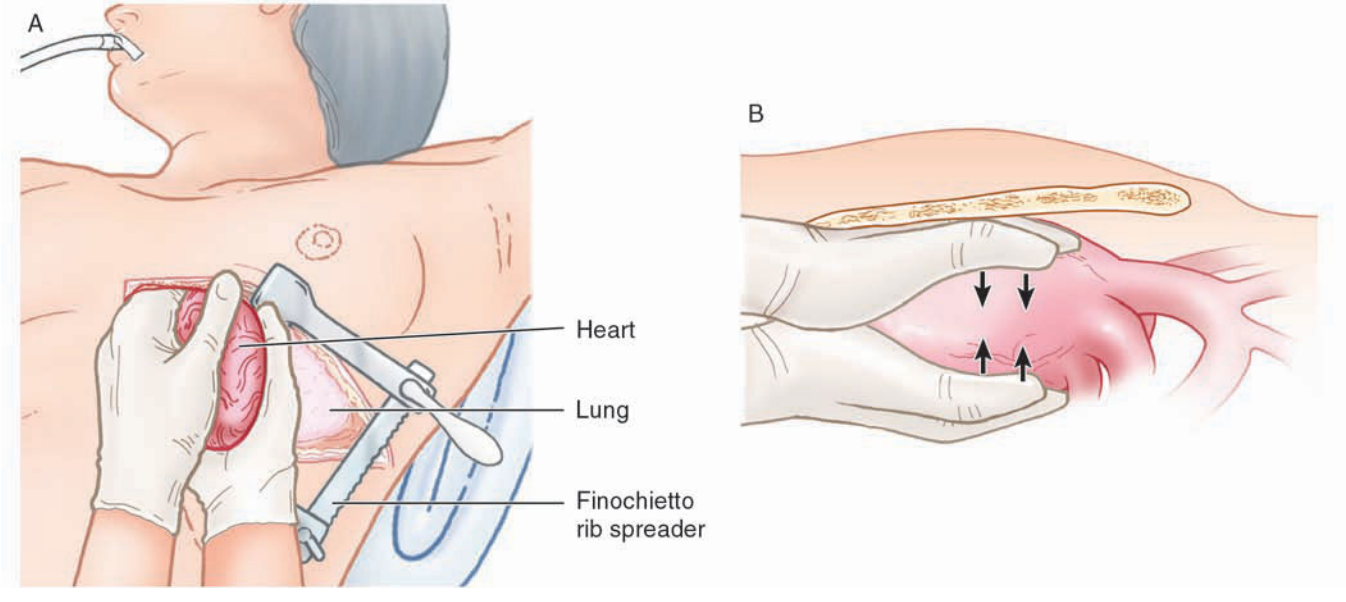


FIGURE 43-3. Two-handed open cardiac massage. **A.** The hands are positioned on the anterior and posterior surfaces of the heart. **B.** Compressions begin at the cardiac apex with the palms and progress toward the base of the heart with the fingers.

ONE-HANDED COMPRESSIONS

Tightly adduct the fingers of the dominant hand to make a flat surface. Insert the hand into the thoracotomy incision and against the anterior surface of the heart (**Figure 43-2C**). Place the thumb against the posterior surface of the heart. The apex of the heart will lie in the palm of the hand (**Figure 43-2C**). Angle the heart 20° to 30° into the left hemithorax. Appose the thumb and fingers to compress the heart. This is not the preferred method, as the thumb can place significant pressure on the left ventricle and possibly cause it to rupture.

TWO-HANDED COMPRESSIONS

This is the technique of choice in children. The child's sternum, the costochondral tissues, and the ribs are mostly cartilage. Thus, the sternum is very pliable. This makes the one-handed massage with sternal compression technique not very effective. The one-handed compression technique can rupture the thin myocardial walls.

Tightly adduct the fingers and cup the left hand. Insert the left hand into the thoracotomy incision and against the anterior surface of the heart (**Figure 43-3A**). Tightly adduct the fingers of the right hand to make a flat surface. Insert the right hand into the thoracotomy incision and against the posterior surface of the heart (**Figure 43-3A**). Angle the heart 20° to 30° into the left hemithorax. Appose the hands to compress the heart (**Figure 43-3B**). Compressions should ideally begin with the heel of the hands and progress toward the fingers.

ASSESSMENT

Compressions should begin at a rate appropriate for the patient's age as specified by the American Heart Association (Pediatric Advanced Life Support and Advanced Cardiac Life Support). Ideally, compress the heart at a rate of at least 100 times a minute if possible. This compression rate is based on consensus and not clinical research. Assess the effectiveness of the cardiac compressions by noting a palpable carotid pulse. A radial or femoral arterial line can be placed to monitor the effectiveness of the compressions. The arterial line allows for repeated blood and blood gas sampling. The arterial line will also allow the Emergency Physician to ensure that the heart is completely relaxed between compressions.

AFTERCARE

If a spontaneous cardiac rhythm and a peripheral pulse return, cover the thoracotomy incision with sterile saline-moistened gauze and a simple dressing. Administer intravenous antibiotics whose spectrum covers skin flora. The patient must be taken emergently to the Operating Room by a Trauma Surgeon or Cardiothoracic Surgeon for definitive treatment and closure of the chest wall.

COMPLICATIONS

The major complication of open cardiac massage is myocardial rupture or perforation. This can occur from compression of the heart against a jagged and fractured rib or sternum. Incorrect technique with too vigorous a massage can result in perforation of the ischemic myocardium by the fingertips. Other complications include decreased cardiac output with compressions if the heart is angled more than 30° into the left hemithorax and kinks shut the vena cava or pulmonary veins. Infection is possible if the patient survives. Parenteral antibiotics should be administered to prevent infection and sepsis. The complications associated with the thoracotomy and the pericardiotomy are discussed in Chapter 42. The quality of life of survivors can be poor to normal.[8]

SUMMARY

Open cardiac massage is a more efficient way of maintaining circulation than closed chest massage. Cardiac compressions can be performed with one or two hands, depending on physician preference. The two-handed technique is preferred, as it generates greater cardiac output than the one-handed techniques. Once a cardiac rhythm and blood pressure are restored, definitive treatment for injuries must be provided expeditiously by a Surgeon in the Operating Room.

44 Cardiac Wound Repair

Eric F. Reichman

INTRODUCTION

Wounds of the heart are highly lethal. Traumatic cardiac penetration carries a 70% to 80% fatality rate.[1] Major factors determining survivability include whether or not cardiac standstill has occurred as well as the amount of tissue destruction sustained from the injury.[2]

Penetrating wounds can be caused by knives, bullets, ice picks, and (infrequently) rib or sternal fragments. **Regardless of the offending agent, repair must be done as expeditiously as possible.** The right ventricle is the most frequently injured chamber. However, injury to the heart may occur at more than one site. This is especially true with gunshot wounds.

The treatment goal in the Emergency Department is temporary hemostasis. Many different techniques of cardiorrhaphy have been described. We will limit our discussion to five possible approaches to dealing with these injuries (i.e., digital or Foley catheter occlusion, vascular clamps, staples, and sutures).

ANATOMY AND PATHOPHYSIOLOGY

The heart is contained within the pericardial sac. Numerous portions of the heart are exposed behind the anterior chest wall (**Figure 36-2**). This includes the right ventricle, left ventricle, right atrium, left atrium, aorta, pulmonary artery, and inferior vena cava. These structures are vulnerable to injury behind the anterior chest wall.[3,4] The surface areas that each of these structures contributes to the anterior cardiac silhouette are as follows: 55% right ventricle, 20% left ventricle, 10% right atrium, 10% aorta and pulmonary artery, 4% inferior vena cava, and 1% left atrium.[5] These numbers also reflect, roughly, the anatomic incidence of injury with cardiac trauma.[5] Traumatic injury to any of these structures can result in a pericardial effusion and cardiac tamponade.

INDICATIONS

Any penetrating injury to the heart requires immediate and temporary repair to prevent the patient from exsanguinating. A bluish hue behind the pericardium or a tense pericardial sac after penetrating trauma suggests an underlying cardiac injury. A pericardiotomy should be performed, any blood and clot removed from the pericardial sac, and the heart explored for the site of injury. The indications to perform a thoracotomy are described in Chapter 42.

CONTRAINDICATIONS

The only absolute contraindication to performing a cardiorrhaphy is if the patient has obvious signs of death. It should not be performed if the patient has not had any vital signs for over 15 minutes, as anoxic brain injury is irreversible. It is also contraindicated in



FIGURE 44-1. Examples of several atraumatic vascular clamps.

patients with penetrating chest trauma who do not meet the criteria for performing an anterolateral thoracotomy (Chapter 42).

EQUIPMENT

- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Silk suture, 4-0 and 5-0 (or Prolene)
- 2-0 silk, on a semicircular atraumatic needle
- 10 in. needle driver
- Foley catheter, sizes 14 to 20 French
- Satinsky, or other, atraumatic vascular clamp (**Figure 44-1**)
- Allis clamps
- Defibrillator with internal cardiac paddles
- Mayo scissors
- Metzenbaum scissors, curved
- Teflon pledgets
- Sterile saline
- 20 mL syringe
- Standard skin stapler, 6 mm wide staples
- Laparotomy pads
- Gauze 4 × 4 squares
- Hemostats

PATIENT PREPARATION

No preparation is required other than that of performing a thoracotomy and a pericardiotomy (Chapter 42). The patient should be intubated, ventilated with 100% oxygen, and fully monitored (i.e., telemetry, a noninvasive blood pressure cuff, and pulse oximetry). Instruct a nurse to administer intravenous broad spectrum antibiotics that cover skin flora, gram-positive organisms, and gram-negative organisms. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids. While time is of the essence and this is an emergent procedure, aseptic technique should be followed.

TECHNIQUES

Bleeding from a cardiac wound should ideally be stopped by placing a finger over the wound and immediately transporting the patient to the Operating Room for definitive repair. Unfortunately,

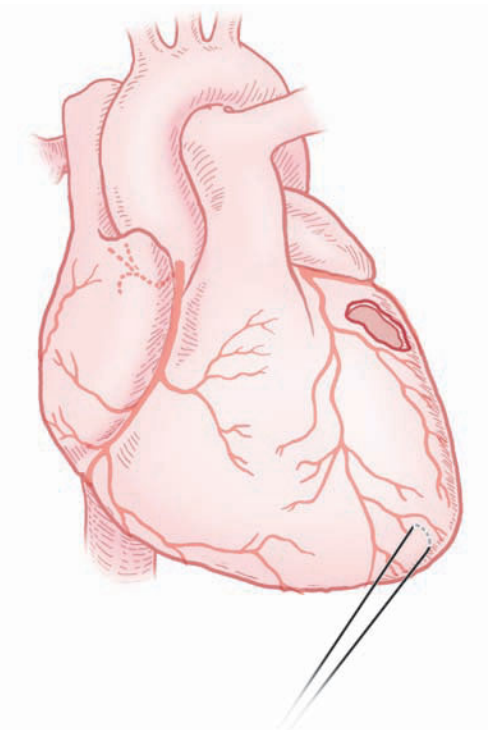


FIGURE 44-2. The apical traction suture known as Beck's suture may be placed to control the heart.

the Anesthesiologist, Surgeon, and/or Operating Room may not be immediately available. If the Emergency Physician performs a thoracotomy, they should be versed in methods of temporary cardiac wound repair. Several techniques are available to control hemorrhage from a cardiac wound.

CONTROL OF THE HEART

It is extremely difficult to maintain a finger over a cardiac wound or to stitch a cardiac wound if the heart is beating. An apical traction suture known as Beck's suture can be placed to control the heart (**Figure 44-2**). The apex of the heart is the ideal site because it is often away from most lacerations, is a thick portion of the heart, and is away from any major coronary arteries. Place a 2-0 silk suture through the apex of the heart and remove the needle from the suture. The ends of the suture can be grasped by hand or with a hemostat to elevate and control the heart while it is beating.

SAUERBRUCH MANEUVER

Large cardiac wounds and wounds with significant bleeding are difficult to repair, as the blood obscures the surgical field. Experienced Surgeons may temporarily clamp the inferior and superior vena cava to maintain a bloodless field. **Clamping the vena cava should not be performed by an Emergency Physician, as it is time-consuming and can injure other structures.** A quicker and safer alternative is the Sauerbruch maneuver, or grip, to partially occlude venous inflow through the inferior and superior vena cava (**Figure 44-3**). This technique will stabilize the heart for wound repair and allow the bleeding site to be identified and repaired.

Insert the nondominant hand into the pericardial cavity and toward the vena cava. Place the middle finger behind the vena cava and the index finger in front of the vena cava (**Figure 44-3**). The thumb should be resting on the anterior surface of the heart. The ring and little fingers should be resting on the posterior surface of the heart. Use the thumb and the ring and little fingers to cradle

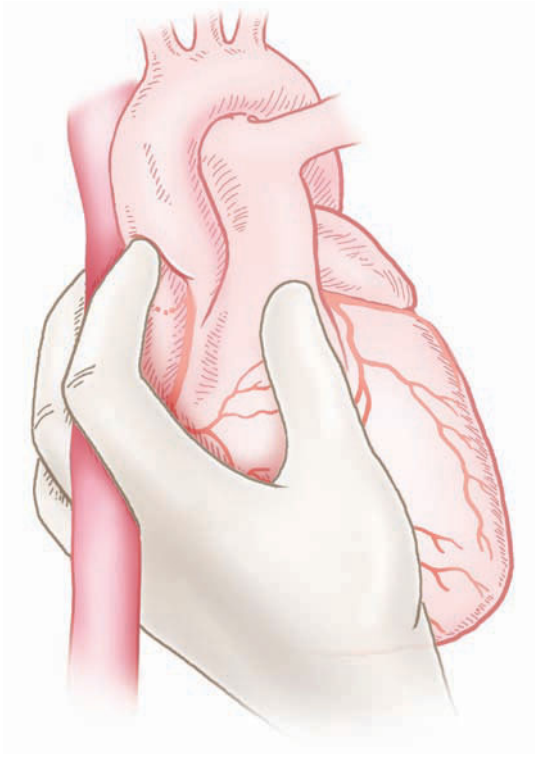


FIGURE 44-3. The Sauerbruch maneuver to partially occlude venous inflow from the superior and inferior vena cava.

the heart while apposing the middle and index fingers to partially occlude the vena cava. This technique can be used to control hemorrhage from the heart, great vessels, or hilum. **While effective at controlling hemorrhage, this technique will significantly reduce cardiac output and result in cardiac arrest. The grip should be released every 30 to 60 seconds to ensure coronary artery perfusion.**

DIGITAL OCCLUSION

Digital occlusion of small cardiac wounds can provide excellent hemostasis while awaiting definitive repair. Once a finger is placed on or over the defect, it must remain there until the appropriate materials to perform cardiorrhaphy are available. **Do not place a finger into the defect as this may increase the size of the wound.** Unfortunately, the fingertip often slips off the wound if the heart is beating. The fingertip interferes with visualization and repair of the wound. It also places the healthcare worker at risk for a needle-stick injury while attempting to repair the wound.

FOLEY CATHETER TECHNIQUE

A Foley catheter may be used to provide temporary hemostasis. As with digital occlusion, this is only a temporizing measure. Inflate the cuff of the Foley catheter with sterile saline to check its integrity and look for leaks. **Deflate the cuff. Place a hemostat on the Foley catheter 3 to 4 cm proximal to the cuff. This will prevent air from being drawn through the catheter and causing an air embolism.**

Identify the location of the cardiac wound (**Figure 44-4A**). Insert the Foley catheter through the cardiac wound until the balloon is

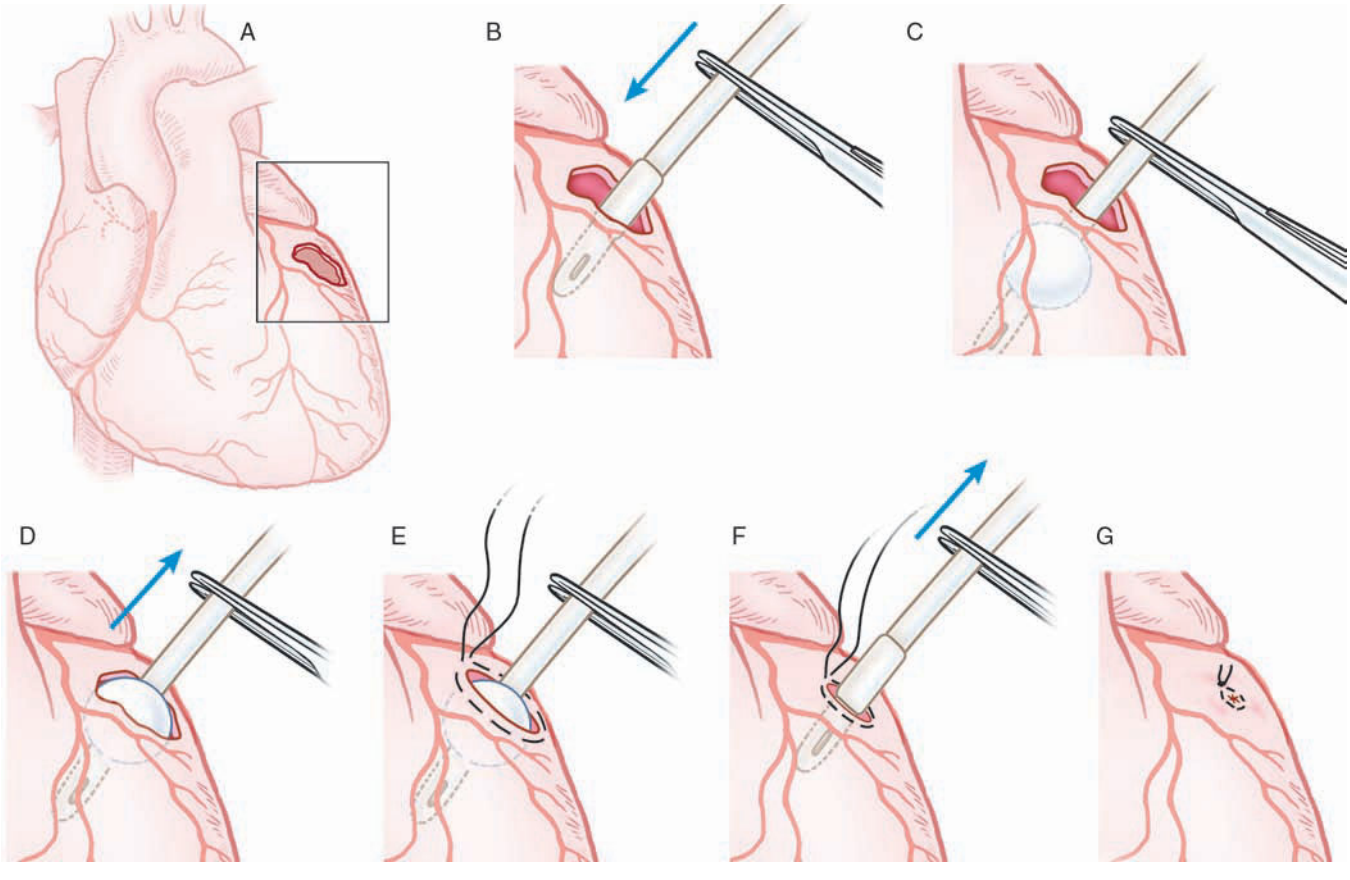


FIGURE 44-4. The Foley catheter technique to occlude and repair a cardiac wound. **A.** The cardiac wound is identified. **B.** The Foley catheter is inserted through the wound. **C.** The cuff is inflated. **D.** Gentle traction is applied to occlude the wound with the cuff. **E.** A purse-string suture is placed around the wound. **F.** The cuff is deflated and the Foley catheter is removed. **G.** The purse-string suture is tightened and tied to occlude the wound.

within the cardiac chamber (**Figure 44-4B**). Release the hemostat, inflate the cuff with 10 to 20 mL of sterile saline, and reclamp the Foley catheter (**Figure 44-4C**). **This step should be done quickly to prevent air from being drawn through the Foley catheter.**

Apply gentle traction to the catheter (Figure 44-4D). Apply just enough traction to mostly occlude the wound and slow the bleeding. A small amount of bleeding is adequate and acceptable to visualize the wound and perform a temporary repair. Do not try to provide complete hemostasis. This will result in excessive traction on the Foley catheter causing the cuff to pull through the wound, enlarge the wound, and further lacerate the myocardium.

Repair the cardiac wound. Place a purse-string suture around the wound (**Figure 44-4E**). **Use caution when placing the suture so that the needle does not pierce and rupture the cuff of the Foley catheter.** The Foley catheter may be advanced into the cardiac chamber temporarily while the suture is being placed. This will prevent the needle from piercing the cuff. **Do not advance the cuff too far into the heart and for too long a time period. The cuff may occlude blood flow through the valves and result in cardiac arrest.** After the purse-string suture is placed, deflate the cuff and quickly remove the Foley catheter (**Figure 44-4F**). Tie the ends of the suture to close the cardiac wound (**Figure 44-4G**). Place additional knots to secure the suture.

The Foley catheter technique is simple and effective. It avoids the problems associated with digital occlusion. The catheter may be placed in posterior cardiac wounds that are difficult to visualize and where it is hard to maintain digital occlusion. The Foley catheter does not interfere with visualization of the wound, wound repair, or the simultaneous performance of cardiac massage. Intravenous catheter tubing may be inserted into the lumen of the Foley catheter to infuse crystalloid solutions or red blood cells directly into the heart and central circulation. This technique is especially valuable in repairing wounds at the junction of the right atrium and vena cava.

CLAMP TECHNIQUE

Atrial wounds can bleed profusely and are difficult to control. The thin walls do not allow digital occlusion to be effective. The atrial wound can be grasped and compressed between the thumb and index finger. An atraumatic Satinsky vascular clamp can be placed around the wound to provide hemostasis (**Figure 44-5**). The wound may then be repaired with 4-0 or 5-0 interrupted silk sutures.

Allis clamps may be substituted if an atraumatic vascular clamp is not available. Place an Allis clamp on each of the opposing edges of the atrial wound. Apply upward traction, then cross the Allis clamps to approximate the wound edges. The wound may now be sutured closed. The Allis clamps do not provide as bloodless a field as does the atraumatic vascular clamp.

STAPLE TECHNIQUE

Skin staplers provide a quick and easy method to repair cardiac wounds. Careful approximation and stapling of the wound will rapidly close the defect and aid in controlling massive blood loss. Staples may be used to close small, large, or multiple lacerations. Its use avoids the potential complication of a needle stick to the Emergency Physician.

Cardiac wounds are closed similarly to skin lacerations (**Figure 44-6**). Obtain a standard skin stapler with 6 mm wide staples. These are readily available in Emergency Departments for wound closure. Use the nondominant hand to appose the wound edges. Grasp the stapler with the dominant hand. Place staples at 5 mm intervals until the wound is closed.

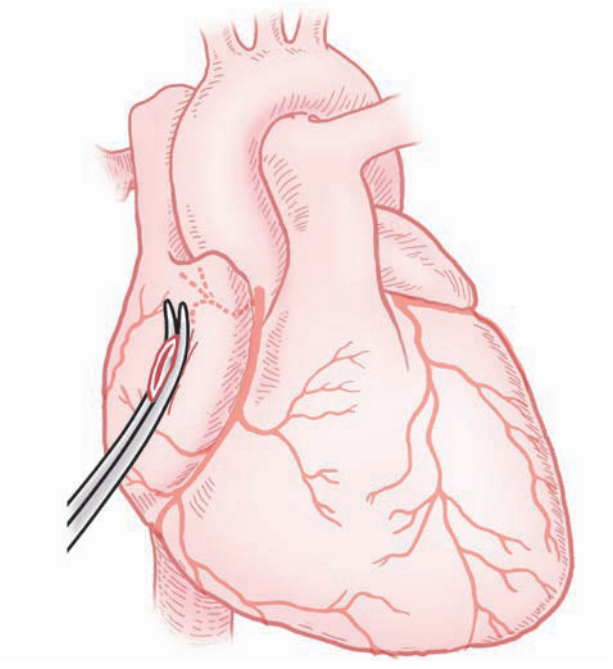


FIGURE 44-5. A Satinsky vascular clamp provides hemostasis for atrial wounds.

SUTURE TECHNIQUES

Suturing of cardiac wounds is more time consuming than the other methods previously described. It requires technical proficiency and understanding of the heart's surface anatomy. Place horizontal mattress sutures using 2-0 or 3-0 silk or Prolene suture material (**Figure 44-7**). **Do not tie the sutures tightly. It is easy to inadvertently tear through the myocardium.** Use teflon pledgets to reinforce the repair and prevent cutting through the heart tissue (**Figures 44-7A & B**). This is especially important when the wound edges are irregular or tattered. Use care to avoid injury to the coronary vessels, which may lie in close proximity to a cardiac wound. Ensure that the sutures are placed adjacent to and underneath the coronary vessels (**Figure 44-7C**).

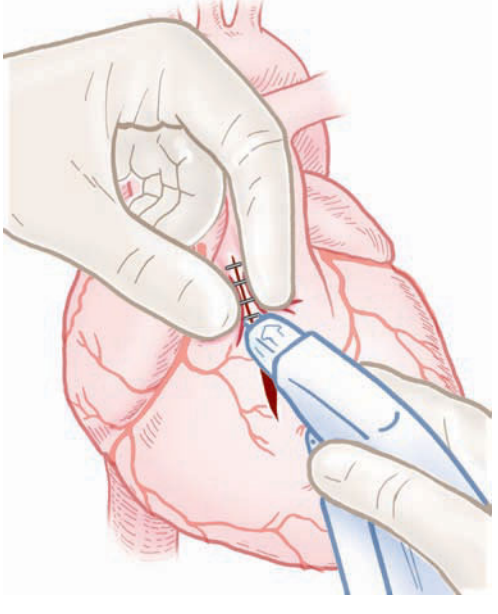


FIGURE 44-6. The cardiac stapling technique provides temporary hemostasis.

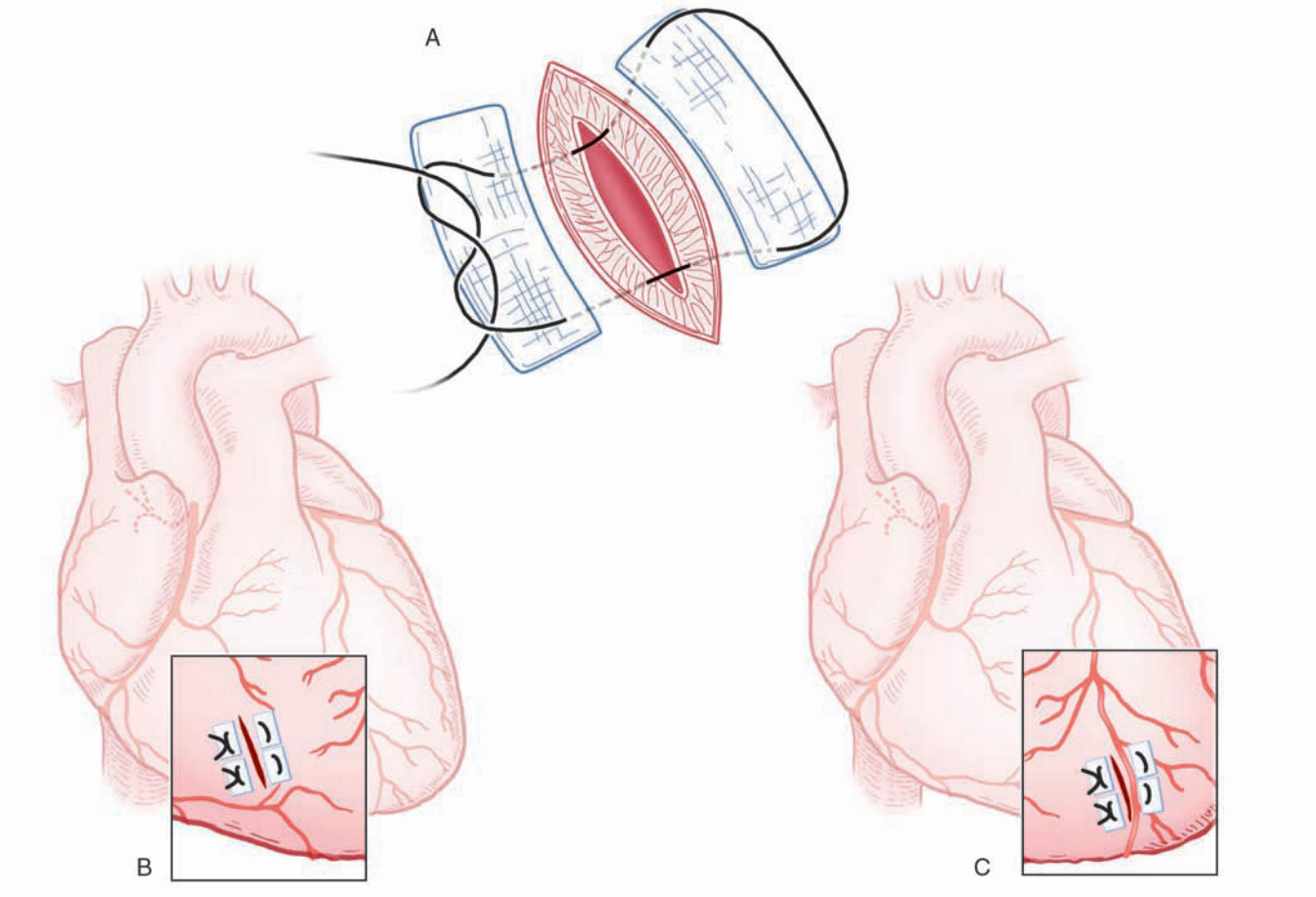


FIGURE 44-7. Horizontal mattress sutures used to close cardiac wounds. **A.** Teflon pledgets are placed on either side of the wound to prevent the suture from pulling through the myocardium. **B.** Wounds are closed with multiple horizontal mattress sutures. **C.** When suturing near a coronary artery, ensure that the sutures pass completely below the artery.

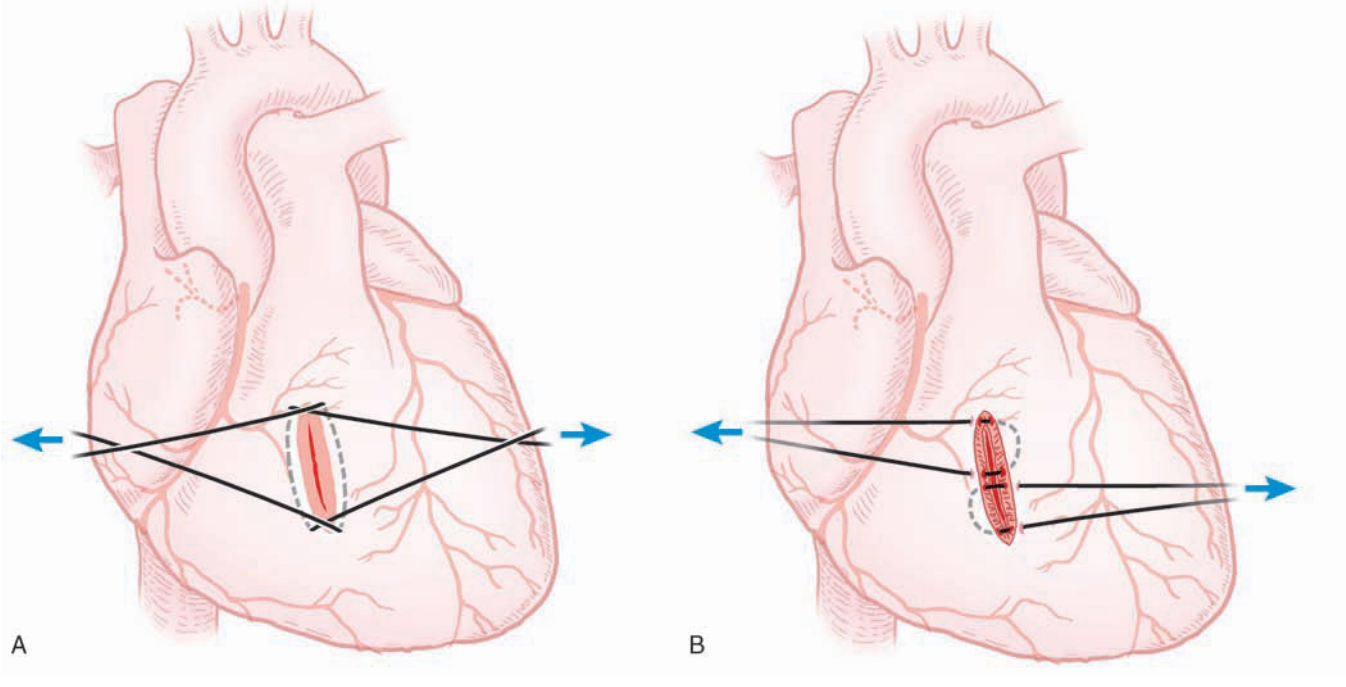


FIGURE 44-8. Incomplete horizontal mattress stitches may be placed on each side of a large wound. Tension applied to the sutures will appose the wound edges (*arrows*).



FIGURE 44-9. The internal cardiac paddles inserted into the handles.

Large cardiac wounds are difficult to repair. They bleed profusely. The digital occlusion and Foley catheter techniques are ineffective on large wounds. The wound edges are difficult to grasp and appose so that they can be repaired with a skin stapler. Place an incomplete horizontal mattress stitch on each side of the wound (**Figure 44-8**). Grasp the free ends of the sutures and cross them across the wound to appose the wound edges. Instruct an assistant to hold the suture ends while the cardiac wound is repaired with 2-0 or 3-0 silk, Prolene, or staples. The incomplete mattress sutures may then be removed or tied to each other.

FIBRILLATION

The myocardium can be deliberately placed in fibrillation to halt myocardial contractions and repair large ventricular wounds. **This should be performed only if other techniques of cardiac wound repair are unsuccessful.** Choose the proper size internal cardiac paddles. The paddle size for an infant is 2 cm, for a child is 4 cm, and for an adolescent or adult is 6 cm. Insert the sterile paddles into the sterile handles (**Figure 44-9**). Pass the cables exiting the base of the handles to an assistant to insert into the defibrillator machine ports. Instruct the assistant to turn on the defibrillator.

Place the internal cardiac paddles on the anterior and posterior surfaces of the heart (**Figure 44-10**). While the paddles can be placed directly on the heart, it is recommended by some to place sterile saline-moistened gauze squares between the paddles and the heart to aid in conduction. Apply 20 Joules (J) of energy through the paddles to fibrillate the adolescent or adult heart. Begin with 5 J of energy to fibrillate the infant or child heart. Proceed upward incrementally as required to a maximum of 20 J to fibrillate the infant or child heart. **Quickly repair the cardiac wound.**

Perform intermittent cardiac massage while repairing the fibrillating myocardium to maintain cardiac output. Do not allow the heart to fibrillate for more than 3 minutes. Defibrillate the heart with the internal paddles using 20 J of energy for the adult and adolescent heart. Repeat the defibrillation with 20 J of energy until the heart begins beating. **In general, do not use more than 20 J to defibrillate the adult or adolescent heart with the internal cardiac paddles as myocardial necrosis can occur.** It may be occasionally necessary increase the energy in the adolescent or adult to 40 J then 60 J if multiple attempts at 20 J are ineffective. Begin with 5 J of energy to defibrillate the infant or child heart. Proceed upward incrementally as required to a maximum of 20 J to defibrillate the infant or child heart.

AFTERCARE

If the patient is resuscitated, cover the thoracotomy wound with saline-moistened gauze and a simple dressing. Administer broad spectrum antibiotics if not done previously. Immediately transport the patient to the Operating Room for definitive repair of the cardiac wound and any other injuries by a Trauma or Cardiovascular Surgeon.

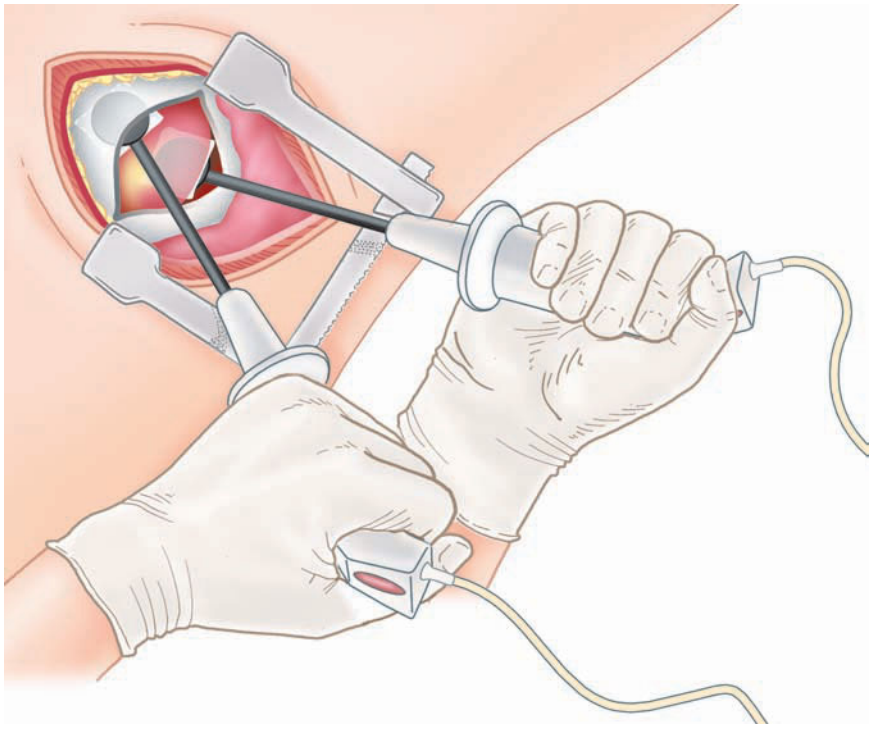


FIGURE 44-10. Application of the internal cardiac paddles. Sterile saline-moistened gauze can be placed between the paddles and the heart to increase conductivity.

COMPLICATIONS

The complications associated with digital pressure include further destruction of tissue. If pulled too tightly, Foley catheters can become dislodged and restart troublesome bleeding. They can also enlarge a cardiac wound if the cuff pulls through the wound. A drop in cardiac output can result if the cuff obstructs the cardiac valves, impinges on the chordae tendineae, or occupies too much space within the cardiac chamber. Decrease the cuff size by withdrawing some of the saline from the cuff. Suturing is probably associated with the greatest rate of complications. Tearing of the myocardium is a frequently encountered problem. The suture should be tied just tight enough to stop the bleeding. Care should be exercised to avoid ligation of the major coronary vessels and their branches. Dysrhythmias can result from occlusion of venous inflow (Sauerbruch maneuver) or injury to the coronary vasculature. If the patient is resuscitated, administer broad-spectrum antibiotics to prevent any potential infectious complication.

SUMMARY

Injuries to the heart can be devastating. The role of the Emergency Physician is to rapidly and temporarily control bleeding and ensure the transport of the patient to the Operating Room for definitive repair. If there is a delay in transporting the patient to the operating room, the Emergency Physician must be versed in the techniques used to repair cardiac wounds and resuscitate the patient.

45 Hilum and Great Vessel Wound Management

Eric F. Reichman

INTRODUCTION

Injuries to the thoracic great vessels can be a significant cause of morbidity and mortality. Large vessels in the hilum of the lung include the pulmonary artery and vein. The great vessels also include the vena cava, aorta, innominate artery, subclavian artery, and subclavian vein. The mortality from injuries to the subclavian artery is approximately 5% if patients who are moribund on admission to the Emergency Department are excluded.[1] However, the mortality from injury to the vena cava and the pulmonary vessels is over 60%.[2] While over 85% of patients with penetrating injuries to the thorax are stable, the remainder present in varying levels of hypovolemic shock. They may have bled externally or into the chest. Each hemithorax can hold up to one-half of an individual's blood volume. In these cases, an Emergency Department thoracotomy may be performed for hypovolemic shock.

ANATOMY AND PATHOPHYSIOLOGY

Injury to the thoracic great vessels may be due to blunt trauma, diagnostic procedures, iatrogenic causes, or penetrating trauma. Crush injuries, deceleration injuries, motor vehicle versus pedestrian collisions, and penetrating thoracic injuries may all signify an injury to a thoracic great vessel. The vessels that are most commonly injured include the aorta, innominate artery, pulmonary vein, and venae cavae.

The portable anteroposterior chest radiograph is the initial radiographic screening. It may reveal loss of the aortic knob contour, left-sided pleural effusions, mediastinal widening, nasogastric tube deviation, or tracheal deviation, all of which suggest injury to a great vessel. Other findings suggestive of such an injury include depression of the left mainstem bronchus, left apical capping, narrowing of the carinal angle, sternal fractures, opacification of the aortopulmonary window, and widening of the paraspinous stripe.

Numerous physical examination findings are suggestive of a thoracic great vessel injury. Asymmetric pulses or unequal blood pressures between the extremities are quick and simple to evaluate. Hypotension may be due to internal or external hemorrhage. Steering wheel contusions, sternal fractures, thoracic spine fractures, and a left-sided flail chest signify potential intrathoracic injury. A thoracic outlet hematoma or a hoarse voice can occur from injury to the aorta or one of its major branches. Paraplegia may be due to hypotension or an aortic disruption.

INDICATIONS

Attempts should be made to control any laceration or rupture of the thoracic great vessels.

CONTRAINDICATIONS

There are no absolute contraindications to temporarily controlling any hemorrhage from a thoracic great vessel after performing a thoracotomy (Chapter 42). The thoracotomy should not be performed if the patient has obvious signs of death, no vital signs in the field, or no vital signs for over 15 minutes. A pericardial tamponade or cardiac injury may require management prior to managing a great vessel injury.

EQUIPMENT

- 3-0 Prolene suture
- Foley catheters, sizes 14 to 20 French
- 10 in. needle driver
- Satinsky, or other, atraumatic vascular clamp (**Figure 45-1**)
- Sterile saline
- 20 mL syringe
- Laparotomy pads
- Gauze 4 × 4 squares
- Umbilical clamp
- Hemostats



FIGURE 45-1. Examples of several atraumatic vascular clamps.

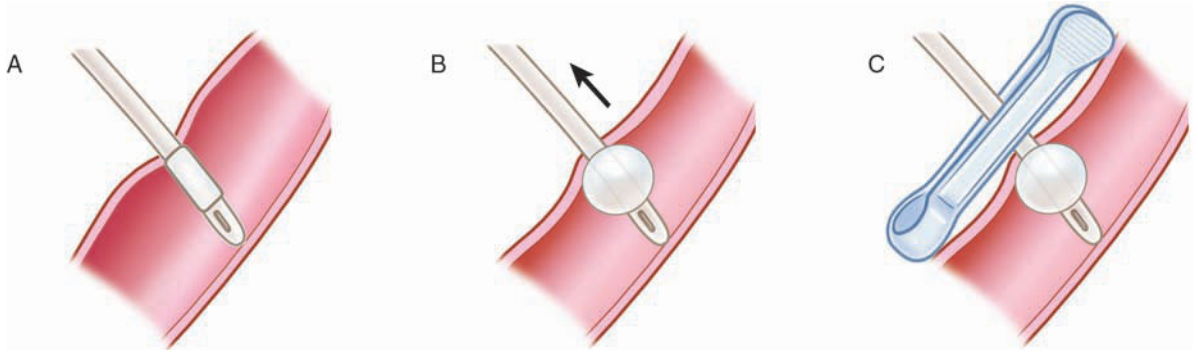


FIGURE 45-2. The Foley catheter technique to occlude an injury to a great vessel. **A.** The catheter is inserted through the wound and into the vessel. **B.** The cuff is inflated and gentle traction (*arrow*) is applied to occlude the wound with the cuff. **C.** An umbilical clamp is placed to prevent the catheter from migrating inward.

PATIENT PREPARATION

There is no preparation required other than performing an anterolateral thoracotomy (Chapter 42). The patient should be intubated, ventilated with 100% oxygen, and fully monitored (i.e., telemetry, a noninvasive blood pressure cuff, and pulse oximetry). Instruct a nurse to administer intravenous broad-spectrum antibiotics that cover skin flora, gram-positive organisms, and gram-negative organisms. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids. While time is of the essence and this is an emergent procedure, aseptic technique should be followed.

TECHNIQUES

DIGITAL OCCLUSION

Digital pressure may be used to control small lacerations of the thoracic vena cava. It will provide adequate hemostasis while repairing the wound. **Place a fingertip over the defect.** Do not place a finger in the defect. Place horizontal mattress sutures using 3-0 Prolene to close the defect. Unfortunately, the fingertip interferes with visualization of the wound and places the Emergency Physician at risk for a needlestick injury. The fingertip will have to be intermittently removed to place the sutures.

Digital pressure and rapid transport to the operating room is the most practical method of dealing with injuries to the subclavian vessels. These vessels are extremely difficult to control through a traditional anterolateral thoracotomy incision. If digital pressure is ineffective, pack the apex of the thoracic cavity with laparotomy pads or gauze squares and apply compression from below.

FOLEY CATHETER TECHNIQUE

By inserting a Foley catheter into the vessel, inflating the cuff, and placing it under gentle traction, one may occlude a wound to a great vessel (**Figure 45-2**). As with digital occlusion, this is only a temporizing measure. Inflate the cuff of the Foley catheter with sterile saline to check its integrity and look for leaks. Deflate the cuff. **Place a hemostat on the Foley catheter proximal to the cuff. This will prevent air from being drawn through the catheter and causing an air embolism.**

Identify the location of the vascular injury. Insert the catheter through the wound until the cuff is within the vessel (**Figure 45-2A**). Open the hemostat, inflate the cuff with 5 to 10 mL of sterile saline, and reclamp the Foley catheter. **This step should be completed quickly to prevent air from being drawn through the catheter. Do not overinflate the cuff so that it occludes flow through the vessel. Apply gentle traction to the catheter (Figure 45-2B). Apply just enough traction to mostly occlude the wound and slow the bleeding. Do not try to provide complete hemostasis.** This will result in excessive traction on the catheter, causing the cuff to pull through the wound, enlarge the wound, and further injure the vessel. Place an umbilical clamp or a hemostat on the catheter just outside the vessel to prevent it from migrating into the vessel (**Figure 45-2C**).

The Foley catheter technique is simple and effective. It avoids the problems associated with digital occlusion. It does not interfere with visualization of the wound or the simultaneous performance of cardiac massage. Intravenous catheter tubing may be inserted into the lumen of the Foley catheter to infuse crystalloid solutions or red blood cells directly into the heart and central circulation.

CROSS-CLAMPING TECHNIQUE

Injuries to the thoracic great vessels can bleed profusely and are difficult to control. Digital occlusion is often ineffective. An atraumatic Satinsky vascular clamp can be placed to partially occlude the great vessel and isolate the injury (**Figure 45-3**). This will provide temporary hemostasis until definitive repair in the Operating Room.

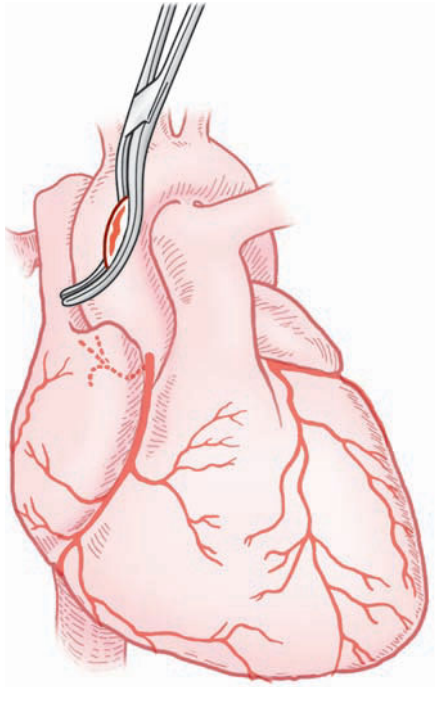


FIGURE 45-3. A Satinsky vascular clamp may be used to partially occlude the great vessel and isolate the injury.

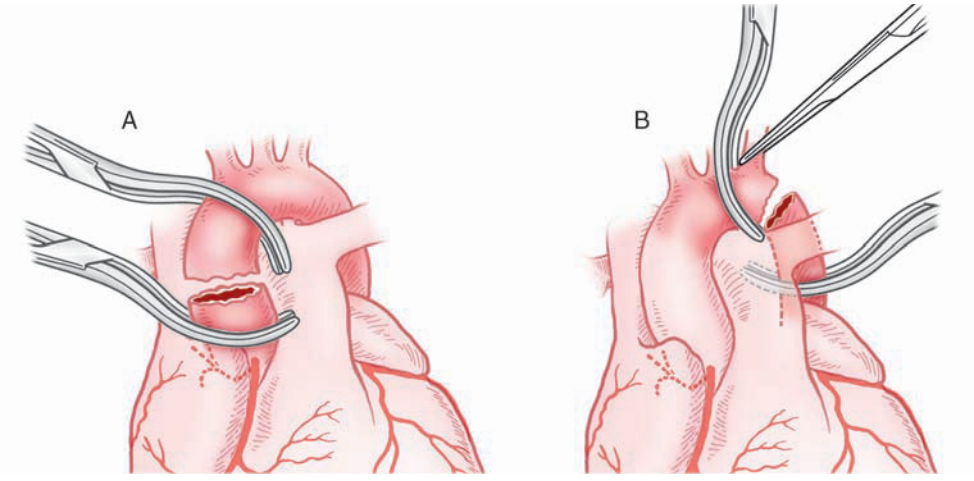


FIGURE 45-4. Cross-clamping of vascular injuries. **A.** Cross-clamp the great vessels to provide temporary hemostasis. **B.** Distal vessels must also be cross-clamped to prevent backbleeding.

Large wounds and complete transections are difficult to manage. Injuries to the pulmonary vasculature in the region of the hilum are most expeditiously controlled by placing an atraumatic vascular clamp across the respective hilum.[3] Grasp the hilum between the thumb and the forefinger. Place the clamp carefully around the entire hilum. Take care not to injure the pulmonary parenchyma or the vessels any further. Vascular injuries may be controlled by placing a cross-clamp proximal to the injury and occluding the backbleeding with additional clamps (**Figure 45-4**). These patients should be immediately transported to the Operating Room to be placed on bypass and repair the injuries. **It is not recommended for the Emergency Physician to suture great vessel injuries in an attempt to repair them.**

AFTERCARE

If the patient is resuscitated, cover the thoracotomy wound with saline-moistened gauze and a simple dressing. Administer broad-spectrum antibiotics if not done previously. Immediately transport the patient to the Operating Room for definitive repair of the great vessel injury and any other injuries by a Trauma or Cardiovascular Surgeon.

COMPLICATIONS

The complications associated with digital pressure include extending the injury if the procedure is not performed carefully. Inaccurate digital control can lead to unnecessary loss of blood during transport of the patient to the operating room. Foley catheters, if pulled too tightly, can become dislodged and restart troublesome bleeding. They can also enlarge a wound if the cuff pulls through the wound. The cuff may obstruct flow through the vessel and compromise cardiac output. Decrease the cuff size by withdrawing some of the saline from the cuff. An overly rough mobilization and clamping can increase the size of the injury and cause massive bleeding. Cross-clamping of the aorta and/or pulmonary artery will obstruct peripheral blood flow. The vessel must be repaired or the patient placed on bypass to prevent anoxia and permanent neurologic dysfunction.

SUMMARY

Injuries to the thoracic great vessels carry a high mortality as bleeding occurs unimpeded into the pleural space. The survival of the patient depends on their presenting condition as well as the speed and accuracy with which the intrathoracic hemorrhage is controlled.

46 Thoracic Aortic Occlusion

Eric F. Reichman

INTRODUCTION

Temporary thoracic aortic occlusion should be performed during an Emergency Department thoracotomy for hypovolemic shock. It preserves cerebral and coronary artery perfusion pressure.[1] The blood flow to the viscera below the cross clamp, however, falls to less than 10% of baseline flow.[2] This can be advantageous since it stops distal hemorrhage, but it can later result in the undesired metabolic consequences of acidosis, hyperkalemia, and multiple organ system failure.[3,4]

ANATOMY AND PATHOPHYSIOLOGY

The aorta begins at the left ventricle and gives rise to the arteries of the body, directly or indirectly (**Figure 46-1**). It leaves the ventricle and is directed upward as the ascending aorta. It arches to the left and backward at the level of the sternal angle to become the aortic arch. The arch gives rise to the brachiocephalic trunk, left common carotid artery, and left subclavian artery. The aortic arch is directed inferiorly after giving rise to the left subclavian artery and is known as the descending aorta. The descending aorta is subdivided into the thoracic portion above the diaphragm and the abdominal portion below the diaphragm. It descends through the posterior mediastinum, lying first against the left side of the fifth thoracic vertebral body. As it descends, it gradually approaches the midline of the 12th thoracic vertebral body, at which point it passes through the diaphragm.

The esophagus is a thin, muscular tube measuring approximately 2.0 to 2.5 cm in diameter. It descends along the vertebral bodies. It travels forward, away from the vertebral bodies, and to the right at the level of the ninth thoracic vertebral body. It traverses the diaphragm at the level of the 10th thoracic vertebral body. It lies posterior and medial to the descending thoracic aorta throughout most of its course. It migrates as it travels distally, so that its lower part lies in front of the aorta just above the diaphragm (**Figure 46-1**).

INDICATIONS

The primary reason to occlude the descending thoracic aorta is to temporarily direct blood flow from below the diaphragm to preserve flow to the brain and heart. The descending thoracic aorta

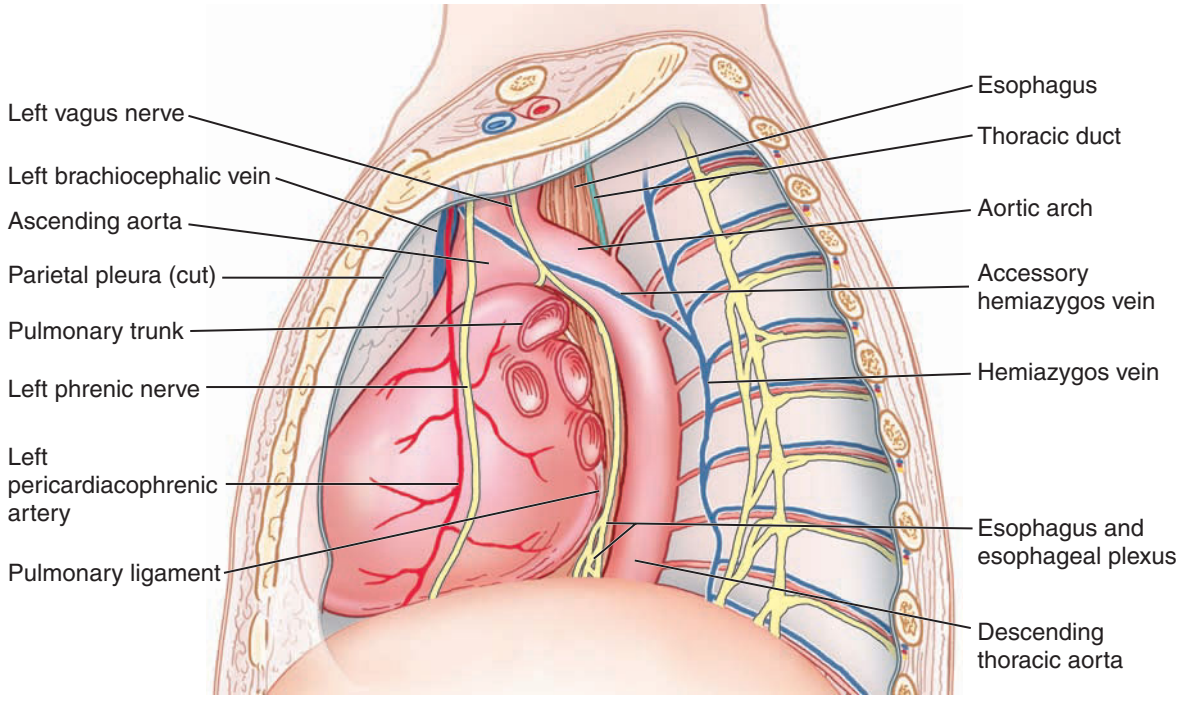


FIGURE 46-1. Anatomy of the aorta and surrounding structures of the mediastinum and left hemithorax. The mediastinal pleura has been removed to visualize the underlying structures.

may be occluded in patients with penetrating thoracic or abdominal trauma in which hypovolemic shock and clinical deterioration are not responsive to aggressive fluid resuscitation and blood transfusion. These patients should have the appropriate indications to perform an anterolateral thoracotomy (Chapter 42). The thoracic aorta may also be occluded immediately prior to laparotomy if the patient has a tense abdomen filled with blood. The abdominal incision will decompress the abdomen and result in hypotension, decreased coronary and cerebral perfusion pressure, exsanguination, and death. Uncontrollable hemorrhage below the diaphragm can be controlled by temporarily occluding the descending thoracic aorta.

CONTRAINDICATIONS

There are no absolute contraindications to temporarily occluding the descending thoracic aorta after performing an anterolateral thoracotomy. The thoracotomy should not be performed if the patient has obvious signs of death, no vital signs in the field, or no vital signs for over 15 minutes.

EQUIPMENT

- Satinsky, or other, atraumatic vascular clamp (**Figure 46-2**)
- Metzenbaum scissors
- DeBakey or large Kelly clamp
- Nasogastric tube
- Aortic compressor, Conn or homemade
- Gauze 4 × 4 squares

PATIENT PREPARATION

No preparation is required other than that of performing a thoracotomy and a pericardiotomy (Chapter 42). The patient should be intubated, ventilated with 100% oxygen, and fully monitored (i.e., telemetry, a noninvasive blood pressure cuff, and pulse oximetry). Insert a nasogastric tube. Instruct a nurse to administer intravenous broad-spectrum antibiotics that cover skin flora, gram-positive organisms, and gram-negative organisms. The Emergency Physician should wear full personal protective equipment to protect themselves from contact with the patient's blood and body fluids. While time is of the essence and this is an emergent procedure, aseptic technique should be followed.

TECHNIQUE

Identify the aorta by palpation. It is often easier to identify and isolate the aorta just above the diaphragm. In this location, the aorta is slightly separated from the adjacent esophagus. Elevate the left lung with the nondominant hand superiorly and medially. Instruct an assistant to maintain the lung out of the way. Place the dominant

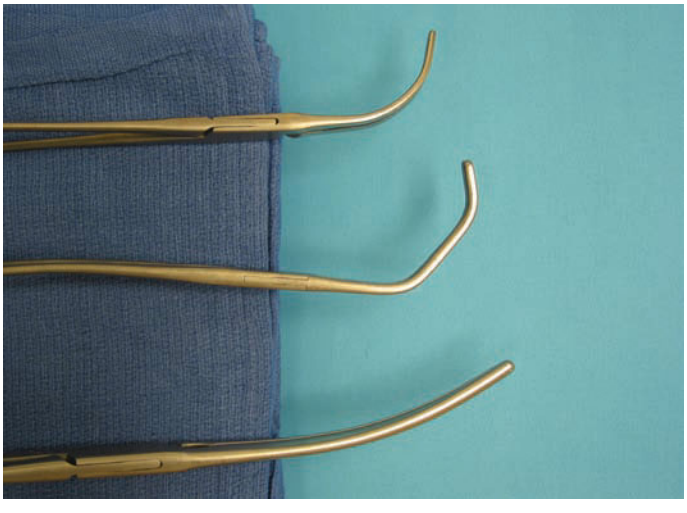


FIGURE 46-2. Examples of several atraumatic vascular clamps.

hand through the thoracotomy incision and into the posteroinferior recess of the thoracic cavity. Advance the hand along the diaphragm and toward the midline. The fingers will first encounter the vertebral bodies. The next palpable structure is the aorta. It lies anterior to the vertebral bodies. The aorta may be difficult to palpate if it is collapsed in the patient with hypovolemic shock. In the elderly, the aorta may be significantly calcified, which helps to identify it despite hypovolemia. The aorta is covered by the mediastinal pleura. Place the thumb and index finger of the nondominant hand over the aorta just above the diaphragm.

Isolate the aorta. Bluntly dissect open the mediastinal pleura overlying the aorta with a DeBakey clamp or a large curved Kelly clamp. **Never use a scalpel to open the mediastinal pleura, as it may lacerate the aorta.** Some physicians may prefer to use a Metzenbaum scissors to dissect and open the mediastinal pleura. Identify the aorta by palpation. Bluntly separate the aorta from the esophagus with the dominant hand. It may be extremely difficult to separate the aorta from the esophagus in the patient with hypotension, hypovolemia, and/or shock. Place a nasogastric tube if this has not been done previously. The nasogastric tube will be palpable within the esophagus and can be used to identify the esophagus. Hook the dominant index finger around the aorta. **Use the finger to separate the aorta from the vertebral bodies. The dissection should not be extensive. It should free approximately 3 to 4 cm of the descending thoracic aorta.**

DIRECT COMPRESSION

Direct compression of the aorta is fast and simple, it does not interfere with the operative field, and it causes less damage than the application of a clamp. Digital compression is often ineffective. Aortic compression devices have a unique shape to occlude the aorta atraumatically by compressing it against the vertebral bodies. It may be applied before or after the aorta is isolated. Homemade compression devices may use rubber tubing to occlude the aorta[5] (**Figure 46-3A**). The Conn compressor is commercially available and uses a metal plate to occlude the aorta (**Figure 46-3B**). Place the distal end of the compression device against the distal descending thoracic aorta (**Figure 46-3C**). Apply downward pressure to occlude the aorta. The degree of occlusion can be controlled by increasing or decreasing the pressure applied to the aorta.

CROSS-CLAMPING

The descending thoracic aorta is most commonly occluded with an atraumatic or Satinsky vascular clamp. Aortic compression devices are rarely available in Emergency Departments or on thoracotomy trays. The aorta must first be separated and isolated from the esophagus, as described above. Place an index finger behind the descending thoracic aorta to elevate it away from the underlying esophagus (**Figure 46-4A**). Place the Satinsky or other atraumatic vascular clamp over the aorta. One jaw should be posterior to the aorta and adjacent to the index finger while the other jaw is anterior to the aorta. Clamp the aorta and remove the index finger (**Figure 46-4B**).

It is imperative not to clamp the esophagus. Do not clamp the aorta before it is dissected from the esophagus. Esophageal injury can lead to perforation, ischemia, and sepsis if the patient is resuscitated. Ideally, the clamp should be placed under direct visualization of the aorta. Unfortunately, this is not always practical. The index finger under the aorta can confirm the proper isolation of the aorta and the proper position of the jaws of the clamp before the aorta is occluded.

AFTERCARE

If—after the thoracotomy, open cardiac massage, and aortic cross-clamping—there is return of a cardiac rhythm and a carotid pulse, the patient must be taken immediately to the Operating Room for definitive treatment. Cover the thoracotomy wound with saline-moistened gauze and a simple dressing. The patient's blood pressure in the upper extremity should be monitored every 30 to 60 seconds after the aorta is occluded. An elevated blood pressure can result in a hemorrhagic stroke or left ventricular failure. Elevated blood pressure will require intermittent release of the aortic occlusion and/or pharmacologic management. Parenteral broad-spectrum antibiotics should be administered to prevent infection if not done previously.

COMPLICATIONS

Intercostal arteries arising from the thoracic aorta can be damaged during mobilization of the aorta. This will result in troublesome bleeding that requires operative control. The aorta, vena cava, or the esophagus can be damaged by the clamp. Aortic cross-clamping can

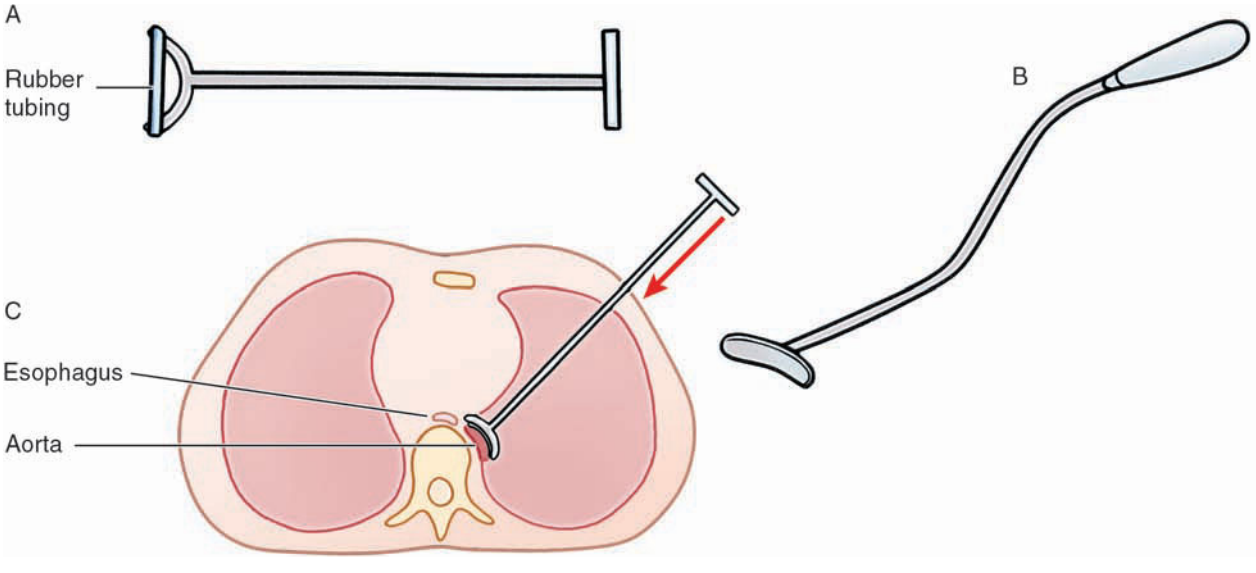


FIGURE 46-3. Aortic compression. **A.** The homemade aortic compression device.[5] **B.** The commercially available Conn compressor. **C.** The aorta is compressed between the distal end of the compression device and the thoracic vertebral body.

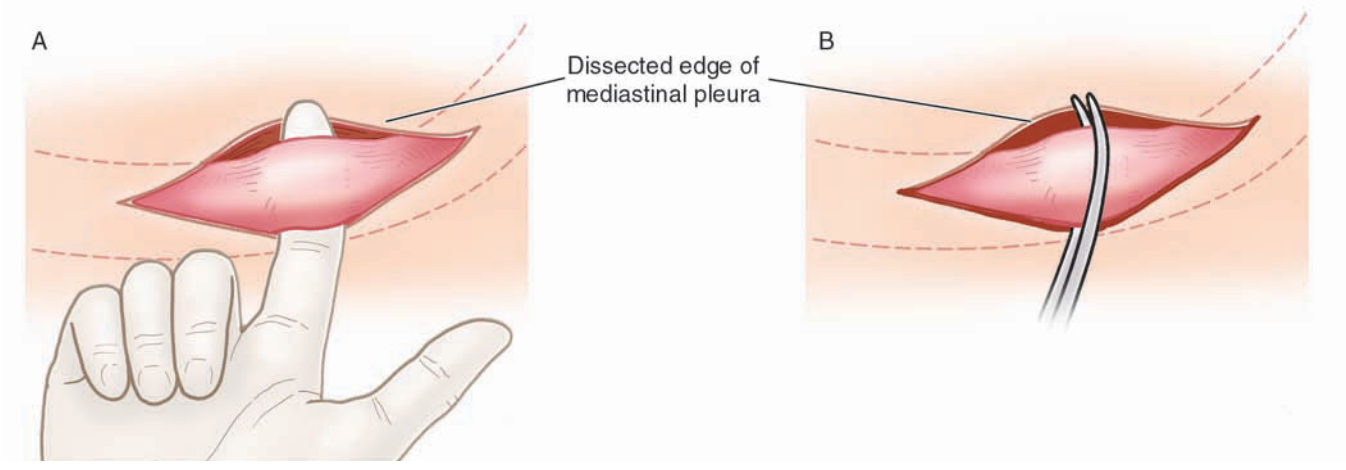


FIGURE 46-4. Aortic cross-clamping. **A.** The mediastinal pleura has been bluntly opened and the aorta isolated from the esophagus. **B.** The Satinsky, or other atraumatic, vascular clamp is placed across the aorta to occlude distal blood flow.

precipitate hypertension, stroke, and left-sided heart failure. If the patient is successfully resuscitated, this should be dealt with by periodically releasing the clamp. Lack of blood flow through the artery of Adamkiewicz will cause ischemia of the distal spinal cord. There is a 5% incidence of paraplegia when the blood supply to the distal aorta and spinal cord is disrupted. This incidence increases dramatically when the spinal cord is ischemic for more than 30 minutes.[6]

Aortic cross-clamping causes visceral ischemia. The gut loses its barrier function and becomes a cytokine-generating organ, which leads to a systemic inflammatory response and multiple organ failure. Renal and liver failure can result from a lack of blood flow.

The organs distal to the aortic clamp become severely ischemic and receive only 10% of the basal cardiac output. The anaerobic metabolism in these organs generates lactic acid. When the aortic clamp is released, acid and potassium are released into the central circulation and can cause a cardiac arrest. Thus, bicarbonate must be given at this time and the cardiac rhythm monitored carefully.

SUMMARY

Aortic cross-clamping is a useful adjunct to open cardiac massage in hypovolemic shock. It can help salvage patients by increasing coronary and cerebral perfusion. It may be performed as a lifesaving and temporizing measure until the patient can be taken to the Operating Room for definitive management.

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SECTION 4

Vascular Procedures

47 General Principles of Intravenous Access

Daniel Belmont

INTRODUCTION

The practice of Emergency Medicine frequently requires access to a patient's venous circulation. Venous access allows sampling of blood as well as administration of medications, nutritional support, and blood products. Devices such as cardiac pacing wires and pulmonary artery catheters can be introduced into the patient's central venous circulatory system.

Percutaneous, as opposed to surgical, venous access is usually rapid, safe, and well tolerated. An understanding of the various techniques available, the venous anatomy, and the indications for the procedure allows the Emergency Physician to choose the appropriate site and method of venous access.

ANATOMY AND PATHOPHYSIOLOGY

Veins, like arteries, have a three-layered wall composed of an internal endothelium surrounded by a layer of muscle then a layer of connective tissue (**Figure 47-1**).[1] The muscular layer of a vein is much smaller than that of an artery. While veins can dilate and constrict somewhat on their own, they do so mostly in response to the pressure within them. Veins with high pressures become engorged and are easier to access. The use of venous tourniquets, dependent positioning, "pumping" via muscle contraction, and the local application of heat or nitroglycerin ointment all contribute to venous engorgement.[2] These maneuvers can be used to aid in the identification of a peripheral vein.[3]

The connective tissue surrounding veins can be a help or a hindrance during attempts at peripheral venous access. Deficient connective tissue permits the vein to "roll" from side to side and evade the needle. Tough connective tissue can impede the entry of a flexible catheter through the soft tissues and into the vein. This tissue also serves to stabilize the vein and prevent its collapse.

Venous valves are an important aspect of peripheral venous anatomy (**Figure 47-2**).[1] They encourage unidirectional flow of blood back toward the heart. Venous valves prevent blood from pooling in the dependent portions of the extremities due to gravitational forces. Valves can impede the passage of a catheter through and into a vein. Forcing a catheter past venous valves may damage them and contribute to later venous insufficiency. Valves are more numerous at the points where tributaries join larger veins and in the lower extremities. Valves are almost totally absent within the large central veins, the veins of the head, and the veins of the neck.

Veins can be subdivided into central veins and peripheral veins. The important central veins with regard to venous access are the internal jugular, subclavian, and femoral veins. Central veins are usually larger than peripheral veins and have fewer tributaries.

Superficial peripheral veins are generally visible beneath the surface of the skin of the extremities and neck. They are often tortuous and continually merge and divide. Peripheral veins are easiest

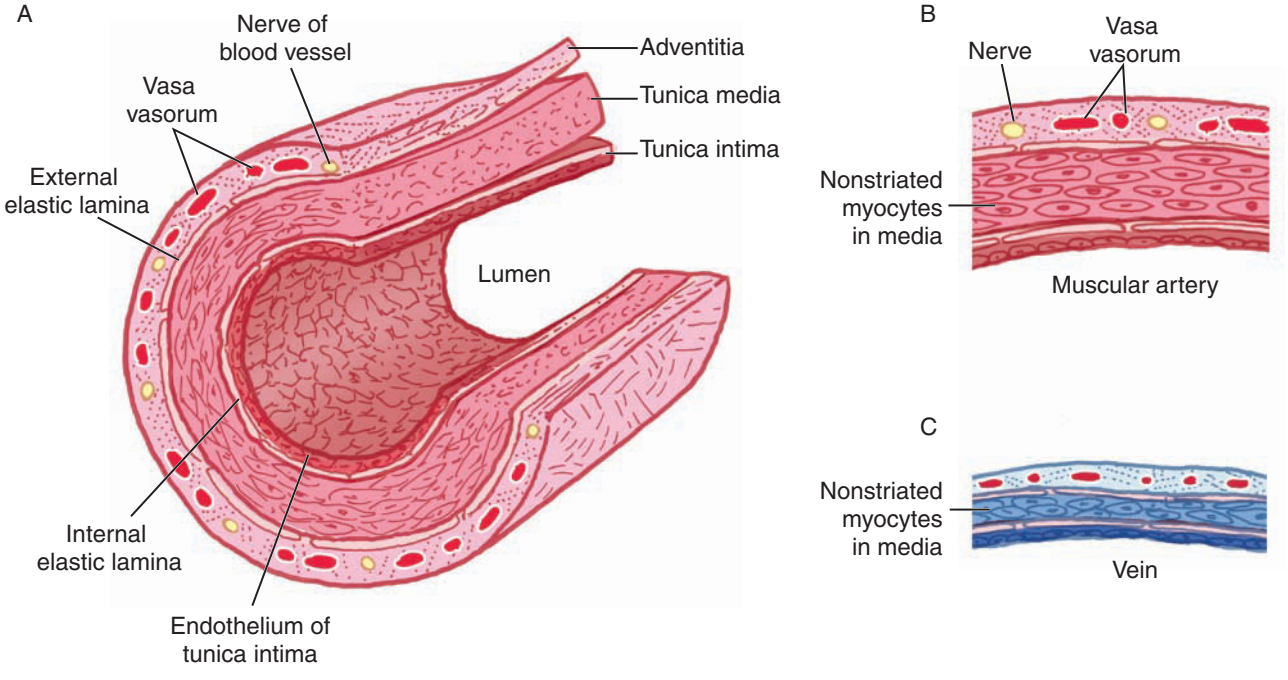


FIGURE 47-1. Comparative anatomy of an artery and a vein. **A.** The generic blood vessel. **B.** A muscular artery. **C.** A vein. Note the vein's thinner wall with fewer myocytes and elastic fibers. This is indicative of the lower pressure within veins compared to arteries.

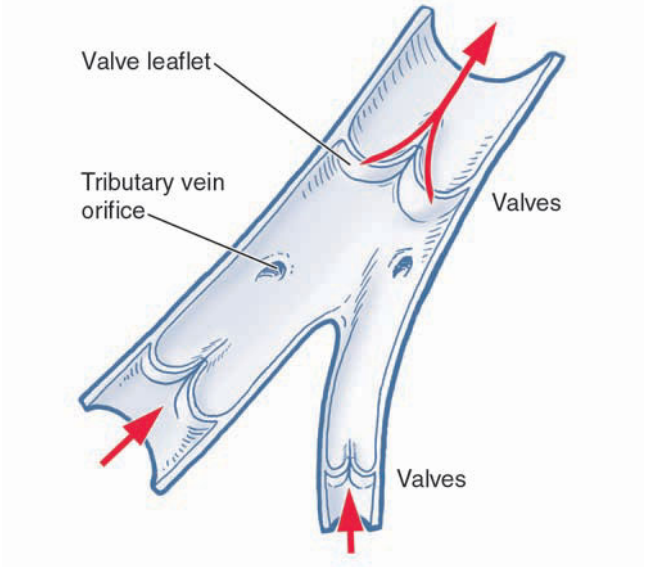


FIGURE 47-2. Venous valves. Cross-section of converging veins demonstrating the valve leaflets that only permit forward flow, proximally, toward the right heart. The arrows represent the directional flow of blood.

to access at the apex of the "Y" formed when two tributaries merge into a larger vein or where the vein is straight and free of branches (and hence valves) for approximately 2 cm proximal to the site of puncture (**Figure 47-3**). These sites tend to be anchored and "roll" less than other sites. The superficial veins of the upper extremity are preferred to those of the lower extremity for peripheral venous

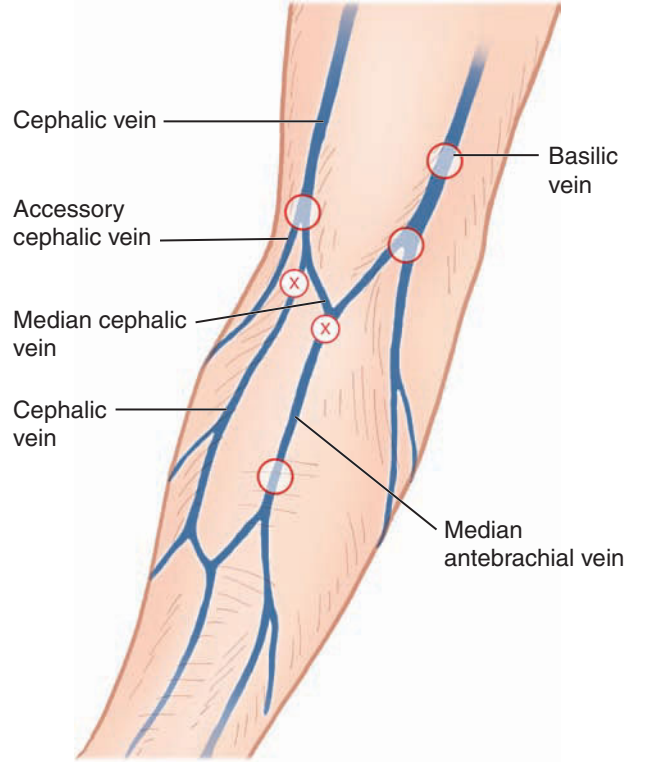


FIGURE 47-3. Preferred venous access sites. Preferred sites (*open circles*) are at the apex of converging veins or in the middle of a long straight vein. Sites just distal to branching or convergence of veins (red ⊗) are best avoided due to the presence of valves and the difficulty in threading a cannula.

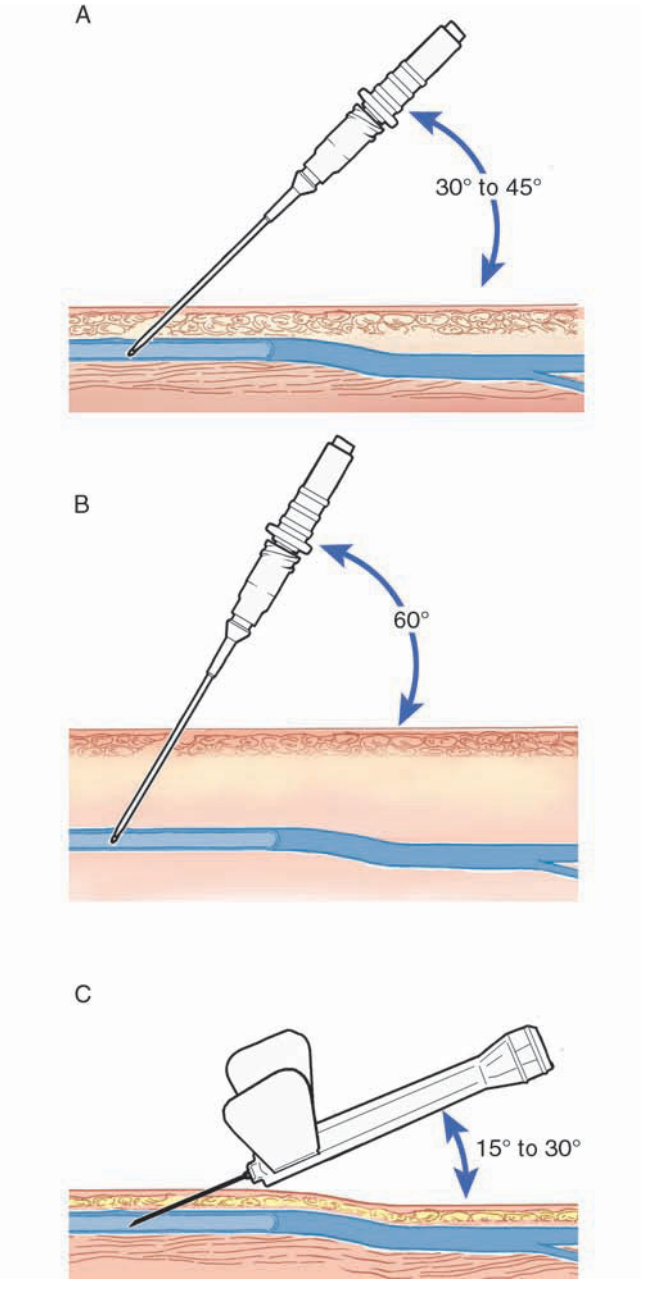


FIGURE 47-4. The angle between the needle and the skin must be varied based upon the depth and diameter of the target vein. **A.** A shallow angle must be used for small and superficial veins. **B.** A steeper angle must be used for deeper veins. **C.** A butterfly-type needle permits the shallowest angle of entry for very small and superficial veins.

access. Indwelling catheters in the upper extremity interfere less with patient mobility and the risk of phlebitis is lower.[1]

The depth of the vein beneath the epidermis will affect the ease with which it may be accessed. Very superficial veins are often small, fragile, and easily passed "through and through" with a needle, resulting in a hematoma. The deeper veins are often not visible and must be located by surface landmarks and palpation. The angle of insertion of the needle must be varied depending on the depth of the vein being punctured (**Figure 47-4**). A shallow angle of approximately 30° to 45° should be used for most small and superficial veins (**Figure 47-4A**). A more obtuse angle of approximately 60° should be used to access deeper veins

(**Figure 47-4B**). This steeper angle allows the vein to be penetrated within a reasonable horizontal distance from the skin puncture site. Very small and superficial veins should be entered at a very acute angle of approximately 15° to 30° (**Figure 47-4C**).

INDICATIONS

Venous puncture (venipuncture) with a needle is indicated only for the sampling of venous blood. Medications may be administered as a one-time dose via this technique. The risk of medication extravasation with this technique is high, and it has therefore fallen out of favor.

Venous cannulation is indicated for repeated sampling of venous blood. It is also performed for the administration of intravenous medications, fluid solutions, blood products, and nutritional support. The specific indications for peripheral venous access, central venous access, and the various techniques of venous cannulation are discussed below and in Chapters 48 and 49.

CONTRAINDICATIONS

Veins should not be accessed through infected skin. A vein proximal to a running venous infusion should not be used for venous blood sampling. The blood sample will be tainted or diluted by the infused solution. The hole in the vein may allow blood, infused solutions, and medications to extravasate into the surrounding tissues.

Venipuncture and venous cannulation of veins in an extremity with an arteriovenous fistula should be avoided. Veins in the upper extremity that may be needed for arteriovenous fistula construction for hemodialysis in the near future should not be punctured unless absolutely necessary. Scarring of the vein may complicate later surgical procedures.

CATHETER MATERIALS

Indwelling catheters are made of flexible polymers that are less likely to break or erode through the blood vessel wall than more rigid materials such as steel or glass. Polymer resins, Teflon, and polyurethane are commonly used materials. Latex-containing products should be avoided due to the risk of allergic reactions. Polyurethane catheters may be weakened by alcohol-based solutions.[1] Thus, such solutions should not be infused through polyurethane catheters.

All catheters are potentially thrombogenic. They should be left in place only as long as needed. Catheters impregnated with antiseptics, such as chlorhexidine and silver sulfadiazine, are commercially available and may decrease the incidence of catheter-related sepsis.[4] Chlorhexidine has been associated with immediate hypersensitivity reactions, most commonly in persons of Japanese descent.[5] Silver sulfadiazine has not been proven safe to use in sulfa-sensitive patients. Catheters are also available that, when immersed briefly in an antibiotic solution prior to insertion, allow an antibiotic to bind to the catheter surfaces. These catheters may reduce the risk of infection with organisms susceptible to the chosen antibiotic.

FLUID-FLOW CONSIDERATIONS

Both the diameter and the length of the infusion device will affect the flow rate through the catheter. Viscous fluids (e.g., blood products and albumin) will infuse more slowly than less viscous fluids (e.g., saline). These relationships can be seen in the solution of Poiseuille's equation for ideal fluid flow through a cylindrical tube:

$$\text{Flow rate} \propto \frac{(\pi \times \text{catheter radius}^4 \times \text{pressure gradient along the tube})}{(8 \times \text{tube length} \times \text{dynamic fluid viscosity})}$$

The pressure gradient and resistance to flow are inversely proportional to the length of the tubing. **Changes in catheter diameter will have the most effect on flow rates.** The flow rate increases to the fourth power as the catheter's internal radius increases. Flow rates can be maximized by using the largest internal diameter (i.e., smallest gauge) catheter that will fit inside the chosen vein. Large-bore venous catheters are preferred for the highest-volume rapid fluid resuscitations, particularly of viscous blood products. Flow rates decrease as the catheter length increases. **Use of the shortest possible catheter to access the chosen vein will permit the highest fluid infusion rates.** External pressure applied to the bag of infusion solution will linearly increase the flow rate.

LOCATING A PERIPHERAL VEIN

Identifying a peripheral vein can sometimes be quite difficult. Dilating a vein (venodilation) can make a vein larger, easier to identify, and easier to access. These techniques are easy to perform.

Several venodilation techniques do not require any special equipment. Place the extremity in a dependent position.[15] This position allows gravity to decrease venous return and dilate the veins.[16] Gently tap the skin in the area to dilate the underlying veins.[15,16] The exact mechanism of how this works is not known. It may be due to the release of chemical mediators, stimulation of nerve fibers, or a combination of both. Instruct the patient to open and close their hand. The muscular contractions of the forearm muscles increase arterial inflow distally while venous outflow is inhibited by the tourniquet.[15,17–19] Try to "milk" the veins in a distal direction. Apply your fingers over the skin, press downward, and then move the fingers distally to "milk" or back-flow the blood and dilate the distal veins.[15] Apply a warm compress, heat pack, warm towel, or submerge the extremity in warm water to dilate the veins. Be careful to not use too hot of a temperature to prevent burning the patient.

Several commercially available devices can be used to produce venodilation. The Esmarch Bandage is a tourniquet system used to exsanguinate a limb prior to surgery. Apply it to the upper extremity starting proximally and wrap it distally, the reverse of applying it to exsanguinate the extremity. It will result in blood pooling in the distal veins and subsequent venodilation. The Rhys-Davies Exsanguinator can also be placed proximal to distal to pool blood distally and cause venodilation.[20] This device is usually not available in the Emergency Department. A vacuum device was developed to aid in obtaining venous access.[21,22] It was cumbersome and is also not available in the Emergency Department.

Topically applied pharmaceuticals can be used to dilate the dorsal hand veins.[23–25] Topical nitroglycerine ointment has been used for many years. Apply 1 in. of the ointment and rub it into the skin on the dorsal hand. Use gloves while applying the ointment to prevent the side effects of a headache or hypotension to the healthcare provider. Allow the ointment to sit for 2 minutes then completely wipe it off the skin. Clean any residual nitroglycerine ointment from the skin with an alcohol swab. Identify a vein by palpation. Topical nifedipine is an alternative, but not currently available in the United States.

In recent years, numerous commercial devices have become available to visualize veins. The VeinViewer (Christie Medical Holdings Inc., Memphis, TN) uses polarized near-infrared light from light-emitting diodes to penetrate the skin and subcutaneous tissues.[26–28] The device projects the underlying blood-filled veins onto the skin using a visible green light. The AccuVein AV300 (AccuVein LLC, Cold Spring Harbor, NY) and the Veinlite (TransLite, Sugar Land, TX) are similar devices, but handheld. The Venoscope (Venoscope LLC, Lafayette, LA) is a handheld device

that is also available in a neonatal version. The major drawback of these devices is their cost.

ANESTHESIA

The use of anesthesia prior to venipuncture or venous cannulation is much appreciated by the patient, especially if the patient is a child. The injection of local anesthetic solution will decrease the pain of venous access. Unfortunately, the pain of injection can be just as uncomfortable as the venous access procedure. The application of a topical anesthetic, such as ELA-Max (Ferndale Laboratories, Ferndale, MI) or EMLA (Astra Zenica, Wilmington, DE), that is designed to enhance transdermal absorption requires approximately 30 to 60 minutes to adequately anesthetize the skin and subcutaneous tissues. This time delay limits their use in the Emergency Department. Refer to Chapters 123 and 124 for a more complete discussion of topical anesthetics.

Numerous alternative anesthesia methods can be considered. These are rarely available or used in the Emergency Department. Local anesthetic absorption through the skin can be enhanced to decrease the time it takes to provide anesthesia. These methods include using sound energy (sonophoresis), electrical energy (iontophoresis), and epidermal tape stripping.[29–31] A portable, handheld laser used prior to the application of topical anesthesia for 5 minutes effectively reduces the pain of venous access.[32,37] Topical vapocoolant spray will briefly anesthetize the skin long enough to allow for venous access.[33–35] Local anesthetic patches that are heat activated to increase transdermal absorption of the local anesthetic agent in approximately 20 minutes have been found to be effective.[36] Needleless jet injections of local anesthetics effectively anesthetize the skin and subcutaneous tissues.[38–40] One study questioned if the anesthesia was due to the local anesthetic agent or the jet injection procedure itself as the placebo group was just as effective in terms of anesthesia.[39] The main advantages of these techniques, compared to injectable anesthetics, are the lack of pain during the application and the lack of tissue distortion making identification of the vein difficult.

VENIPUNCTURE

Five types of devices are used for vascular access (**Figure 47-5**). There are numerous variations of these devices. The butterfly needle and hollow needle are used for venipuncture. Blood may be withdrawn using a butterfly-type needle (**Figure 47-6**) or a standard hypodermic needle. The butterfly needle, attached to a short length of plastic tubing, allows for greater control while accessing small and superficial veins. It is often too short to reach deeper veins. Versions with an integral sheath to minimize accidental needlestick injuries are available (**Figure 47-7A**).

Venous blood sampling can be accomplished by one of several methods. Blood may be allowed to drip from the open end of the butterfly extension tubing into small-volume collection tubes for pediatric patients. Some form of suction is used to withdraw the blood more rapidly in older children and adults. A syringe or a vacuum tube may be used (**Figure 47-8**). Vacuum tubes reduce the risk

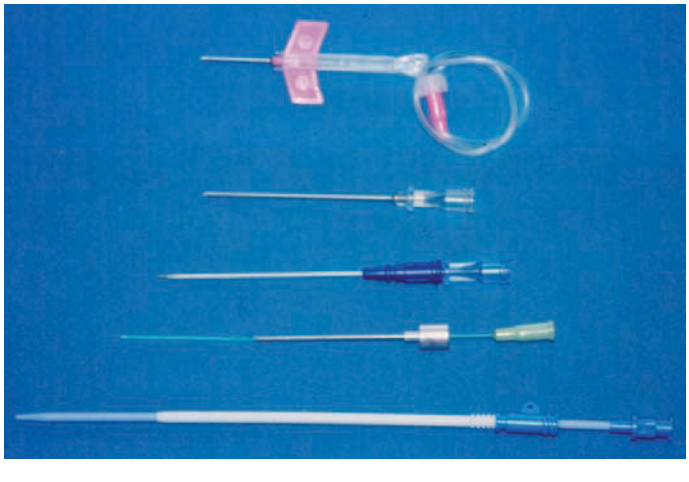
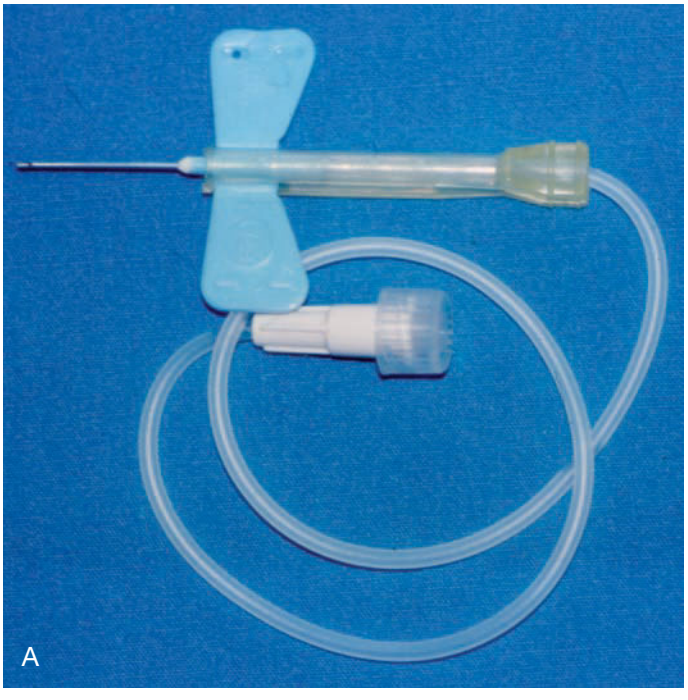


FIGURE 47-5. Venous access devices. *From top to bottom:* butterfly needle with extension tubing, hollow needle, catheter-over-the-needle, catheter-through-the-needle, and the wire-guided catheter.



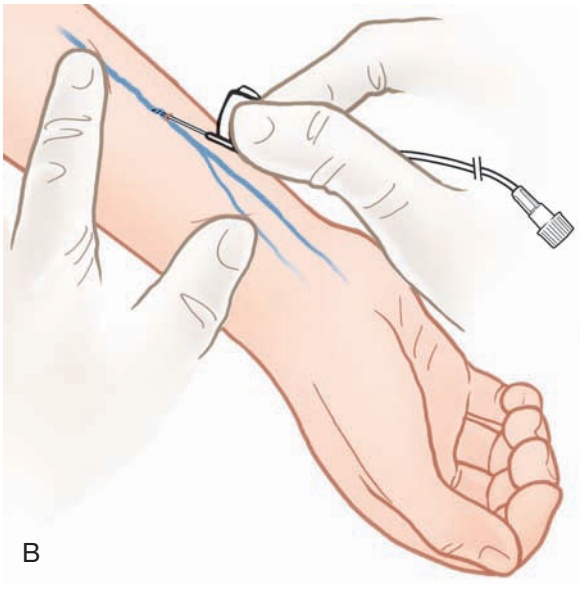


FIGURE 47-6. The butterfly-type needle. **A.** Butterfly needle with attached extension tubing. **B.** The wings of the catheter are folded together and used to direct the needle into the superficial vein. The needle may be secured within the vein and used as an infusion cannula or removed after blood samples are collected.

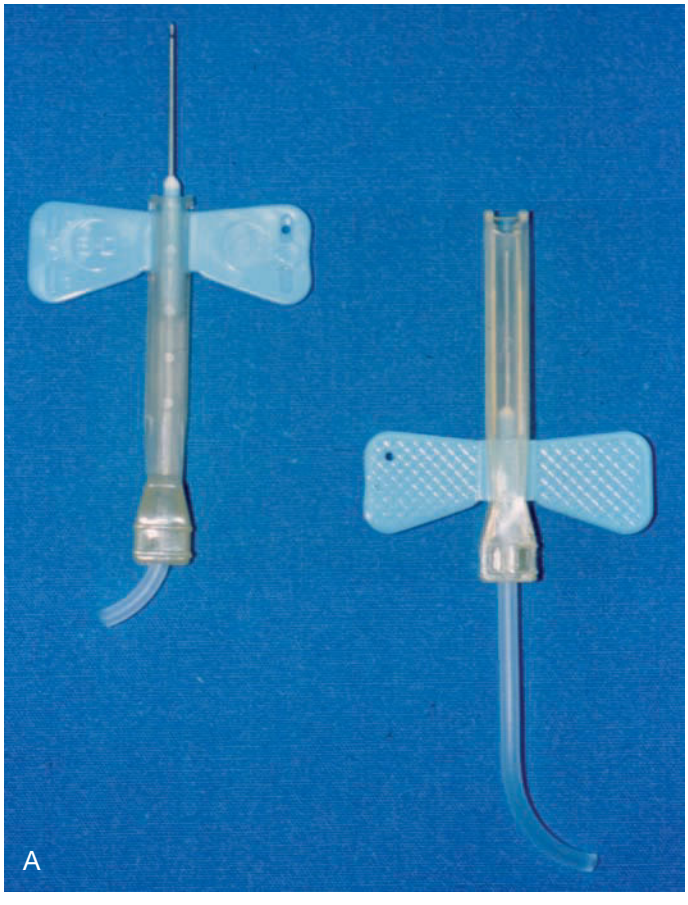


FIGURE 47-7. Needle stick prevention devices. **A.** Butterfly needle with an integral needle sheath. The left figure demonstrates the sheath retracted and the needle exposed. The right figure demonstrates the needle safely sheathed. **B.** The spring-loaded catheter-over-the-needle system. The top figure demonstrates the catheter-over-the-needle. The bottom figure demonstrates the needle inside the safety handle.

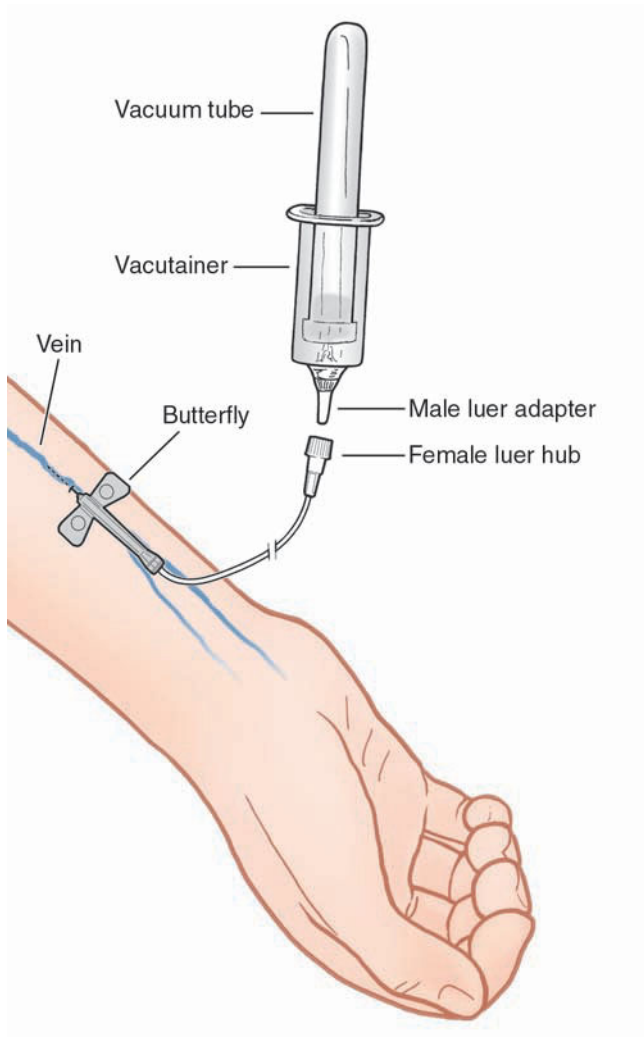


FIGURE 47-8. The Vacutainer. Once the needle is inserted into the vein, a Vacutainer adapter is connected to the female Luer hub. Specimens can be collected into different types of vacuum tubes without the risk of an accidental needle stick. However, the suction applied by the vacuum tube, unlike a syringe, cannot be controlled and may cause hemolysis and/or a small vein to collapse.

of needlestick injuries. The amount of suction provided is fixed and may result in hemolysis of the specimen and cause small veins to collapse. Syringe aspiration allows greater control over the amount of suction applied. Large syringes can be difficult to manipulate while maintaining the tip of the needle within the vein. Use a 5 to 10 mL syringe, as larger syringes result in hemolysis of the specimen and collapse of the vein. Use caution, as the needle used to transfer the specimen from the syringe to the laboratory tubes can cause a needlestick injury.

VENOUS CANNULATION TECHNIQUES

There are four main techniques of vein cannulation.[6–8] The first is the needle-only technique using a butterfly-type needle. This is seldom used today. The catheter-over-the-needle technique is the one most commonly used for peripheral venous cannulation. The catheter-through-the-needle technique is occasionally used but not very popular. The Seldinger wire-guided technique is most commonly used for central venous access. The major advantages and disadvantages of each technique are summarized in **Table 47-1**.

Identify the vein to be cannulated and the site of the skin puncture. Clean the area of any dirt and debris. Cleanse the skin with isopropyl alcohol, chlorhexidine solution, or povidone iodine solution and allow it to dry. Apply a tourniquet to the extremity, proximal to the venous cannulation site, to engorge the vein. Additional engorgement of the vein or the use of a device to locate a vein, both described previously, can aid in the identification of a peripheral vein. **Do not attempt cannulation if the vein cannot be seen, palpated, or otherwise visualized (e.g., ultrasound) in the engorged state.** Place a small subcutaneous wheal of local anesthetic solution, or some other previously mentioned alternative, at the skin puncture site to provide some comfort to the patient. The next step is to cannulate the vein by one of the methods described below.

NEEDLE-ONLY TECHNIQUE

This technique is used occasionally for short-term venous access in young children and elderly patients with fragile veins. This system is

TABLE 47-1 Features of Venous Catheterization Techniques

	Butterfly needle	Catheter-over-the-needle	Catheter-through-the-needle	Seldinger
Diameter of vein punctured compared to catheter diameter	Same	Slightly smaller	Larger	Smaller
Catheter length compared to needle	Same	Slightly shorter	Longer, up to 61 cm (24 in)	Unlimited
Speed of insertion	Rapid	Rapid	Slower	Slowest
Risk of extravasation	Highest	Low, higher with shorter catheters	Low	Very low
Security of catheter with patient movement	Lowest	Fair to good	Good	Excellent when sutured
Best choice for	Peripheral venous sampling	Peripheral venous infusion	Central venous access	Central venous access
Can change catheter without new venous puncture?	No	Can use small wire and Seldinger technique	No	Yes

prone to malposition and infiltration. The tip of the needle can easily lacerate the vein if the needle is not secure and allowed to move.

Grasp and fold the wings of the butterfly needle with the dominant index finger and thumb (**Figure 47-6B**). Briskly insert the needle, with the bevel facing upward, through the skin and into the vein.[14] A flash of blood will be seen in the tubing when the tip of the needle enters the vein. Carefully advance the needle an additional 3 to 5 mm into the vein. Attach a 5 mL syringe to the extension tubing and aspirate blood. The flow of blood into the syringe confirms proper intravascular placement of the needle. Remove the tourniquet from the extremity. Securely tape the wings of the butterfly needle to the patient's skin. Remove the 5 mL syringe, attach intravenous tubing to the catheter, and begin the intravenous infusion.

CATHETER-OVER-THE-NEEDLE TECHNIQUE

The catheter-over-the-needle systems are the ones most commonly used for venous access. The infusion catheter fits closely over a hypodermic needle. The needle and the catheter are advanced as a unit into the vein. These devices are inexpensive (about $1-4 each), come in a variety of diameters (12- to 24-gauge) and lengths, and are widely available. Versions designed to minimize accidental needlestick injuries are available and their use is encouraged (**Figure 47-7B**).[9]

Insert the catheter-over-the-needle, with the bevel facing upward, through the skin and into the vein (**Figure 47-9A**).[14] A flash of blood in the hub of the needle confirms that the tip of the needle is within the vein. Advance the unit an additional 2 to 3 mm to ensure that

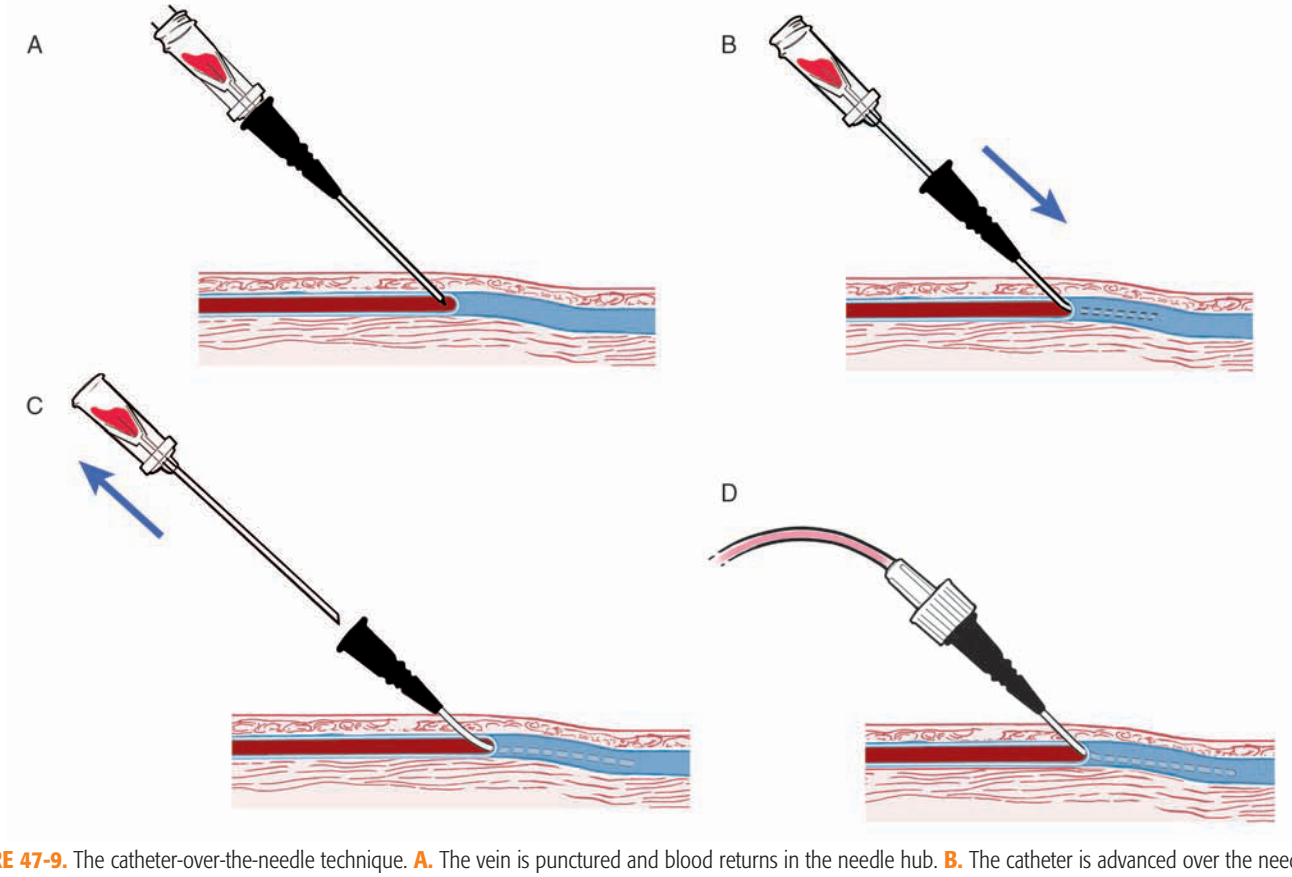


FIGURE 47-9. The catheter-over-the-needle technique. **A.** The vein is punctured and blood returns in the needle hub. **B.** The catheter is advanced over the needle and into the vein. **C.** The needle is removed. **D.** Intravenous extension tubing is attached to the catheter.

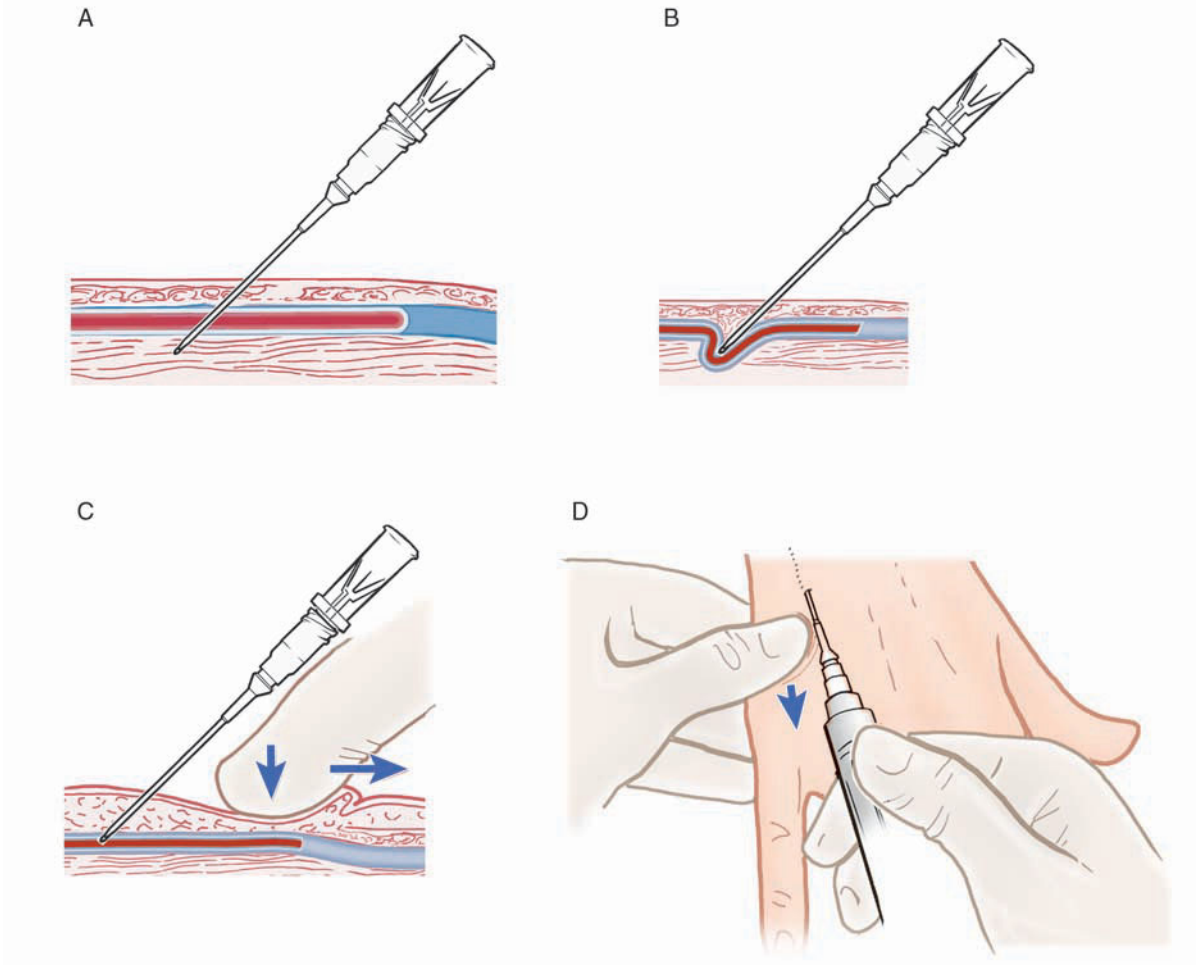


FIGURE 47-10. Pitfalls of the catheter-over-the-needle technique. **A.** Through-and-through puncture of the vein. **B.** The catheter can push the vein off the needle and prevent cannulation. **C.** Push a finger into the skin distal to the puncture site and pull back (*arrow*) to keep the vein straight and prevent it from moving. **D.** The nondominant thumb is used to pull the skin and stabilize the vein.

the catheter is within the vein. Hold the hub of the needle securely. Advance the catheter over the needle until its hub is against the skin (**Figure 47-9B**). Apply pressure, with the nondominant index finger, over the skin above the catheter to prevent blood from exiting the catheter. Remove the tourniquet from the extremity. Securely hold the hub of the catheter against the skin. Withdraw the needle (**Figure 47-9C**). Attach intravenous tubing to the hub of the catheter and begin the infusion (**Figure 47-9D**). Secure the catheter to the skin with tape.

Placement of these catheters is usually quick and simple. Several considerations should always be kept in mind when using the catheter-over-the-needle technique. Intravascular placement of the system is indicated by a flash of blood in the hub of the needle. If the patient's venous pressure is very low or if the needle is long and narrow, both sides of the vessel may be traversed (i.e., through-and-through) before the practitioner realizes that the needle was within the vein (**Figure 47-10A**). If the tip of the needle has withdrawn from the vein, the catheter will not advance. If the catheter is advanced when the tip of the needle but not the catheter is within the vein, the catheter will not advance. The catheter will push the vein off the needle (**Figure 47-10B**). Place a finger just distal to the puncture site. Depress the skin and pull it distally to prevent the vein from "rolling" as the catheter-over-the-needle is inserted into the vein (**Figures 47-10C & D**).

CATHETER-THROUGH-THE-NEEDLE TECHNIQUE

As opposed to the over-the-needle approach, this technique eliminates the need for a needle that is as long as the catheter and eliminates the possibility of pushing the vein off the end of the needle when the catheter is advanced.[10] This system is used most commonly for central, rather than peripheral, venous access. Catheters up to 61 cm (24 in) long are available and allow central venous access from the antecubital vein or the femoral vein. Select a catheter size that is appropriate for the patient and the site of entry. Packaged with each catheter are a needle and a needle guard. The needle will have an inner diameter that is slightly larger than the outer diameter of the catheter. The needle guard has a beveled channel in which the needle can reside. The needle guard hinges closed over the needle to hold it securely and prevent the needle from shearing the catheter. Holes in the corners of the needle guard allow it to be sewn to the patient's skin.

Place the needle on a tuberculin syringe. Insert the needle, with the bevel facing upward, through the skin and into the vein while applying negative pressure to the syringe (**Figure 47-11A**).[14] A flash of blood in the syringe confirms that the tip of the needle is within the vein. Advance the needle an additional 2 mm to ensure that the tip of the needle is completely within the vein. Grasp and hold the needle securely with the nondominant hand. Remove the syringe

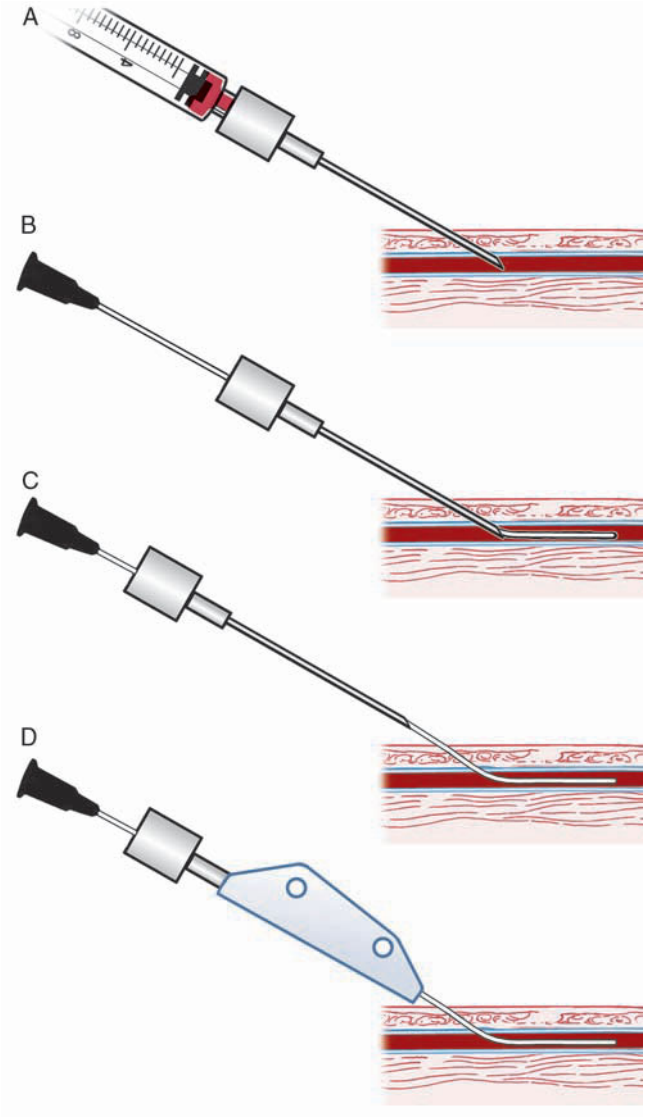


FIGURE 47-11. The catheter-through-the-needle technique.[9,11] **A.** The vein is punctured with the needle. **B.** The syringe has been removed. The catheter is inserted through the needle and into the vein. **C.** The needle is withdrawn over the catheter and completely outside the skin. **D.** The needle guard is attached to secure the needle and prevent it from shearing the catheter.

with the dominant hand. Immediately place the nondominant thumb over the needle hub to prevent air from entering the vein. Remove the tourniquet from the extremity.

Insert the catheter through the hub of the needle (**Figure 47-11B**). Advance the catheter through the needle until the desired length of catheter is within the vein. **If the catheter will not advance, remove the catheter and needle as a unit. Never withdraw the catheter through the needle. The sharp bevel of the needle may cut the catheter as it is being withdrawn and result in a catheter embolism in the central venous circulation.**

Withdraw the needle over the catheter (**Figure 47-11C**). **Do not allow the catheter to be withdrawn through the needle.** Continue to withdraw the needle until the tip is completely outside the skin. Apply the needle guard over the needle (**Figure 47-11D**). Attach intravenous tubing to the hub of the catheter and begin infusing fluids through the catheter. Secure the catheter and needle guard to the skin with tape and/or sutures.

The main disadvantage of this technique is the possibility of the needle tip shearing off the catheter, causing a catheter embolism in the venous circulation. **This can be prevented by not withdrawing the catheter through the needle and applying the needle guard immediately after the needle is withdrawn from the skin.** The contaminated needle must be handled to some extent, creating a potential risk for a needlestick injury. The needle used for the venipuncture must be larger in diameter than the catheter. This limits the practical diameter of the catheter. The needle punctures a hole in the vessel larger than the catheter and increases the risk of hematoma formation.

SELDINGER TECHNIQUE

First described by Seldinger in 1953, this technique allows for the placement of a catheter over a wire rather than directly over a needle.[11,12] The wire used must be longer than the catheter. The needle used to insert the wire can be short and of a smaller gauge than the catheter. If desired, the catheter type may be changed later without the need for a new venous puncture. Materials needed for catheter insertion are commercially available in a prefabricated kit (Teleflex Medical, Cleveland, OH; Cook Medical Inc., Bloomington, IN).

The Seldinger technique is most commonly used for central venous catheter insertion. It can be used for peripheral venous access if a short, thin guidewire is available. Ultrasound may be a useful adjunct with this technique.[13] Please refer to Chapter 50 regarding ultrasound-guided vascular access for a complete discussion. All-in-one arterial line kits are commercially available. They are intended for peripheral arterial line placement but can also be used to place catheters in peripheral veins, the brachial veins, and the external jugular veins.

The Seldinger technique for venous catheter insertion is described briefly here. Refer to Chapter 49 (central venous access techniques) for a more complete discussion. Choose the puncture site. Prepare the patient for the procedure. Clean and prepare the puncture site as previously described. The vein may first be located with a small "finder" needle if there is doubt about its exact location. Insert a 25 or 27 gauge needle attached to a 5 mL syringe, with the bevel facing upward, through the skin. Advance the needle while applying negative pressure to the syringe. A flash of blood signifies that the tip of the needle is within the vein. Note the depth and location of the vein based on the depth and direction of the "finder" needle.

Insert the thin-walled introducer needle while applying negative pressure to the syringe. The introducer needle has a tapered hub on the proximal end to guide the wire into the needle lumen. Avoid using a standard hypodermic needle, as it does not allow for the passage of the guidewire. A flash of blood in the needle hub signifies that the tip of the needle is within the vein (**Figure 47-12A**). Advance the needle an additional 1 to 2 mm into the vein. Hold the needle securely in place and remove the syringe.

Occlude the needle hub with a sterile gloved finger. This will prevent air from entering the venous system. Insert the guidewire through the hub of the needle (**Figure 47-12B**). Advance it to the desired depth, ensuring that it is at least several centimeters beyond the beveled end of the needle. **To prevent loss of the wire into the venous circulation, never let go of the guidewire with both hands at the same time.** Hold the guidewire securely in place. Remove the needle over the guidewire (**Figure 47-12C**). Make a small nick in the skin adjacent to the guidewire with a #11 scalpel blade (**Figure 47-12D**). **Direct the sharp edge of the scalpel blade away from the guidewire to prevent nicking the guidewire.**

Place the dilator over the guidewire. Advance the dilator over the guidewire to enlarge the subcutaneous passage for the catheter. Continue to advance the dilator until its hub is against the skin. Withdraw the dilator over the guidewire while leaving the guidewire in place. Advance the catheter over the guidewire until its hub

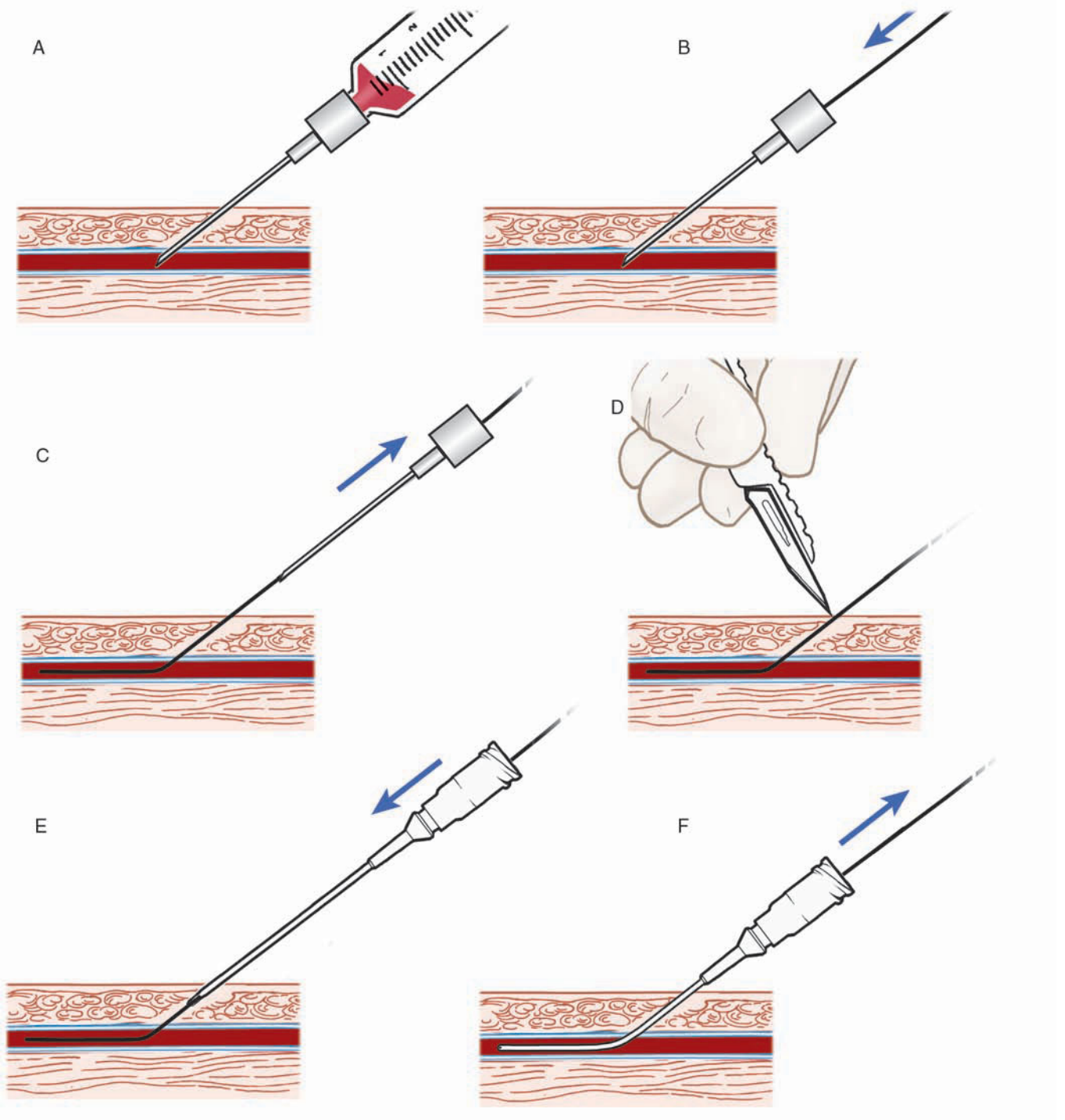


FIGURE 47-12. The Seldinger technique. **A.** The vein is punctured by the needle and blood is aspirated. **B.** The syringe has been removed. The guidewire is inserted through the needle and into the vein. **C.** The needle is withdrawn over the guidewire. **D.** The skin puncture site is enlarged to permit catheter passage. **E.** The catheter is advanced over the guidewire and into the vein. **F.** The guidewire is withdrawn through the catheter.

is against the skin (**Figure 47-12E**). A twisting motion of the catheter may aid in its advancement through the subcutaneous tissues and into the vein. Securely hold the hub of the catheter. Remove the guidewire through the catheter (**Figure 47-12F**).

Aspirate blood from the catheter with a syringe to confirm intravenous placement. Flush the catheter with sterile saline or begin an infusion. Secure the catheter to the skin with sutures and tape. While this technique seems complicated at first glance, it is easy to learn and can be performed in a few minutes by an experienced Emergency Physician.

COMPLICATIONS

Complications specific to each technique and site are discussed more fully in the following chapters. Venous catheters should be assessed immediately after their placement and also be reassessed frequently. The assessment must include the skin puncture site, catheter function, the extremity distal to the catheter, and the patient's overall condition. Some of the common problems are noted in **Table 47-2**. Other specific complications of peripheral and central venous access are discussed in the following chapters.

TABLE 47-2 Complications of Venous Catheterization

	Observation	Complications	Errors in technique	Response
Skin puncture site	Immediate swelling	Hematoma	Laceration or through-and-through puncture	Remove catheter, apply pressure
Skin puncture site	Delayed swelling	Extravasation or hematoma	Catheter dislodged or damaged, vein lacerated	Remove catheter, apply pressure
Skin puncture site	Erythema or discharge	Infection	Catheter in place too long, catheter or skin contaminated	Remove catheter, give parenteral antibiotics
Catheter	Cannot infuse	Thrombosis or kinking	Catheter not flushed enough, catheter not secured properly	Flush catheter, check position, remove catheter
Catheter	Blood runs up IV tubing	Arterial placement	Arterial puncture not recognized	Remove catheter, apply pressure
Catheter	Cannot aspirate from proximal lumens of multilumen line	Extravascular placement or migration of proximal lumens	Not enough catheter inserted; patient movement; catheter not properly secured	Change catheter over a wire if distal port is intravascular
Systemic	Fever	Line sepsis	Catheter left in place too long or contaminated	Remove catheter once infection is verified
Systemic	Hemodynamic or respiratory compromise	Pneumothorax, pericardial tamponade	Pleura punctured during insertion; catheter tip malpositioned	Chest radiograph, auscultate chest; pericardial or pleural drainage

SUMMARY

Venous access is an essential skill for all providers of care to the acutely ill and injured. As with most procedures, success rates increase and complication rates decrease with experience. Successful venipuncture or cannulation is not the end of the provider's obligation to the patient. Frequent reassessment of the venous access site, the equipment, and the patient is essential to prevent complications.

48 Venipuncture and Peripheral Intravenous Access

Daniel Belmont

INTRODUCTION

Puncture of a peripheral vein is the most common invasive procedure performed in the Emergency Department. While some newer point-of-care testing techniques require only capillary blood, the vast majority of laboratory studies require venous blood. Cannulation of a peripheral vein is performed on a daily basis and is the cornerstone of circulatory resuscitation. It is an essential skill for all emergency personnel, from phlebotomists to nurses to the Emergency Physician. A variety of approaches for obtaining peripheral venous access are described in this chapter.

ANATOMY AND PATHOPHYSIOLOGY

Veins and arteries are composed of a three-layered wall of internal endothelium surrounded by a layer of muscle then a layer of connective tissue (**Figure 48-1**).[1] The muscular layer of a vein is much thinner and weaker than that of an artery. While veins can dilate and constrict somewhat on their own, they do so mostly in response to the pressure within them. Veins with high internal pressures become engorged and are easier to access. The use of venous tourniquets, dependent positioning, "pumping" via muscle contraction, and the local application of heat or nitroglycerin ointment all contribute to venous engorgement.[2] These maneuvers can be used to aid in the identification of a peripheral vein.

The connective tissue surrounding veins can be a help or a hindrance during attempts at gaining peripheral venous access. Deficient connective tissue permits the vein to "roll" from side to side and evade the needle. Tough connective tissue can impede the entry of a flexible catheter through the soft tissues and into the vein. This tissue also serves to stabilize the vein and prevent its collapse.

Venous valves are an important aspect of peripheral venous anatomy (**Figure 48-2**).[1] Venous valves encourage unidirectional flow of blood back to the heart. Because of gravitational forces, they prevent blood from pooling in the dependent portions of the extremities. Valves can impede the passage of a catheter through and into a vein. Forcing a catheter past venous valves may damage them and contribute to later venous insufficiency. Valves are more numerous at the points where tributaries join larger veins and in the lower extremities. Valves are almost totally absent within the large central veins and the veins of the head and neck.

Veins can be subdivided into central veins and peripheral veins. The important central veins with regard to venous access are the internal jugular, subclavian, and femoral veins. Central veins are usually larger than peripheral veins and have fewer tributaries.

Superficial peripheral veins are generally visible beneath the surface of the skin of the extremities and neck. They are often tortuous and continually merge and divide. Peripheral veins are easiest to access at the apex of the "Y" formed when two tributaries merge into a larger vein or where the vein is straight and free of branches (and hence valves) for 2 cm or more proximal to the site of puncture (**Figure 48-3**). These sites tend to be anchored and hence "roll" less than other sites. The superficial veins of the upper extremity are preferred to those of the lower extremity for peripheral venous access. Indwelling catheters in the upper extremity interfere less with patient mobility, and they pose a lower risk of phlebitis.[2] The superficial veins of the extremities are shown in **Figures 48-4 & 48-5**. The veins most commonly used for venipuncture and venous access are the basilic and cephalic veins as well as their branches and tributaries (**Figure 48-4**). The veins of the dorsal foot and the distal saphenous veins are the most commonly used veins in the lower extremity (**Figure 48-5**).

The depth of the vein beneath the epidermis will affect the ease with which it may be accessed. Very superficial veins are often small, fragile, and easily passed "through-and-through" with a

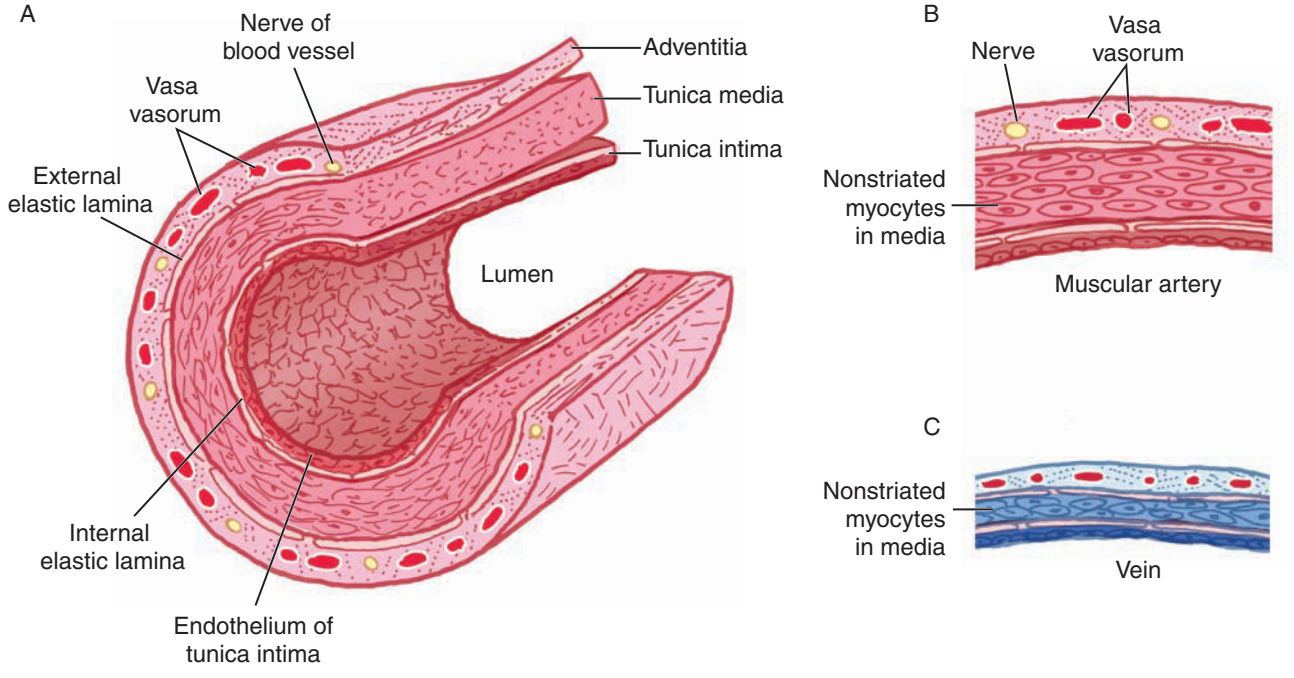


FIGURE 48-1. Comparative anatomy of an artery and a vein. **A.** The generic blood vessel. **B.** A muscular artery. **C.** A vein. Note the vein's thinner wall with fewer myocytes and elastic fibers. This is indicative of the lower pressure within veins compared to arteries.

needle, resulting in a hematoma. The deeper veins are often not visible and must be located by surface landmarks and palpation. The angle of insertion of the needle must be varied depending on the depth of the vein being punctured (**Figure 48-6**). A shallow angle of approximately 30° to 45° should be used for small and superficial veins (**Figure 48-6A**). A more obtuse angle of approximately 60° should be used to access deeper veins (**Figure 48-6B**). This angle allows the vein to be penetrated within a reasonable horizontal distance from the skin puncture site. Very small and very superficial veins should be entered at a very acute angle of approximately 15° to 30° (**Figure 48-6C**).

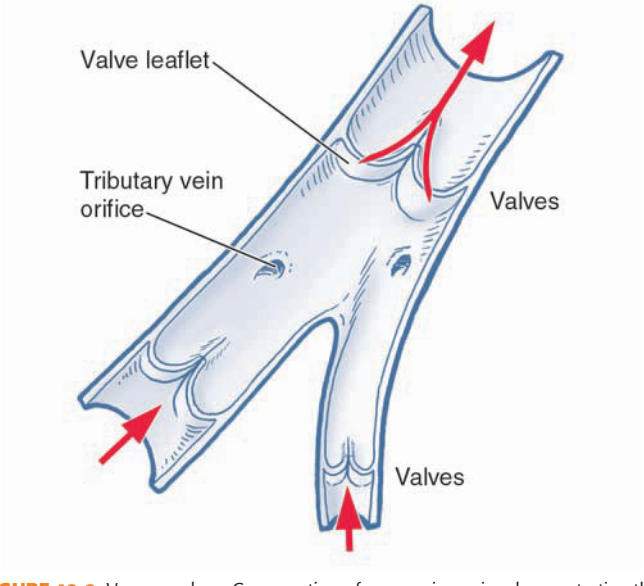


FIGURE 48-2. Venous valves. Cross section of converging veins demonstrating the valve leaflets that permit only forward flow, proximally, toward the right heart. The arrows represent the directional flow of blood.

The upper extremity is preferred to the lower for venous cannulation, and distal placement should be attempted before moving proximally.[3] Avoid veins overlying a joint if possible. Adherence to these simple principles will allow the patient maximum mobility

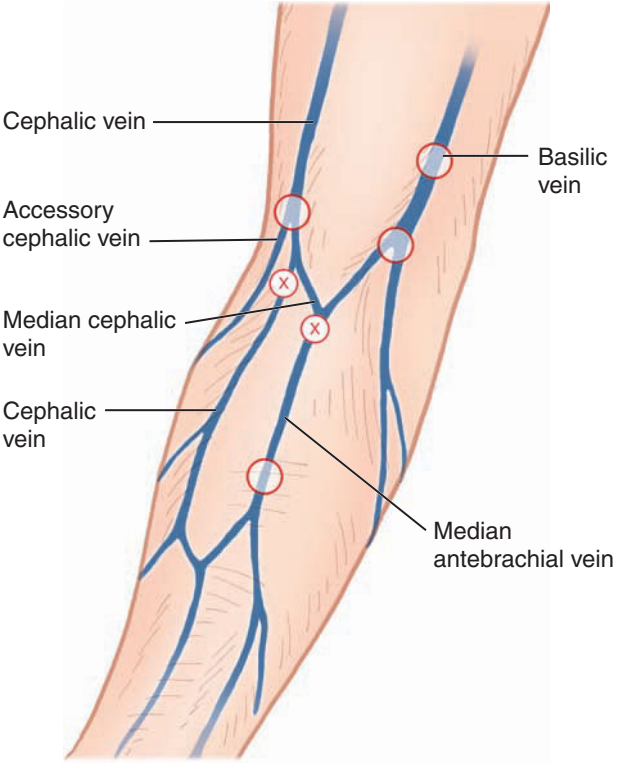


FIGURE 48-3. Preferred vein entry points. Preferred sites (*open circles*) are at the apex of converging veins or in the middle of a long straight vein. Sites just distal to branching or convergence of veins (red ⊗) are best avoided due to the presence of valves and the difficulty in threading a cannula.

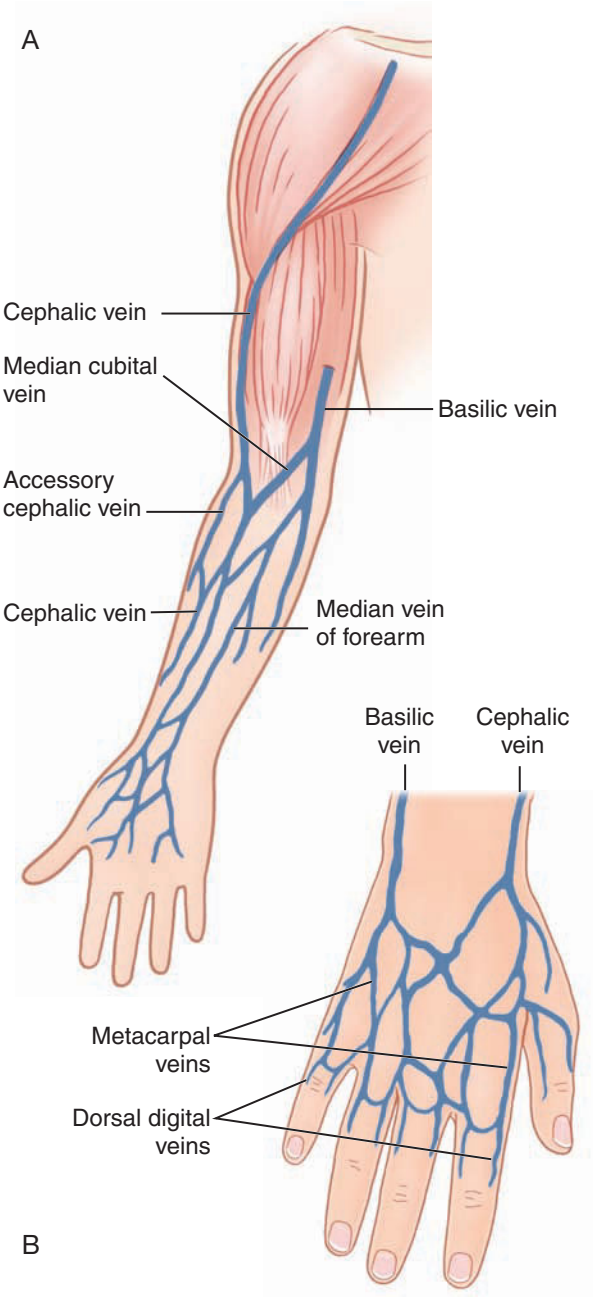


FIGURE 48-4. Superficial veins of the upper extremity. **A.** Volar surface of the upper extremity. **B.** Dorsal surface of the hand and wrist.

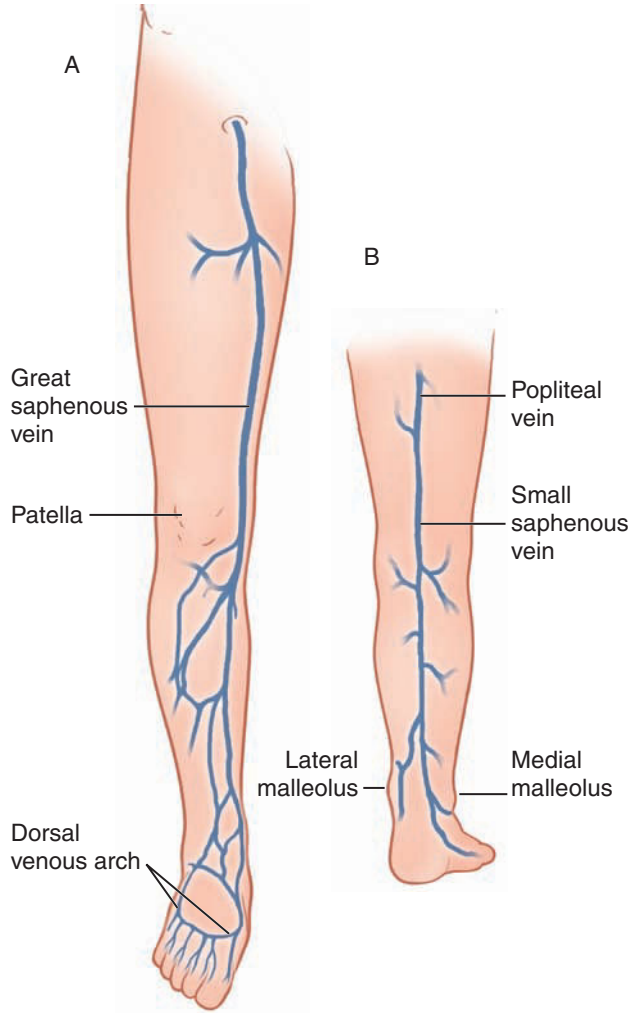


FIGURE 48-5. Superficial veins of the lower extremity. **A.** Anterior surface. **B.** Posterior surface.

and increase the chance of successfully cannulating a vein in the chosen extremity. Any solutions or medications infused distally can extravasate and injure the surrounding tissues once a proximal vein has been punctured unsuccessfully.

It is easiest to insert a venous cannula where two tributaries merge and form a "Y." Choose a straight portion of vein without branches to minimize the chance of hitting valves within the vein. This also makes it easier to thread the catheter (**Figure 48-3**).

The deep brachial veins are variably located alongside the brachial artery, running lateral and/or medial to the artery (**Figure 48-7**).[4,5] The brachial veins are relatively small, deep and not visible, have a close relationship to the brachial artery, and are thus not normally accessed. **It is important to prevent injury to the brachial artery when cannulating or puncturing the brachial veins.** The brachial artery is the sole arterial supply of the forearm, hand, and median nerve. The deep brachial veins may be used when superficial veins have been destroyed by scarring due to intravenous drug abuse, chemotherapy, or prior infusions. The location and cannulation of the brachial veins can be aided through the use of ultrasound.[6]

The neck is an important potential site for peripheral venous access through the external jugular vein (**Figure 48-8**). This vein begins at the level of the mandible and runs obliquely across the sternocleidomastoid muscle. It dives beneath the fascia in the subclavian triangle in the neck to join with the subclavian vein.[5] Some patients have two external jugular veins on one or both sides as an anatomic variant. The external jugular vein has two sets of valves (**Figure 48-8**). One is located where the external jugular vein joins the subclavian vein and the other is located approximately 4 cm above the clavicle. These valves are not fully competent but may prevent the passage of a guidewire or catheter.[5,7]

INDICATIONS

Peripheral venous access is indicated for venous blood sampling. It is also performed for the administration of intravenous medications, fluid solutions, and blood products. Peripheral venous lines may be used for short-term partial nutritional support; full nutritional support requires central venous access.

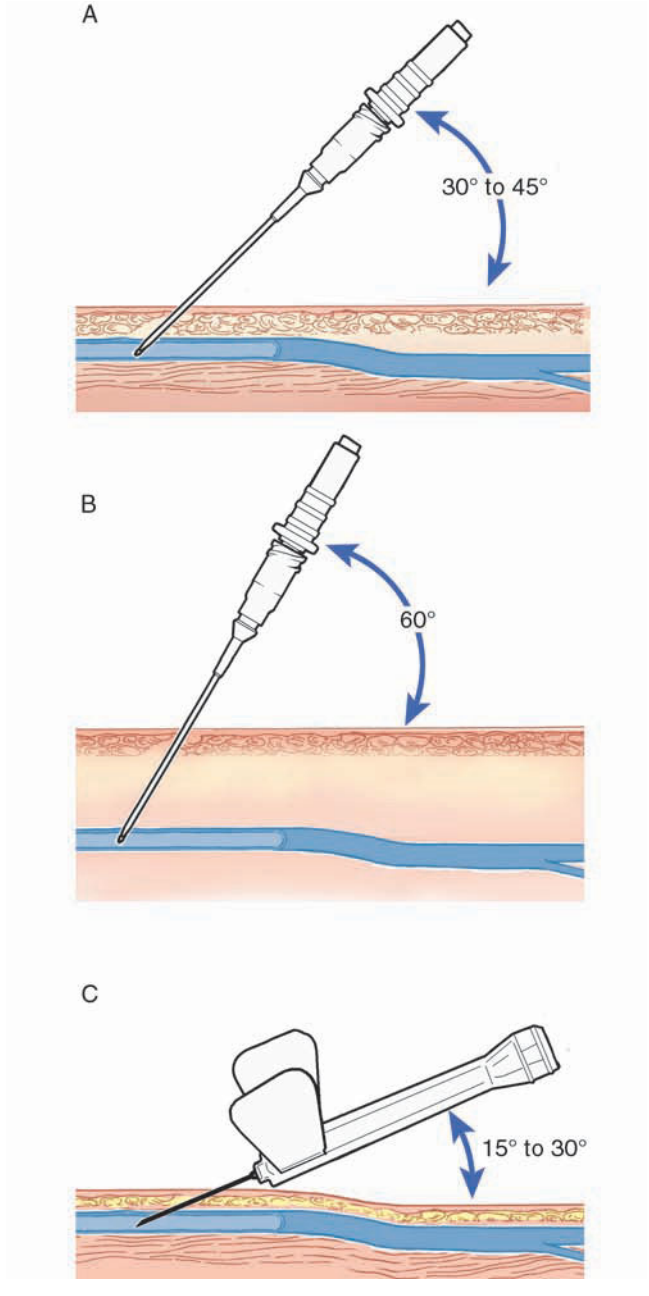


FIGURE 48-6. The angle between the needle and the skin must be varied based upon the depth and diameter of the target vein. **A.** A shallow angle must be used for small and superficial veins. **B.** A steeper angle must be used for deeper veins. **C.** A butterfly-type needle permits the shallowest angle of entry for very small and superficial veins.

CONTRAINDICATIONS

Sclerosing solutions, vasopressors, concentrated solutions of electrolytes or glucose, and chemotherapeutic agents are more safely infused into a central vein. Peripheral venous access in an injured extremity should be avoided, if possible, so as not to interfere with care of the injury and venous drainage of the limb. Avoid using the veins of an upper extremity for peripheral venous access if they may be used for the construction of an arteriovenous fistula for future dialysis. If possible, venipuncture should not be performed through infected or burned skin.

EQUIPMENT

- Alcohol swabs
- Povidone iodine or chlorhexidine solution
- Local anesthetic solution
- 25 gauge needle
- 1 mL syringe
- Gloves
- Immobilization supplies if necessary
- 1 in. tape, waterproof or plastic
- Transparent dressing
- Gauze 4 × 4 squares
- Tourniquet
- Desired venous access device
- Heparin/saline lock or infusion set
- Intravenous fluids
- Vacuum blood collection tubes
- Heparin
- Medicine cup
- Scissors
- Gauze roll or stockinette

PATIENT PREPARATION

Explain the procedure to the patient and/or their representative. Obtain verbal consent for the venipuncture unless it is an emergency. Select a site for the venipuncture. A site in the upper extremity is preferred. While a satisfactory vein is usually evident upon inspection, the placement of a venous tourniquet will aid the process greatly. It is easiest to place the tourniquet a few inches proximal to the elbow when first trying to locate a vein in the upper extremity. This restricts venous return from the entire extremity distal to the tourniquet and allows rapid inspection of the entire limb. Release the tourniquet once the site is chosen.

If difficulty is encountered in finding a vein, the use of dependent positioning, "pumping" via muscle contraction, and the local application of heat or nitroglycerin ointment will all contribute to venous engorgement.[2] These maneuvers can be used to aid in the performance of a venipuncture or peripheral venous access. A device specifically designed to identify veins may also be used. Refer to Chapter 47 for a more complete discussion regarding how to locate a vein.

Clean the puncture site of any dirt and debris. Apply an alcohol swab, povidone iodine solution, or chlorhexidine solution to the area above the identified vein and allow it to dry.[8] If using povidone iodine, wipe it off with an alcohol swab after it dries to lessen the chance of a local skin reaction. Infiltrate a small amount of local anesthetic solution subcutaneously, with a 25 gauge needle, over the puncture site. Take care not to puncture the target vein accidentally. Other methods of anesthesia are reviewed in Chapter 47. Reapply the tourniquet.

TECHNIQUES

PERIPHERAL VENIPUNCTURE

Stabilize the vein with the nondominant hand (**Figure 48-9**). Insert the needle attached to a syringe or vacuum tube adapter, with the bevel upward, into the vein at a 30° to 45° angle (**Figure 48-6A**). Lower angles, at times nearly parallel to the skin, may be needed

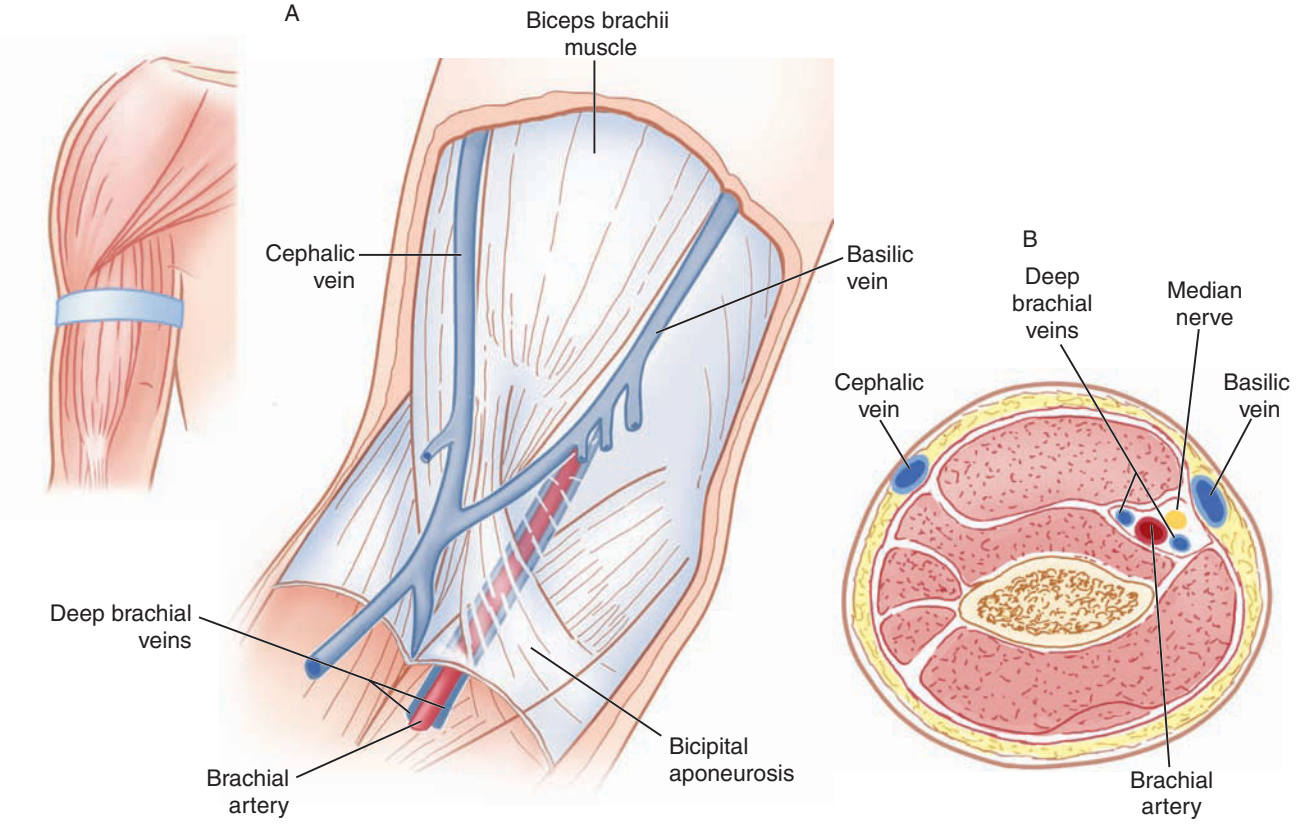


FIGURE 48-7. The deep brachial veins. **A.** The deep brachial veins are located deep to biceps tendon and muscle and adjacent to the brachial artery. **B.** Cross section of the arm 2 cm above the elbow. Note the two deep brachial veins, one on each side of the brachial artery.

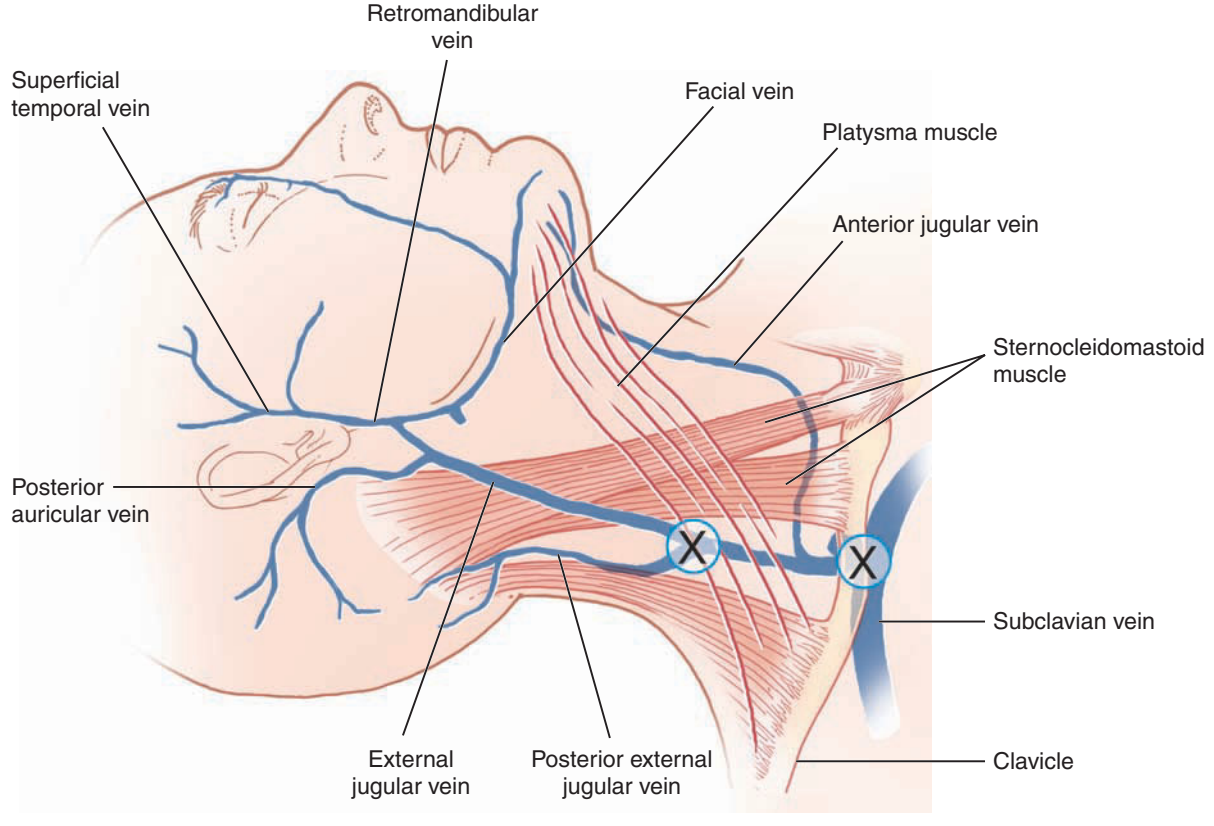


FIGURE 48-8. The external jugular veins. The anterior external jugular vein is usually larger than the posterior and runs deep to the platysma muscle. Note its relationship to the internal jugular vein. Valves (noted by the ⊗) are normally present in the external jugular vein where it enters the subclavian vein and approximately 4 cm superior to the clavicle.

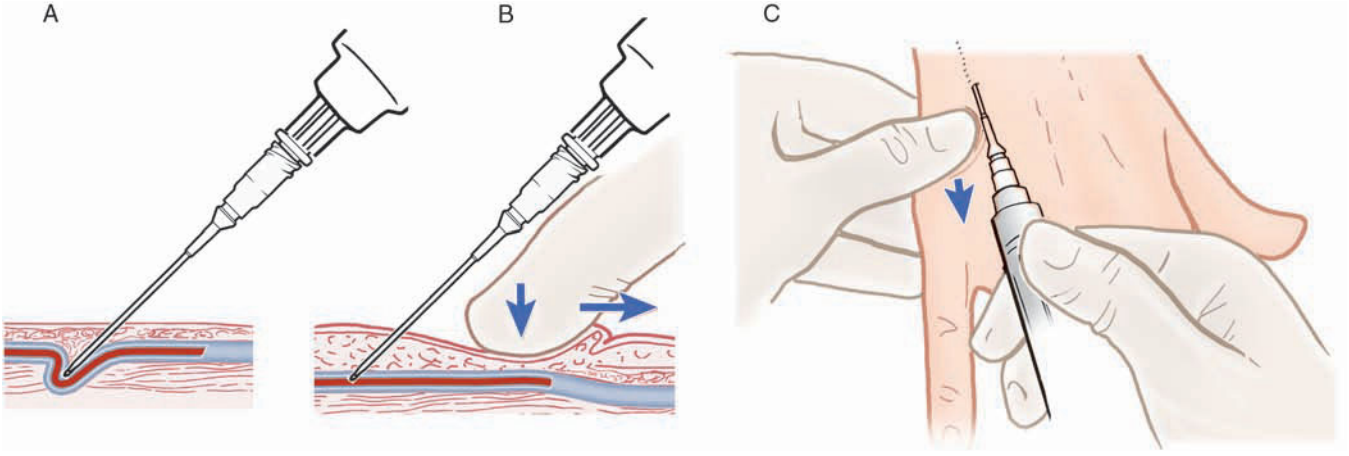


FIGURE 48-9. Stabilization of the vein during venipuncture. **A.** Without stabilization, the vein may kink or roll away from the tip of the hypodermic needle. **B.** Gentle stabilizing pressure with the operator's fingertip allows entry into the vein, as shown in (**C**).

to enter very narrow or superficial veins. This is easiest to achieve with a butterfly-type needle (**Figure 48-6C**). Apply negative pressure to the syringe. A flashback of blood in the hub of the needle indicates that the tip of the needle is within the vein. Pulsatile blood that pushes back the syringe plunger indicates an arterial puncture. Unless venous blood is specifically needed for a test, collect the necessary samples before removing the needle. No additional harm will be done by withdrawing a blood sample from an artery that has already been punctured.

If no blood is obtained, slowly advance the needle until it is deeper than the judged depth of the vein. Apply negative pressure to the syringe and slowly withdraw the needle. Occasionally, the advancing needle can collapse a vein (**Figure 48-10A**). The vein will often have been punctured through-and-through (**Figure 48-10B**), and the specimen will be obtained as the needle is withdrawn (**Figure 48-10C**). If no blood is obtained by the time the needle is withdrawn to just beneath the skin, redirect the needle and make another attempt at puncturing the vein. Before redirecting the needle, it must be withdrawn to just beneath the skin. **Never sweep the point of the needle around without withdrawing it, as the sharp bevel of the needle can lacerate nearby structures.** If swelling develops, indicating a hematoma formation, remove the tourniquet and apply direct pressure for several minutes. Search for another venous access site. Accidental peripheral arterial punctures should have direct pressure applied for at least 5 minutes.

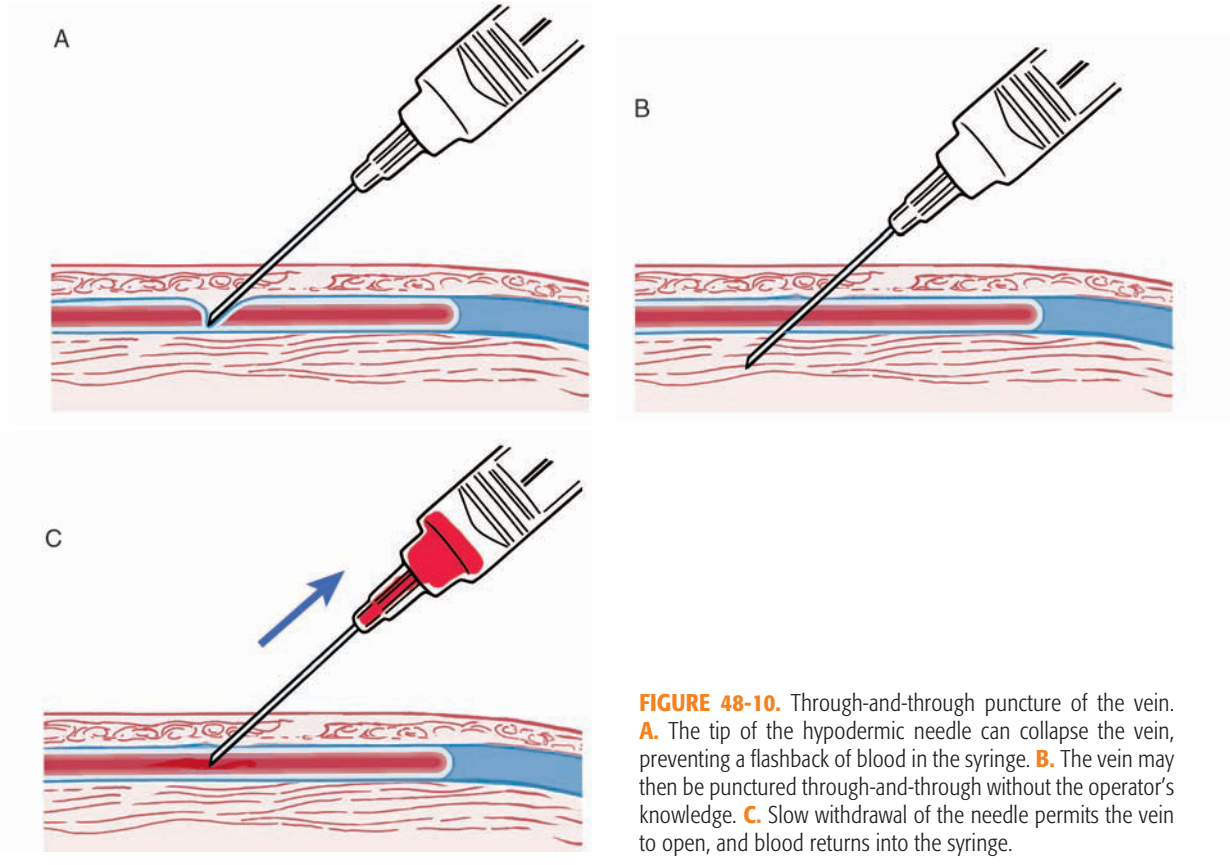


FIGURE 48-10. Through-and-through puncture of the vein. **A.** The tip of the hypodermic needle can collapse the vein, preventing a flashback of blood in the syringe. **B.** The vein may then be punctured through-and-through without the operator's knowledge. **C.** Slow withdrawal of the needle permits the vein to open, and blood returns into the syringe.

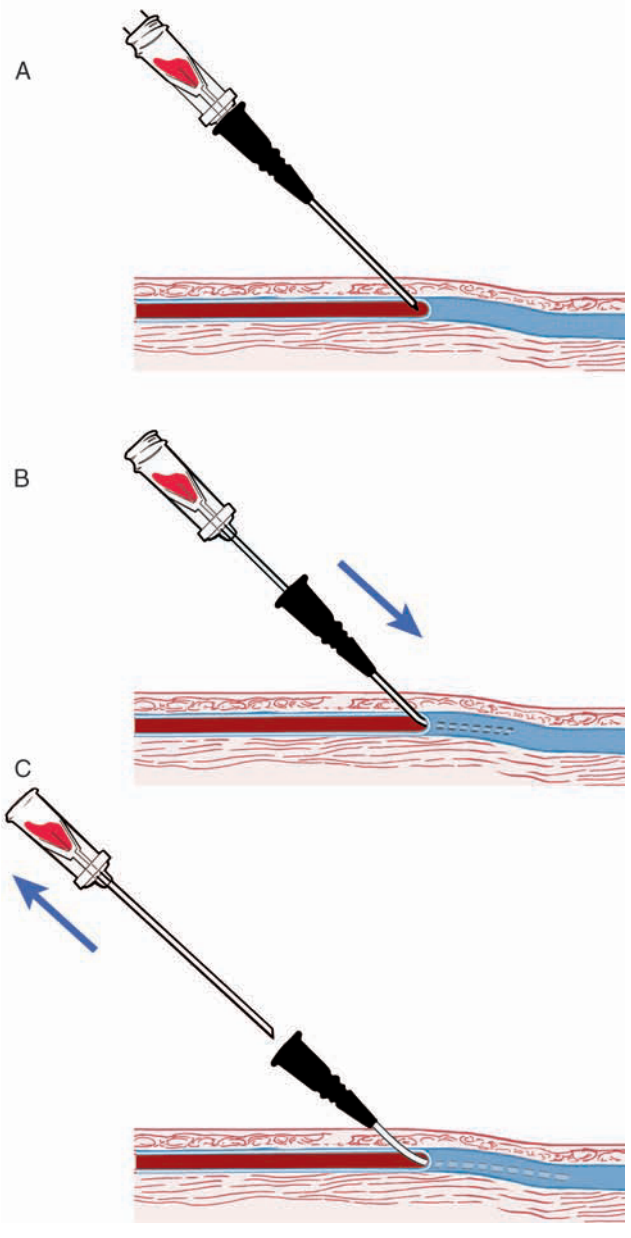


FIGURE 48-11. The catheter-over-the-needle technique. **A.** The vein is punctured and blood returns in the needle hub. **B.** The catheter is advanced over the needle and into the vein. **C.** The needle is removed.

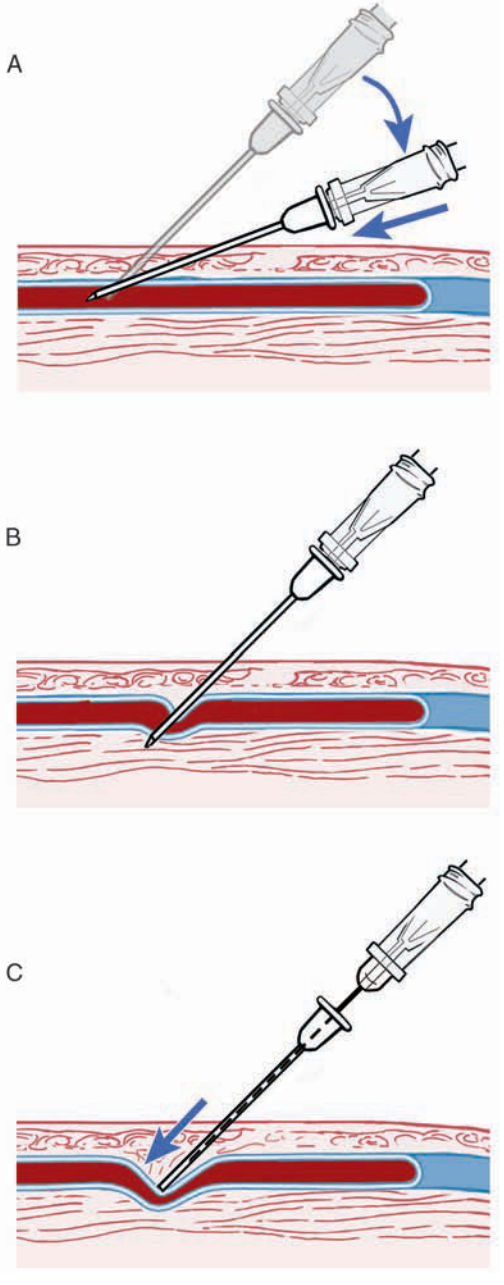


FIGURE 48-12. Advancing the catheter-over-the-needle. **A.** Drop the catheter hub toward the skin, then advance the catheter-over-the-needle 2 to 3 mm into the vein. **B.** If it is advanced at the original angle to the skin, the far wall of the vein may be punctured. **C.** If the catheter is advanced over the needle as soon as the vein is entered, the catheter may push the vein off the end of the needle, resulting in unsuccessful venous cannulation.

PERIPHERAL INTRAVENOUS CANNULATION

Cannulation of a vein begins with a successful venipuncture with the desired device, as described above. This section focuses on the use of the catheter-over-the-needle technique of peripheral venous access, as it is the most commonly used method.

Insert the catheter-over-the-needle through the skin and into the vein (**Figure 48-11A**). A flash of blood in the hub of the needle confirms that the tip of the needle is within the vein. Advance the catheter-over-the-needle an additional 2 to 3 mm to ensure that the catheter is within the vein. An alternative is to drop the hub of the needle nearly parallel to the skin before advancing the catheter-over-the-needle (**Figure 48-12A**). This will prevent the needle from puncturing the far wall of the vein (**Figure 48-12B**) and the catheter from pushing the vein away from the needle (**Figure 48-12C**). Hold the hub of the needle securely. Advance the catheter over the needle until its hub is against the skin (**Figure 48-11B**). Securely hold the hub of the catheter against the skin. Withdraw the needle (**Figure 48-11C**). Apply pressure, with the nondominant index finger, over the skin above the catheter to prevent blood from exiting the catheter (**Figure 48-13A**).

While applying digital pressure over the catheter, apply a device or intravenous tubing to the hub of the catheter. A syringe or vacuum device may be attached to the catheter to draw blood samples (**Figure 48-13B**). Intravenous tubing can be attached to the catheter to begin a fluid infusion (**Figure 48-13C**). A saline or heparin lock may be attached to the catheter to be used later for intravenous access (**Figure 48-13D**).

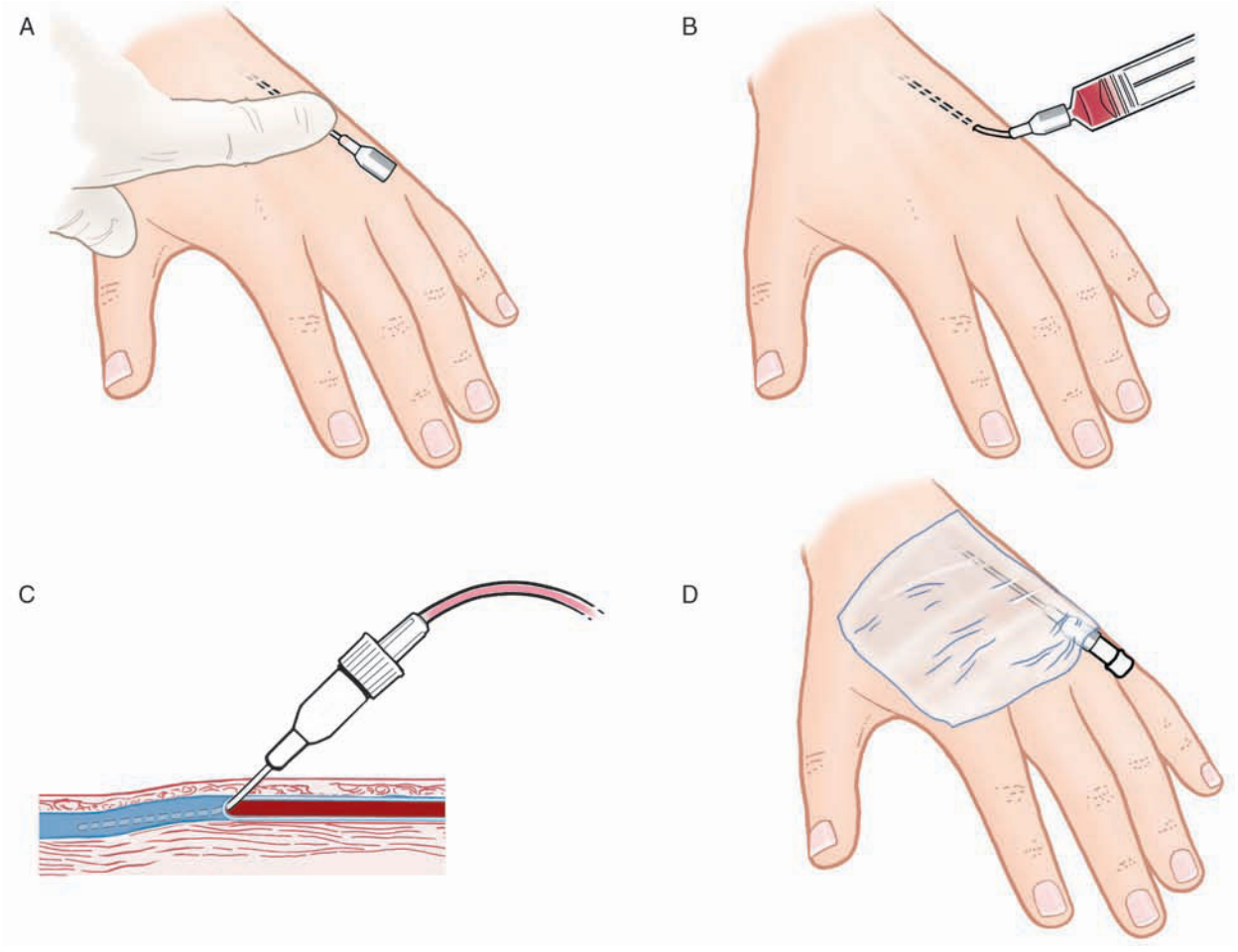


FIGURE 48-13. Peripheral intravenous cannulation. **A.** Apply gentle pressure over the catheter with a gloved finger to prevent hemorrhage from the catheter hub. **B.** Blood samples may be withdrawn from the cannula via a syringe or vacuum tubes. **C.** Intravenous infusion tubing is attached to the catheter. **D.** A saline (heparin) lock is attached to the catheter.

Secure the intravenous catheter to the skin (**Figure 48-14**). There are numerous methods to tape the catheter to the skin; only a few are described here. Place a 2 in. piece of adhesive tape sticky side up under the catheter hub (**Figure 48-14A**). Fold the ends of the adhesive tape over the catheter and onto the skin to form a "chevron" (**Figure 48-14B**). Alternatively, fold the adhesive tape to form a "U" (**Figure 48-14C**). Apply a 2 in. piece of adhesive tape over the catheter hub (**Figure 48-14D**). Place a transparent dressing over the catheter hub and distal intravenous tubing (**Figure 48-14E**). Some prefer to use the transparent dressing without the adhesive tape. The catheter may be sutured to the skin when vascular access is essential and when the catheter may be pulled out by a young child or combative patient. It is very rare that a peripheral intravenous catheter must be sewn into place.

ALTERNATIVE TECHNIQUES

ARTERIAL LINE KIT

The modified Seldinger technique, used with a QuickFlash radial artery catheterization set (Arrow International, Bloomington, IN), is very useful for the catheterization of deep brachial and external jugular veins. The unit is commonly available in Emergency Departments and Intensive Care Units. It consists of a one-piece unit that incorporates a catheter-over-the-needle, a guide-wire in a feed tube, and a lever to advance the guidewire (**Figure 48-15**). The black mark on the feed tube is a reference mark. The tip of the guidewire is positioned at the tip of the needle when the advancement lever is at the reference mark. The unit is also available without the catheter-over-the-needle as the Positive placement Spring-Wire Guide (Arrow International, Bloomington, IN). It can be attached to a standard stock catheter-over-the-needle. A similar device is The WAND (Access Scientific, San Diego, CA).

The integral guidewire and soft, 2 in. long, 20 gauge catheter found in the QuickFlash set can ease the process of catheterization considerably. The depth of the deep brachial vein combined with the overlying skin (which is often scarred from previous venipunctures) makes catheterization with the usual 1¼ in catheter difficult. The external jugular vein is quite mobile, and the overlying tissues are fairly tough. This can make it quite difficult to thread an over-the-needle catheter into the vein without pushing the vein off the end of the needle.

Select a vein to cannulate. Clean and prep the skin overlying the puncture site. Place a tourniquet on the extremity. Open the package and remove the unit. Advance the guidewire through the needle and then retract it. Do not use the catheterization unit if the guidewire does not advance and retract smoothly. Ensure that the guidewire advancement lever is retracted as far as possible so that the guidewire is not within the needle. **The flashback of blood will not be seen if the guidewire is not fully retracted and out of the needle.**

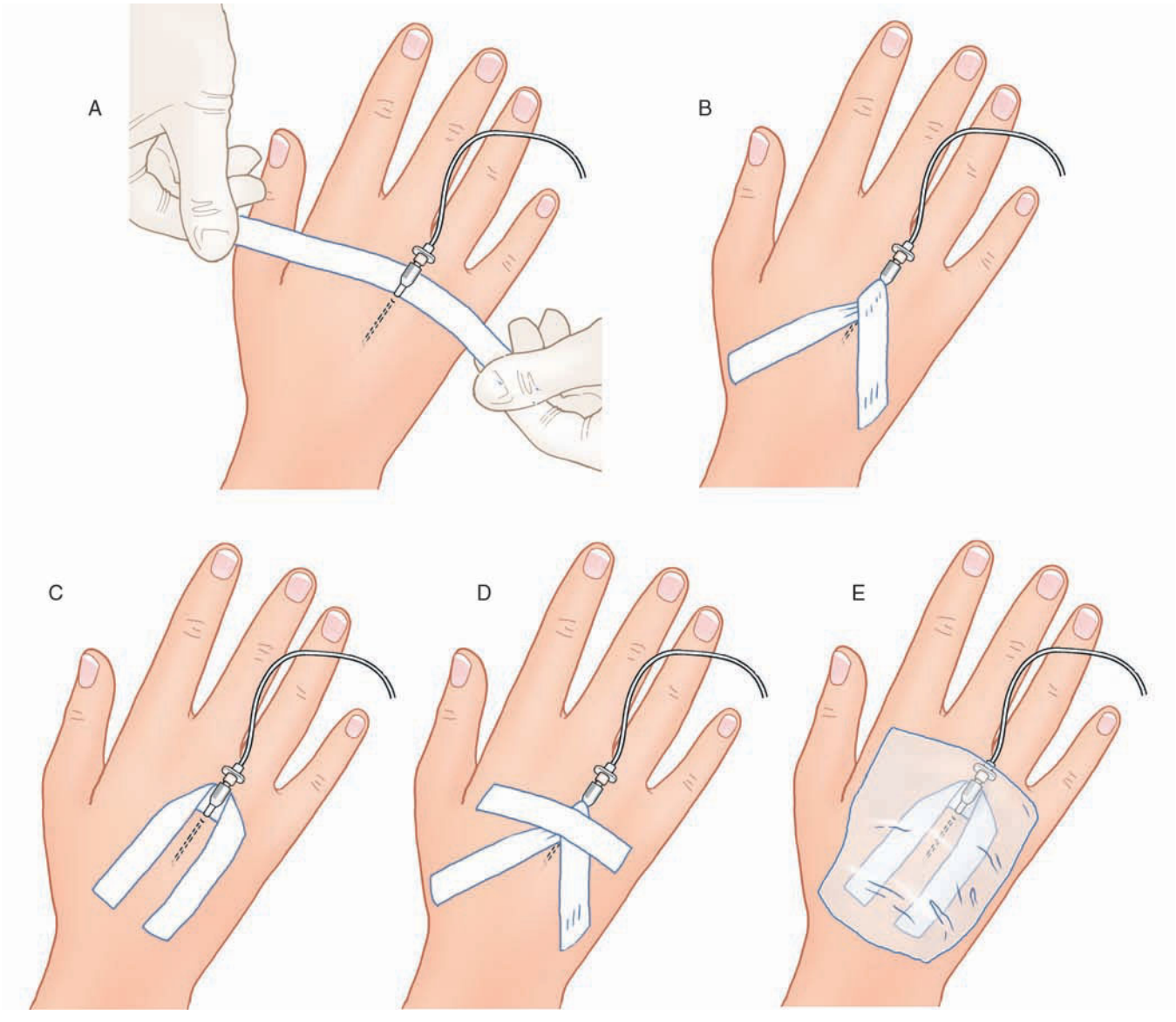


FIGURE 48-14. Securing the intravenous catheter. **A.** Place a narrow strip of adhesive tape sticky side up under the catheter hub. **B.** Fold the tape over the catheter to form a "chevron." **C.** Alternatively, the tape with the sticky side up can be folded to form a "U." **D.** A second piece of tape is applied to better secure the catheter to the skin. **E.** A transparent dressing is applied over the catheter.

Stabilize the vein with the nondominant hand. Insert the catheter-over-the-needle through the skin and into the vein (**Figure 48-16A**). A flash of blood in the hub of the needle indicates that the tip of the needle is within the vein. Hold the needle hub securely. Advance the guidewire, using the advancement lever, into the vein (**Figure 48-16B**). Continue to advance the guidewire as far as possible into the vein. The advancement lever must be distal to the reference mark to ensure that the guidewire is past the tip of the needle. **Stop advancing the guidewire if resistance is encountered. Do not force the guidewire against resistance. Do not retract the guidewire if resistance to advancement is encountered. Doing so may damage the vein or shear off a piece of the guidewire. Withdraw the entire unit and repeat the procedure with a new unit.**



FIGURE 48-15. The Arrow QuickFlash radial artery catheterization set. Note the different positions of the guidewire. The guidewire is within the feed tube (*top*). The tip of the guidewire is at the tip of the needle when the advancement lever is at the reference mark (*middle*). The guidewire is advanced through the catheter-over-the-needle (*bottom*).

Advance the guidewire as far as possible into the vein. Advance the catheter-over-the-needle an additional 1 to 2 mm into the vein. This will ensure that the tip of the catheter is within the vein. Hold the hub of the needle securely. Advance the catheter over the needle and guidewire until its hub is against the skin (**Figure 48-16C**). A twisting motion may help to advance the catheter against resistance. Release the tourniquet. Hold the catheter hub firmly against the skin. Remove the needle and guidewire, through the catheter, as a unit. Attach a syringe, vacuum blood collection system, intravenous line, or saline (heparin) lock onto the catheter hub. Secure the catheter with adhesive tape.

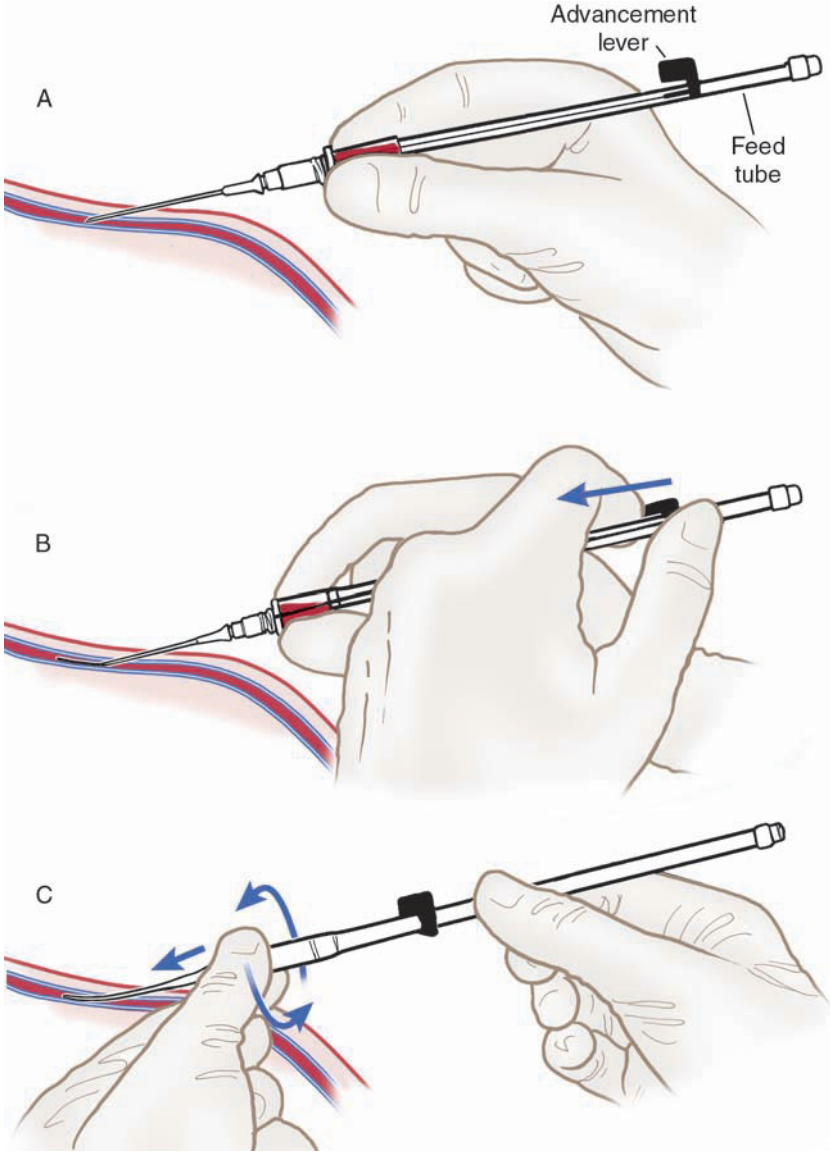


FIGURE 48-16. The Arrow QuickFlash radial artery catheterization set. **A.** The vein is punctured and blood returns into the hub of the needle. **B.** The guidewire is advanced into the vein. **C.** The catheter is advanced over the needle and guidewire with a back-and-forth rotating motion. The needle and guidewire are then removed as a unit.

EXTERNAL JUGULAR VEIN CANNULATION

Place the patient in the Trendelenburg position to distend the external jugular vein. Turn the patient's head to the opposite side. This will gently stretch the vein and prevent it from rolling. Clean and prep the skin of the neck. Place the nondominant thumb or index finger above the midportion of the clavicle to obstruct outflow and distend the external jugular vein. Align the catheter-over-the-needle parallel to the vein with the bevel of the needle upward and the tip of the needle pointing toward the clavicle. Enter the vein midway between the angle of the mandible and the midclavicle. Insert the catheter-over-the-needle during inspiration, when the valves of the external jugular vein are open. **Be sure to cover the open hub of the needle and/or catheter with a finger at all times to prevent an air embolism.** If the vein rolls, attempt to insert the catheter-over-the-needle obliquely into the vein. Another option is to cannulate the vein in the area where a tributary joins it. These areas are often anchored in the subcutaneous tissue. The remainder of the technique is similar to that described previously.

DEEP BRACHIAL VEIN CANNULATION

Extend the patient's arm. By palpation, identify the brachial artery pulse in the antecubital fossa. Clean and prep the skin of the antecubital fossa. Place a tourniquet on the upper arm. Reidentify the brachial artery pulse. Place a 2 to 3 in. long catheter-over-the-needle onto a 5 mL syringe and insert it just medial or lateral to the brachial artery pulse and at a 30° to 45° angle to the skin with the tip of the needle pointing cephalad. Advance the catheter-over-the-needle while applying negative pressure to the syringe. A flash of blood in the syringe indicates that the vein has been entered. If a flash is not seen, slowly withdraw the catheter-over-the-needle. It may have gone "through-and-through". A flash will be seen as the catheter-over-the-needle is withdrawn and the tip of the needle reenters the vein. The remainder of the technique is similar to that described previously. The use of ultrasonography can significantly improve the success rate of deep brachial vein cannulation. Complications include brachial artery puncture, hematoma formation, loss of vascular access, and transient paresthesias.[20,21]

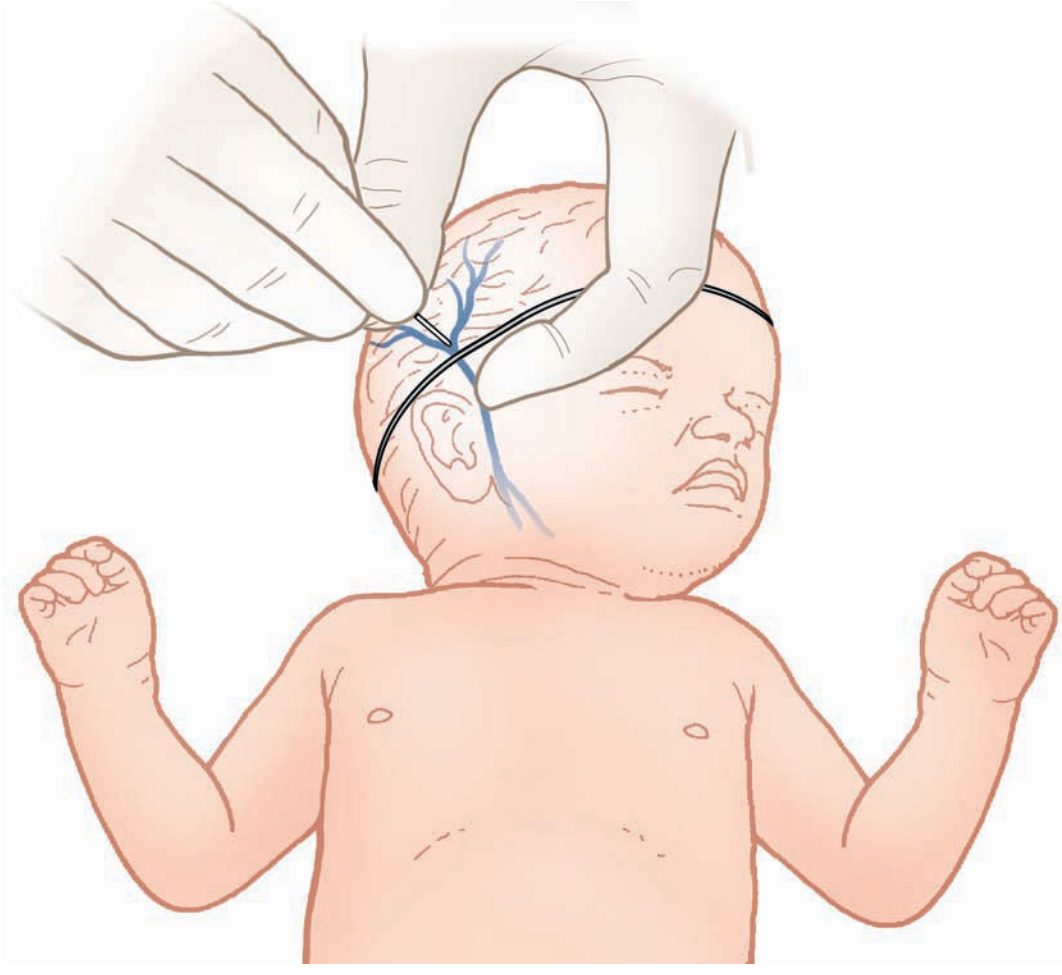


FIGURE 48-17. Scalp vein cannulation in the neonate. A rubber band makes a convenient tourniquet.

ULTRASOUND-GUIDED PERIPHERAL VEIN CANNULATION

A deep peripheral vein, often the brachial or basilic vein, may be cannulated under direct visualization using ultrasonography.[9] Ultrasound may also be used to identify a superficial vein when one is not palpable or visible. Place a tourniquet on the upper arm. Identify the vein by placing the ultrasound probe perpendicular to the vein. Identify the vein as a thin-walled, nonpulsatile, vascular structure. Move the probe along the vein to identify its most superficial and easiest accessed point. A catheter-over-the-needle can then be inserted in the vein under direct visualization.[10,11]

The easiest way to determine the depth of the vein is to note its depth on the ultrasound screen. Move the ultrasound probe distally this same distance while still maintaining visualization of the vein. Insert the catheter-over-the-needle at a 45° angle and advance it until the tip of the needle is seen on the ultrasound screen. Puncture the vein wall using a quick and short jabbing motion. Take care to not puncture through the posterior wall of the vein. Once the tip of the needle is seen within the vein, advance the catheter over the needle and into the vein. Refer to Chapter 50 for the complete details of ultrasound-guided vascular access.

PEDIATRIC CONSIDERATIONS

Venipuncture and peripheral venous access can be quite a challenge in the infant, neonate, and small child. Proper restraint of the extremity with a board or an assistant will greatly aid the process. Aside from the techniques discussed above, there are a few techniques that can facilitate pediatric vascular access.[12,13] The scalp veins can be used for venous access in newborns, infants, and children up to 1 year of age. They are most easily cannulated with a small (i.e., 23 or 25 gauge) butterfly needle or catheter. A rubber band can be placed about the baby's head as a tourniquet (**Figure 48-17**). Other veins commonly used include those of the antecubital fossa, dorsal hand, dorsal foot, external jugular vein, and the saphenous vein at the knee or groin. For small and superficial veins, it can be helpful to place a small bend at the hub of the catheter-over-the-needle assembly (**Figure 48-18**). This allows for the use of a less acute angle and easier entry into the vein without puncturing the far wall.

The best guide to the gauge or diameter of catheter to use is to compare the catheter to the vein. The catheter should be at least slightly smaller than the vein. In practice, the smallest readily available catheters are 24 gauge. A 22 gauge catheter will allow a much higher flow rate if it can be inserted successfully.

Keeping a peripheral intravenous line from being pulled out by an active child is quite a challenge. Each institution has its own "recipe" for securing pediatric IVs. The catheter is taped to the skin in the usual manner. Several strips of tape can be placed to secure the tubing to the skin and act as "strain reliefs" to prevent traction applied to the tubing from being transmitted to the catheter. Half of a medicine cup can be used as a shield for the catheter itself (**Figure 48-19A**). Apply tape over the cut edges of the cup to prevent the sharp edges from cutting the child's

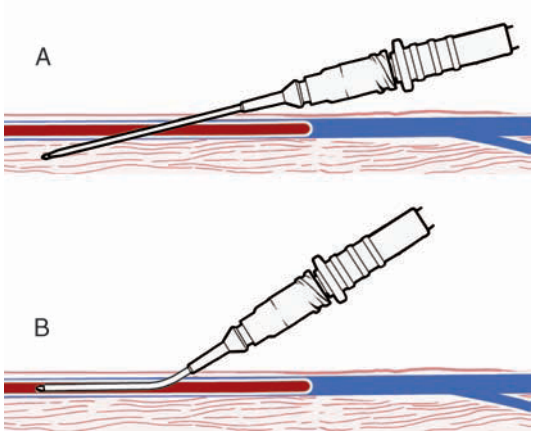


FIGURE 48-18. Cannulation of a small superficial vein with a catheter-over-the-needle. **A.** The "shoulder" of the catheter hub prevents the needle from being placed nearly parallel to the skin. **B.** A slight bend at the base of the needle permits the needle to run nearly parallel to the skin surface, enabling the subcutaneous vein to be cannulated. Always make sure that the catheter can be advanced over the needle before puncturing the patient's skin.

delicate skin. The clear medicine cup acts as a window, so that the catheterization site can easily be inspected without removing all the dressings. The whole assembly, or just the taped intravenous line, can then be covered with a gauze roll or stockinette (**Figure 48-19B**). A cup with one-quarter or one-third cut away may be used to protect a scalp vein access site (**Figure 48-19C**). A splint applied to the extremity will increase the duration of intravenous line patency.[14]

ASSESSMENT

Refer to **Table 47-2**, in the preceding chapter, for some general principles of intravenous line assessment. The line should flush easily. Any infusions should flow by gravity alone. Progressive swelling at the catheterization site indicates the formation of a hematoma or extravasation of infused fluids. Peripheral infusions of vasopressors and caustic solutions require the skin puncture site to be assessed frequently and carefully, since extravasation may lead to extensive local soft tissue necrosis. Pain at the intravenous access site must be taken seriously and should prompt a search for the cause. Pinched skin, extravasation, or thrombosis must be looked for and ruled out.

AFTERCARE

Most authorities recommend changing peripheral infusion sites at least every 3 days, although this is probably overly cautious.[15,16] It may be impractical if the patient has poor superficial veins. Any cannula with signs of venous thrombosis, skin erythema, or puncture site discharge must be removed at once. Heparin or saline locks that have not been accessed should be flushed regularly, usually every 8 hours. Saline works as well as heparin solutions for most applications.[17] Approximately 1 to 2 mL of sterile saline to flush is adequate for peripheral venous catheters. Heparin flushed cannulations have an increase in duration of patency.[12]

Dressings should be inspected and changed if they have become moist or contaminated. Routine dressing changes are probably unnecessary.[17] The transparent dressings are widely used despite some studies suggesting that transparent occlusive dressings are associated with higher rates of infection than plain gauze dressings.[18] Transparent dressings have the advantages of allowing easy inspection of the catheter site and holding the catheter securely in place. Individual institutions often have their own nursing guidelines and infection control statistics to support their choice of dressing.

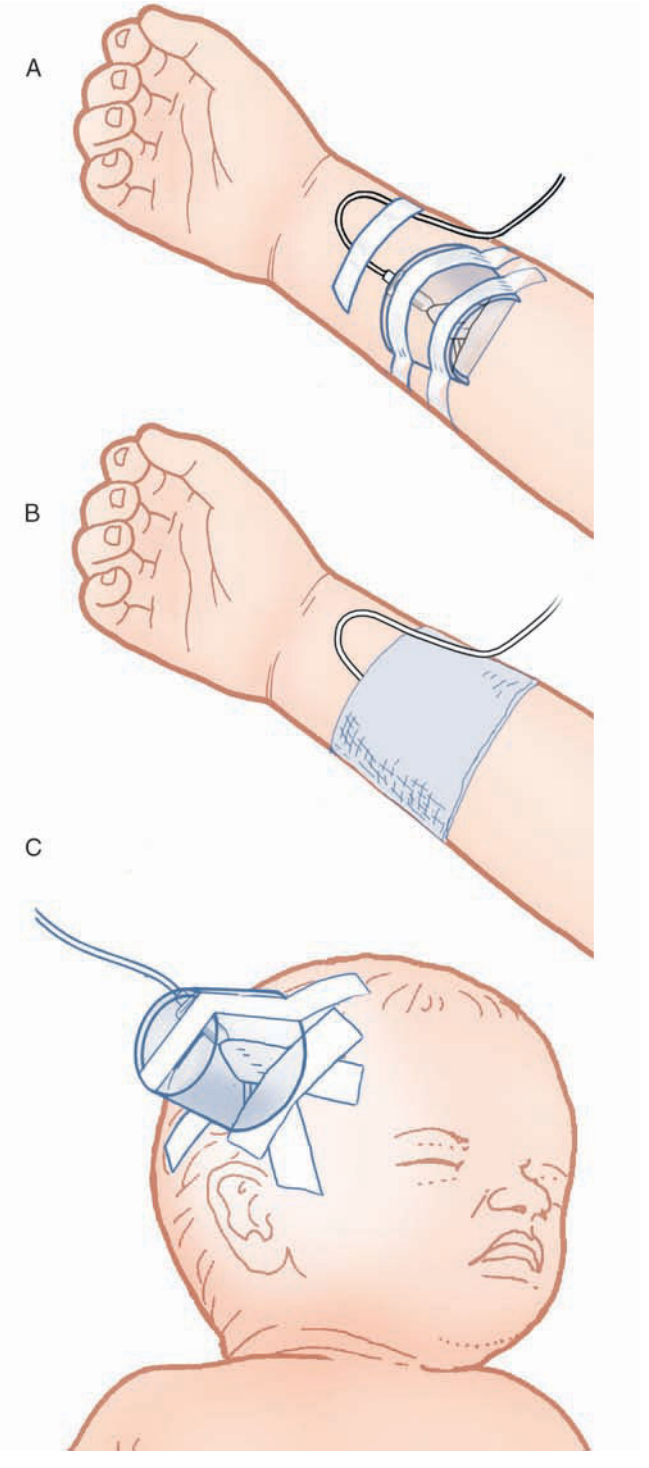


FIGURE 48-19. Securing pediatric intravenous lines. **A.** Use a clear plastic medicine cup, cut in half lengthwise, to protect the skin puncture site. **B.** A stockinette or gauze roll can be used to further protect the site from manipulation. **C.** Protecting a scalp vein cannula with tape and a clear plastic medicine cup.

REMOVAL OF INTRAVENOUS CATHETERS

Turn off any intravenous infusions and clamp the tubing. Place the infusion site in a dependent position below the right atrium to prevent a venous air embolism. Remove any tape and dressings from the infusion site. Apply direct pressure to the skin puncture site with a gauze pad. Briskly remove the catheter or needle. Hold firm direct pressure for several minutes. Apply a bandage. Instruct the patient to check for signs of thrombophlebitis, cellulitis, and an infection for the next several days.

COMPLICATIONS

PERIPHERAL VENIPUNCTURE

The main complications of venipuncture are pain and hematoma formation. Pain during venipuncture can be minimized by using small gauge needles, clearly identifying a vein before attempts at venipuncture, and minimizing the number of attempts at venipuncture. Hematomas and bleeding can be prevented by removing the tourniquet before removing the needle and applying direct pressure after the needle is removed. Hematomas are self-limited and easily treated with nonsteroidal anti-inflammatory drugs, cool compresses for analgesia, and warm compresses to hasten hematoma resorption. Other complications include nerve injury, usually reversible paresthesias. Arterial puncture is common with deep brachial lines and may rarely be catastrophic if it causes thrombosis of the brachial artery, the sole arterial supply of the forearm and hand.[18] Infection from simple venipuncture is uncommon.

PERIPHERAL INTRAVENOUS CANNULATION

In addition to the complications described for venipuncture, indwelling venous catheters pose additional risks. Some of these are summarized in **Table 47-2** of the preceding chapter. The steel needle cannula of the butterfly needle can move easily, causing lacerations of the vein and neighboring structures. The risk of infection is greater the longer a catheter is left in place. Intravenous catheters increase the risk of superficial venous thrombosis and thrombophlebitis. This may be prevented by limiting catheter manipulation during tubing changes and by using extension tubing at the catheter hub. Complications are more common when the intravenous catheter is placed in the hand or forearm when compared to other sites.[19] This may be the result of the higher frequency of catheters placed in these two sites in this small study. It is possible to injure a number of structures in the neck during external jugular vein cannulation. This includes the carotid artery, internal jugular vein, and trachea. It is also possible to cause a pneumothorax. None of these complications should occur as long as deep penetration with the needle is avoided.

Extravasation of vasopressors or caustic solutions can cause local skin necrosis. Extravasation of large volumes into a muscle compartment can lead to a compartment syndrome, although this is rare with superficial peripheral venous lines. Extravasation and tissue injury may be prevented by using a small gauge catheter in a large vein, diluting medications before administration, and observing intravenous access sites frequently.

Infections can often be prevented by using aseptic technique and sterile dressings, and changing peripheral catheters every 48 to 72 hours. The complications of peripheral nerve palsies, pressure necrosis, and compromised peripheral circulation are rare but do occasionally occur. They can be prevented with frequent neurovascular checks to any restrained extremity, by padding all pressure points, and by avoiding the placement of circumferential tape on an extremity.

SUMMARY

Venipuncture and peripheral venous access is an essential skill for nearly all medical practitioners, from paramedics to physicians. The only way to become proficient at these techniques is to master them during training and to practice them regularly. Equally important is the frequent reassessment of venous cannulas so that complications can be detected and treated early, before they become major problems for the patient and the Emergency Physician.

49 Central Venous Access

Arun Nagdev and Craig Sisson

INTRODUCTION

Percutaneous cannulation of the central veins is an essential technique for both long-term and emergent medical care. Access to the major veins of the torso allows rapid high-volume fluid resuscitation, administration of concentrated ionic and nutritional solutions, and hemodynamic measurements.

Obtaining venous access is an essential skill for the Emergency Physician. Indications for peripheral venous access are broad, ranging from simple fluid and medication administration to delivery of intravenous (IV) contrast for imaging studies. Central venous access is less often compulsory, but still remains an indispensable procedure in the practice of Emergency Medicine. Central venous access allows for multiple critical actions to be performed from the administration of blood products and vasoactive medications to transvenous cardiac pacing. Central venous access is often undertaken in cases where peripheral IV access cannot be obtained.

Even the most experienced provider can have difficulty securing rapid and functional access to the venous system in specific situations such as severe dehydration, cardiac arrest, large body habitus, and injection drug users with sclerosed veins. The classical "blind" technique, based on anatomical and vascular landmarks, has been the most commonly taught method. The growing integration of bedside ultrasound (US) into the practice of Emergency Medicine has slowly changed the way Emergency Physicians are choosing to perform central venous access. US visualization of the patients' vascular anatomy allows the specific advantage of determining the ideal location to access the central venous circulation. A thrombosed femoral vein can be identified, allowing the Emergency Physician to preemptively choose another site. The visualization of the overlap of the right internal jugular vein and the carotid artery may prevent inadvertent arterial puncture and the resultant sequelae in the anticoagulated patient. US guidance for central venous access has altered the clinical algorithm of obtaining vascular access, making the procedure easier for the Emergency Physician and safer for the patient.

Evidence supporting US guidance for central vascular access is fairly robust.[1–5] Convincing data from the Critical Care and Emergency Medicine literature indicate an increased success rate and a decrease in the complication rates. Recently, the Agency for Healthcare Research and National Institute for Clinical Excellence both recommended US guidance for central venous access. The availability of small, low cost, and portable US machines has made US guidance for central venous access a requisite skill for all Emergency Physicians. A brief description of US-guided central venous access is discussed in the following sections as appropriate. Refer to Chapter 50 for the complete details.

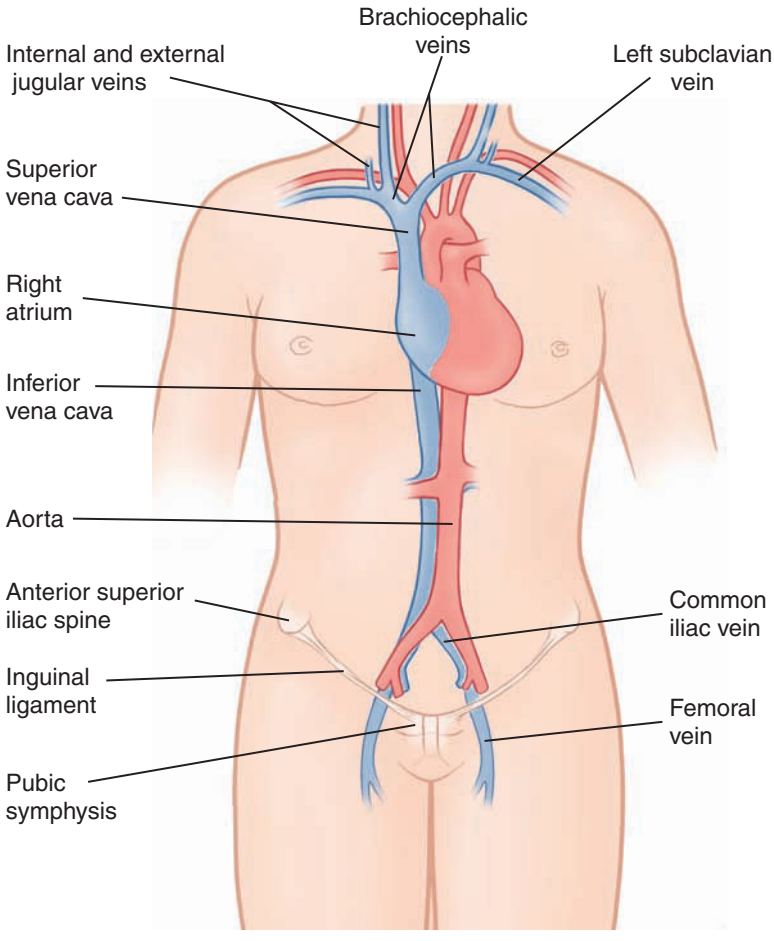


FIGURE 49-1. The anatomy of the central venous system.

ANATOMY AND PATHOPHYSIOLOGY

The tip of the central venous catheter must lie in the superior or inferior vena cava and never in the right atrium. The thin wall of the right atrium may easily be perforated by the catheter tip, resulting in hemorrhage and cardiac tamponade. The central venous anatomy is shown in **Figure 49-1**. The superior vena cava is accessed through the internal jugular veins, the subclavian veins, and less commonly via the external jugular veins. The inferior vena cava is accessed through the femoral veins. These access routes are discussed in greater detail in the corresponding sections below. The advantages and disadvantages of each route for central venous access are summarized in **Table 49-1**.

INTERNAL JUGULAR VEIN

The internal jugular vein is not directly visible from the surface of the skin. A thorough knowledge of its anatomic relationships is essential for successful cannulation. The internal jugular vein is a direct continuation of the sigmoid sinus and exits the skull through the jugular foramen, just anteromedial to the mastoid process.[6] It joins the subclavian vein deep and just lateral to the head of the clavicle (**Figure 49-2**).[6] The internal jugular vein drains blood back to the heart from the brain, face, and neck. There is a proximal and distal dilatation of the vein known as the superior and inferior bulbs of the internal jugular vein. The inferior bulb contains a bicuspid valve to prevent retrograde flow. The surface projection of the internal jugular vein runs from the earlobe to the medial clavicle, between the sternal and clavicular heads of the sternocleidomastoid muscle. The internal jugular vein increases in diameter as it descends. It is joined by tributary veins in the upper neck, making it easier to cannulate below the level of the cricoid cartilage.

The internal jugular vein is collapsible (**Figure 49-3**). Its overall diameter is dependent on the patients' intravascular volume status as well as their position. It has a very small diameter in low-flow

TABLE 49-1 Characteristics of the Different Routes for Central Venous Cannulation

	Internal jugular vein	External jugular vein	Subclavian vein	Femoral vein
Risk of infection	Low	Low	Low	High
Patient mobility	Fair	Poor	Good	Bedridden
Trendelenburg required?	Yes	Yes	Yes	No, best for CHF or dyspnea
Need to stop CPR?	Probably	Probably	Yes	No, may continue CPR
Suitable for long-term use?	Yes, but not if ambulatory	No	Yes–best choice	No, remove within 2–3 days
Risk of venous thrombosis	Low	Low	Low	High

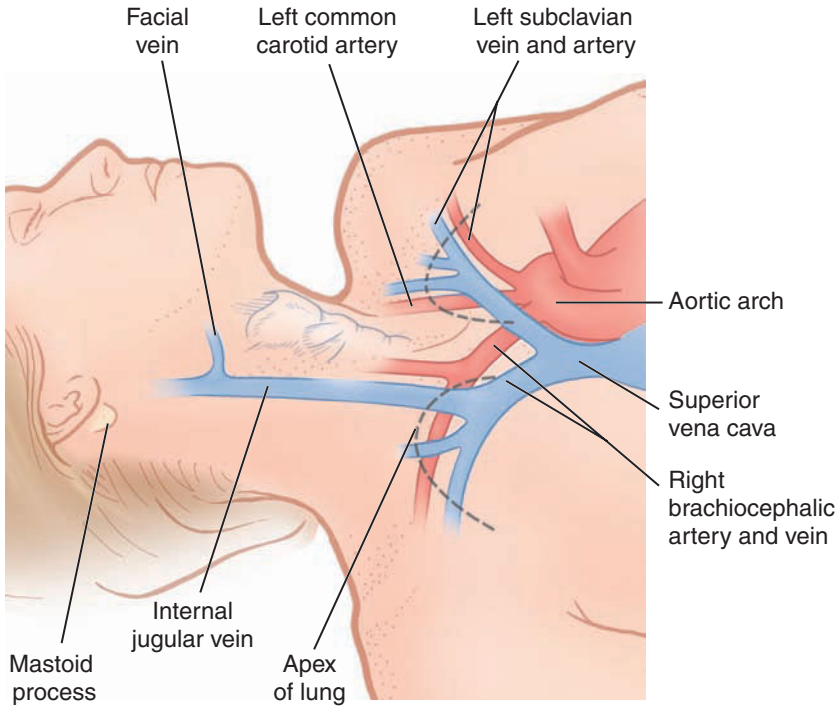
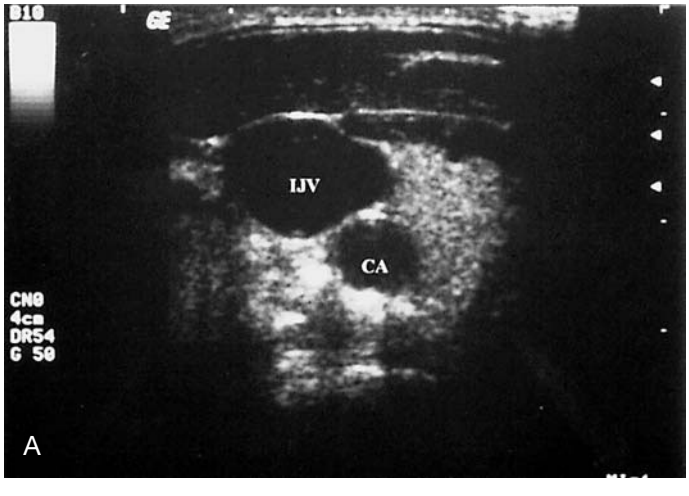
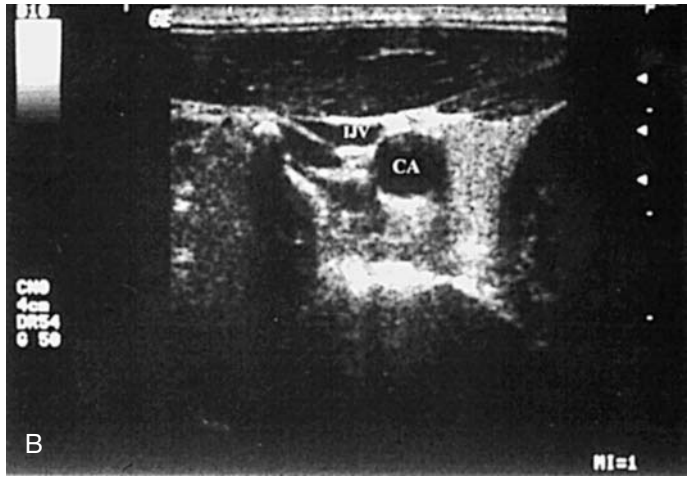


FIGURE 49-2. Anatomy and surface relationships of the internal jugular vein.





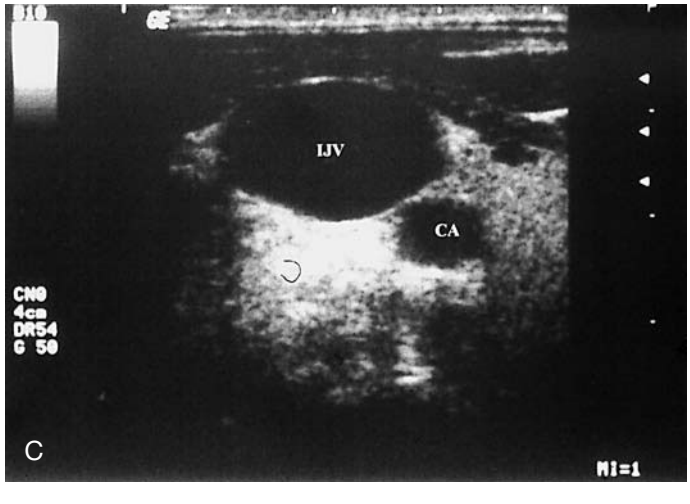


FIGURE 49-3. Transverse US images of the left internal jugular vein (IJV) and carotid artery (CA). **A.** The patient is supine. **B.** With gentle external pressure applied, the low-pressure internal jugular vein collapses easily while the carotid is still patent. **C.** The Valsalva maneuver or placement of the patient in the Trendelenburg position dilates the internal jugular vein.

states, as during cardiopulmonary resuscitation (CPR) and when the patient is upright. The vein is easily compressible and will collapse with gentle external pressure from a palpating finger or a large-diameter needle indenting the skin (**Figure 49-3B**). Local masses such as tumors, a goiter, and a hematoma can also easily collapse the internal jugular vein. Fortunately, the vein is also very distensible. Placing the patient in the Trendelenburg position or having the patient perform the Valsalva maneuver will distend the vein, making it easier to locate and cannulate (**Figure 49-3C**).

Along its course, the internal jugular vein lies in close proximity to the carotid artery, vagus nerve, phrenic nerve, brachial plexus, cervical sympathetic plexus, thyroid gland, and the pleural cupula of the lung. Inferiorly, the left internal jugular vein also lies in close proximity to the thoracic duct. The location of these structures places them at risk for injury during central venous cannulation of the internal jugular vein.

The position of the internal jugular vein in relation to the common carotid artery within the carotid sheath can vary considerably between individuals. The simple assumption that the internal jugular vein is always lateral to the carotid artery has not born out in ultrasonographic studies. Overlap with the carotid artery can vary from 0% to 100% depending on individual anatomic variation, patient positioning, and where along its course the internal jugular vein is imaged.[7–12] It can even lie medial to the carotid artery in some patients, making blind needle puncture nearly impossible and extremely dangerous.[7,8,12]

This variability in location is mirrored by the size variability of the internal jugular vein. Between individuals, the actual and apparent size of the internal jugular vein can vary widely for anatomic and physiologic reasons. Mey et al. showed that an internal jugular vein size of less than 0.7 cm may be an independent risk factor for unsuccessful venous cannulation.[13] The internal jugular vein can vary in size and location when comparing the right to the left and the proximal vein to the distal vein.[7,10] Each of these individual factors form a strong argument for ultrasonographic assistance during internal jugular vein central line placement.

The common carotid artery travels alongside the internal jugular vein and is an important anatomic landmark for locating the internal jugular vein. The carotid artery runs deep and slightly anterior to the internal jugular vein. The left internal jugular vein usually overlaps the carotid artery in the lower neck (**Figure 49-3A**). The right internal jugular vein and the right carotid artery are usually separated slightly.

The right internal jugular vein is generally preferred to the left internal jugular vein as the site of central venous cannulation. The right internal jugular vein provides a nearly direct route to the superior vena cava. The dome of the right lung is somewhat lower than that of the left lung and thus decreases the chance of an iatrogenic pneumothorax. The thoracic duct is relatively large and lies high in the left chest. These favor the right internal jugular approach to central venous cannulation to minimize complications.

There are three main "blind" or landmark approaches to the internal jugular vein as defined by their relationship to the sternocleidomastoid muscle. These are the anterior, central, and posterior approaches (**Figures 49-4** to **49-6**). The central approach is most commonly used. These three approaches are summarized in **Table 49-2** and described below.

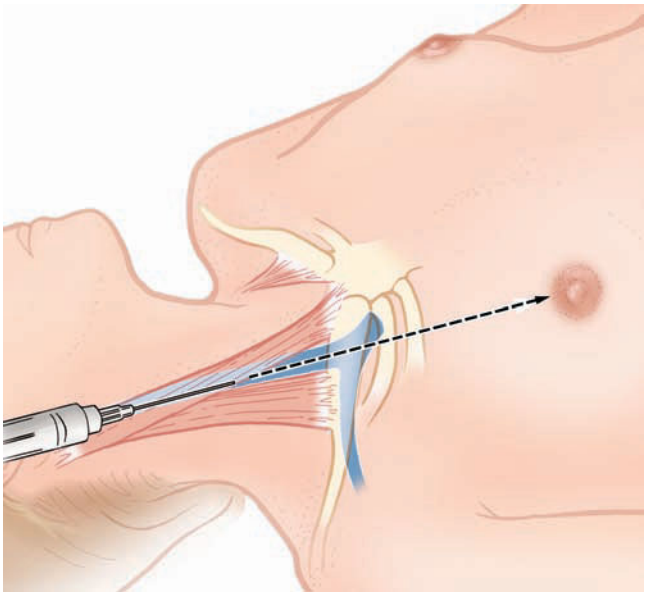


FIGURE 49-4. Central approach to the right internal jugular vein.

SUBCLAVIAN VEIN

The subclavian vein begins as the continuation of the axillary vein at the lateral edge of the first rib (**Figure 49-7**). The subclavian vein courses anterior to the anterior scalene muscle, which separates it from the subclavian artery. The subclavian vein descends to join the internal jugular vein and form the brachiocephalic trunk, which empties into the superior vena cava. Because the subclavian vein lies directly underneath the clavicle, US visualization of the vein is not usually possible.

The subclavian veins are 1 to 2 cm in diameter in an adult. Fibrous connective tissue joins the subclavian vein to the clavicle and first rib, preventing collapse of the vessel even in the event of a low-flow state. Anatomically associated structures include the thoracic duct, which joins the left subclavian vein at its junction with the left internal jugular vein. The right subclavian vein is preferred to the left for central venous access for this reason. The domes of the pleura lie posterior and inferior to the subclavian veins and medial to the

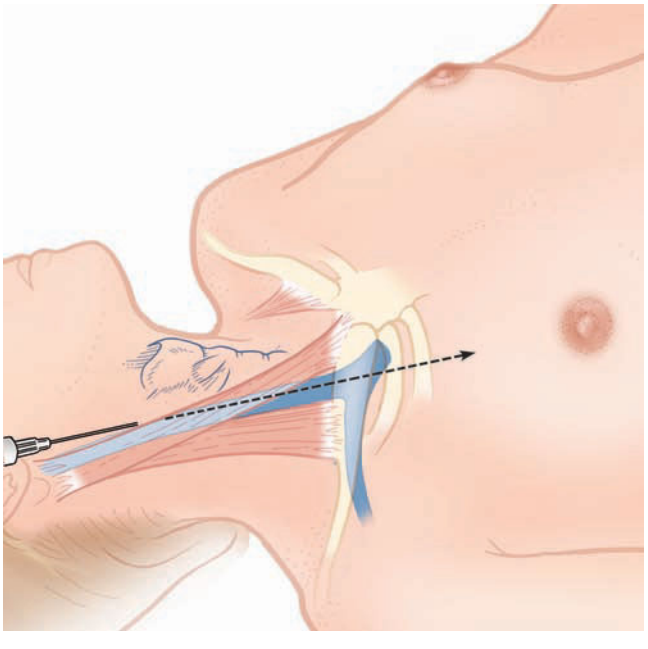


FIGURE 49-5. Anterior approach to the right internal jugular vein.

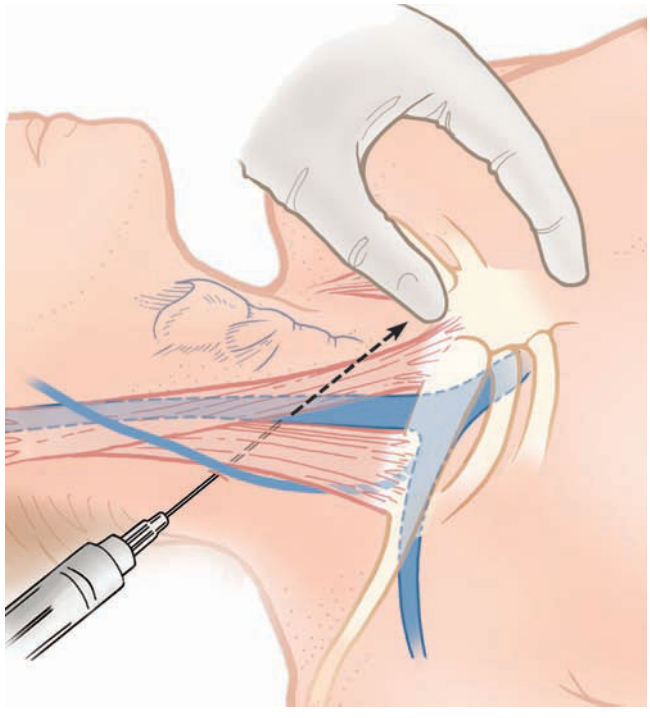


FIGURE 49-6. Posterior approach to the right internal jugular vein.

anterior scalene muscles. The subclavian arteries lie immediately posterior to the veins (**Figure 49-7**).

Subcutaneous fatty tissue, chest morphology, the close proximity of the pleura, and the close proximity of the subclavian artery make the subclavian vein the least favored site for central venous access in children. This is especially true in infants. An experienced Emergency Physician must perform the procedure if this route must be used in a neonate, an infant, or a small child.

AXILLARY VEIN

The axillary vein is defined as the continuation of the brachial vein from the medial border of the teres major to the lateral border of the first rib. The axillary vein continues under the clavicle as the subclavian vein, which then joins the internal jugular vein to form the brachiocephalic vein (**Figure 49-2**). Cadaver-based and radiologic studies have demonstrated a great variation in the anatomic relationship between the axillary vein and artery.[14,15] This makes the blind or landmark technique difficult for even the most experienced Emergency Physician.[14,15] An US study of the axillary vein in volunteers demonstrated a decreased overlap between the axillary vein and artery, and a farther distance from the pleura, as it was followed laterally.[16]

FEMORAL VEIN

Anatomically, the femoral vein is a continuation of the iliac vein after it crosses the inguinal ligament (**Figure 49-8**). The femoral vein lies within the femoral sheath and just medial to the femoral artery in the groin. This relationship can be remembered by the mnemonic "toward the NAVEL." This describes, from lateral to medial, the contents of the femoral sheath (femoral Nerve, femoral Artery, femoral Vein, Empty space, and Lymphatics). The femoral artery lies at the midpoint of the line connecting the symphysis pubis and the anterior superior iliac spine.[17,18] The femoral vein lies approximately 1 cm medial to the femoral artery pulse in an adult and approximately 0.5 cm medial in infants and young children.[19,20]

Recent anatomical US surveys on adult and pediatric populations have demonstrated variation in the classical anatomical teaching. Hughes et al. demonstrated an increased overlap between the femoral vein and artery as they moved distally to the inguinal ligament.[21] Warkentine et al. evaluated the amount of venous and arterial overlap in euvolemic children 1 cm distal to the inguinal ligament.[22] They noted that in 12% of cases, the femoral vein had either partial or complete overlap with the femoral artery. Both these studies noted the great variability of the vascular anatomy and recommended US visualization before femoral venous cannulation attempts.

Classically, the puncture site for femoral vein cannulation lies medial to the femoral artery and inferior to the inguinal ligament (**Figure 49-8**).[17,18,23] Femoral venous cannulation should be performed 1 to 2 cm inferior to the inguinal ligament (a commonly difficult landmark in the obese patient), in order to prevent inadvertent intraabdominal external iliac vein puncture. The femoral vein becomes the external iliac vein superior to the inguinal ligament (**Figure 49-8**). **Blood can flow freely into the retroperitoneal space, forming a potentially large and externally invisible hematoma if the posterior wall of the femoral vein is punctured by a through-and-through needle track above the inguinal ligament. It is imperative to puncture the femoral vein inferior to the inguinal ligament!**

Despite the believed higher rates of line infection and thrombosis associated with femoral venous cannulation, this access remains a popular route due to its relative ease of placement.[24] A recent large, randomized, multicenter study put into question the classically held notion that the femoral venous cannulations have higher rates of infection.[25] The study did not demonstrate a higher rate of infection between catheter tips (a well-accepted surrogate marker) removed from the femoral vein and the internal jugular vein. The rate of catheter-related bloodstream infection between femoral vein cannulation and internal jugular vein cannulation were similar (2.3% vs. 1.5%, respectively).

CENTRAL VENOUS ACCESS IN THE OBESE PATIENT

Central venous access is more complicated in the obese patient.[26] Surface landmarks may be obscured by adipose tissue and skin folds. The clavicle, carotid artery pulses, the thyroid cartilage, and

TABLE 49-2 Approaches to the Internal Jugular Vein

	Central	Anterior	Posterior
Insertion landmark	Superior apex of the triangle formed by the two heads of the sternocleidomastoid muscle and the clavicle	Medial edge of the sternocleidomastoid muscle at the level of thyroid cartilage	Lateral edge of sternocleidomastoid muscle, 1/3 of the way from the clavicle to the mastoid process
Angle with skin	30° (child), 45°–60° (adult)	30° (child), 45° (adult)	30°–45°, dive under the border of the sternocleidomastoid muscle
Aim toward	Ipsilateral nipple	Ipsilateral nipple	Sternal notch
Internal jugular vein depth in an adult	Within 3 cm	Within 3 cm	Within 5 cm

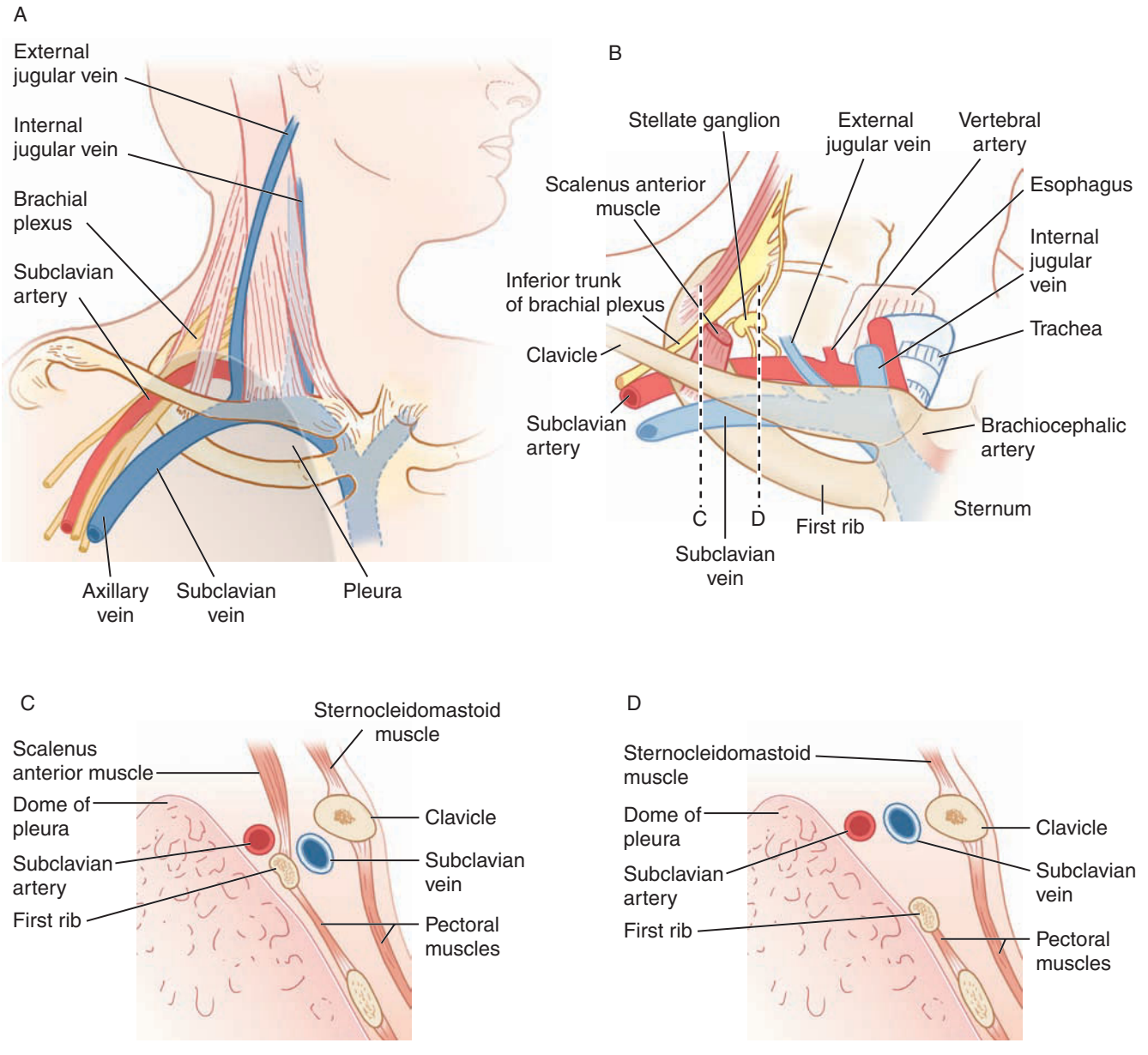


FIGURE 49-7. The anatomy of the subclavian vein. **A.** The right subclavian vein. **B.** Magnified view of the right subclavian vein demonstrating adjacent structures that may be injured during attempted cannulation. **C.** Sagittal section through the midclavicle. Note that the first rib protects the subclavian artery during an infraclavicular approach to the subclavian vein. **D.** Sagittal section through the medial third of the clavicle. Note the proximity of the subclavian artery and pleural dome to the subclavian vein.

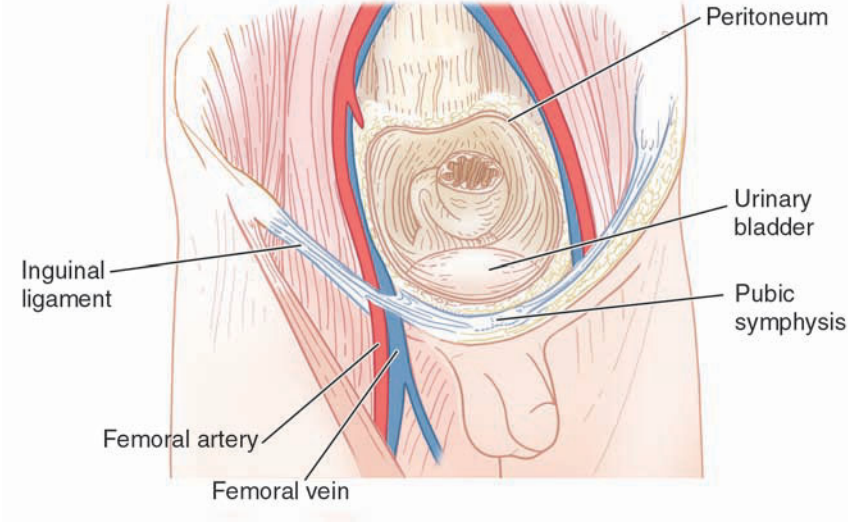


FIGURE 49-8. Anatomy of the femoral vein.

the trachea can be difficult to palpate. This makes internal jugular and subclavian venous access problematic. The anterior superior iliac spine, femoral artery pulse, and the pubic symphysis can be difficult to palpate. This makes femoral venous access problematic. Femoral venous access is often performed lower than normal due to an overhanging pannus. Placing the obese patient in the Trendelenburg position may not be possible. They may acutely decompensate in this position due to their poor pulmonary reserves, decreased lung and tidal volumes, increased intraabdominal pressure against the diaphragm, and difficult airway anatomy. All these factors may increase the rate of complications in the obese patient.

INDICATIONS

The internal jugular route is acceptable for central venous access in most cases. It allows ready access to the superior vena cava for long-term central venous access, caustic infusions, and monitoring of central venous pressure. Pulmonary artery catheters and transvenous pacing wires can be introduced through the right internal jugular vein. The internal jugular vein is accessible without terminating CPR efforts, although chest compressions and the lack of carotid pulsations make accessing it difficult. The risk of an iatrogenic pneumothorax is probably less with internal jugular vein cannulation as opposed to the subclavian vein, although patient mobility is less and discomfort is greater. In the coagulopathic patient, the internal jugular vein puncture site is compressible, but a hematoma formation may lead to airway compromise. Oguzkurt et al. showed that patients historically labeled as having "difficult access" had very low complication rates using US-guided central venous access of the internal jugular vein.[27] In this study, 27.7% (61/220) of the total procedures performed were on patients with disorders of hemostasis.

The subclavian vein is the preferred route for long-term central venous access. This site allows for ambulation (unlike a femoral line) and neck movement without discomfort (unlike an internal jugular line). The catheter is concealable under clothing, making outpatient use more acceptable.

The axillary vein is not a commonly used venous access site. It is more commonly used in children for long-term access. The use of US guidance has allowed the axillary vein to be used as an alternate access site. Due to the depth of the vessel and its close proximity to the brachial plexus, the axillary vein should only be cannulated in thin patients and as an alternative site when other sites are not available, have failed, or are contraindicated.

The femoral vein is often the preferred route for emergent central venous cannulation. The indications are the same as for any other site with a few exceptions. The femoral vein is not a suitable route for ambulatory patients beyond the initial resuscitation and stabilization period, as patients with femoral central venous lines must be confined to bed. Femoral venous access is easily obtained in patients with respiratory distress and pulmonary edema, since they do not need to be placed in the Trendelenburg position. Femoral venous access is relatively easy during CPR and does not require the cessation of chest compressions. The femoral vein is easily compressible. This makes it preferable to the subclavian vein in coagulopathic patients or those undergoing thrombolysis, although peripheral access would be preferred in these cases.[6] There is no risk of injury to the airway, pleura, or carotid arteries in very young or combative patients. Femoral central venous lines are generally preferred for initial central venous access in the very young or combative patient if deep sedation or neuromuscular paralysis is contraindicated or otherwise unnecessary.

CONTRAINDICATIONS

The usual contraindications to any invasive procedure apply to central venous access. Cellulitis or overlying infection at the puncture site is a contraindication to central venous access. A mass or hematoma causing external compression and/or obliteration of the vessel lumen, an intraluminal thrombosis, or a small size vein when visualized by US are also contraindications. An alternative should be sought if the patient is combative, agitated, or uncooperative. These patients require sedation and/or paralysis prior to insertion of the central venous line. Distorted anatomic landmarks due to fractures, deformities, obesity, previous catheterization at the site, surgery, or trauma are relative contraindications. There is a small but real risk of serious morbidity and even death due to the procedure. **Do not place a central venous line unless a peripheral IV line or an intraosseous line is inadequate or unobtainable and unless personnel capable of managing the procedural complications are immediately available.**

INTERNAL JUGULAR VEIN CANNULATION

Anatomic distortion of the neck, such as from subcutaneous emphysema or a hematoma, may make placement of an internal jugular line difficult and hazardous. Known severe carotid artery stenosis or atherosclerosis on the desired side of cannulation is a relative contraindication to internal jugular vein cannulation. Accidental carotid artery puncture during line placement may result in plaque rupture and a subsequent stroke. The vein may be collapsed and difficult to access in the hypovolemic patient. Other contraindications to cannulating the internal jugular vein include cervical spine fractures (actual or suspected) or penetrating neck injuries. Do not cannulate the ipsilateral internal jugular vein if the patient has an implanted pacemaker or a defibrillator. Central venous access can result in needle injury to the leads, lead displacement, and thromboembolism.

The subclavian or femoral route may be preferable in some circumstances. The subclavian route is probably a better choice for long-term lines in ambulatory patients, as for hemodialysis. The limited neck mobility due to an internal jugular line is very uncomfortable. Ongoing or impending thrombolytic administration is a relative contraindication to internal jugular puncture. A femoral central venous line is preferable in this case. Successful internal jugular cannulation requires the patient to be placed supine and preferably in 15° to 30° of Trendelenburg tilt. This may be impossible in a patient with severe pulmonary compromise. The femoral route is preferred in this case. Internal jugular vein cannulation is difficult in children under 1 year of age due to poor landmarks and a very short neck. Internal jugular cannulation is contraindicated in any child who cannot be adequately immobilized or paralyzed after insertion of the central venous line. Internal jugular cannulation will be more difficult if the patient's neck cannot be turned. However, the more rotation applied to the neck the greater the vascular overlap between the internal jugular vein and carotid artery. This will increase the risk of arterial puncture. Head rotation should be minimized if a blind technique is used. US guidance can minimize head rotation and free the Emergency Physician from the historical anatomic approaches. This allows for any needle approach to be used depending on the location of the internal jugular vein in relation to the carotid artery.

A left bundle branch block is a relative contraindication to central venous cannulation. The guidewire can induce complete heart block when it enters the right ventricle.[28] Extreme caution should be taken if an internal jugular or subclavian central

line is necessary. **Avoid inserting the guidewire into the heart.** Continuous cardiac monitoring should be used and transcutaneous and transvenous cardiac pacing equipment should be readily available.

SUBCLAVIAN VEIN CANNULATION

The subclavian vein is incompressible and should be accessed with care in any patient who is coagulopathic. Current or imminent systemic thrombolysis is an absolute contraindication to placing a subclavian vein catheter.[6] Subclavian vein cannulation should be performed on the contralateral side if the patient is relying on a single lung. Chest wall deformities, distorted anatomy, and suspected vascular injury to the chest or ipsilateral upper extremity are also contraindications. This route should also be avoided if the patient has had prior surgery or trauma to the clavicle, the first two ribs, or the subclavian vessels. Do not cannulate the ipsilateral subclavian vein if the patient has an implanted pacemaker or defibrillator. Central venous access can result in needle injury to the leads, lead displacement, and thromboembolism.

AXILLARY VEIN CANNULATION

US-guided axillary vein cannulation can be difficult for the Emergency Physician inexperienced in accessing this vein. Use the axillary vein as an access point only when other central veins are not accessible or contraindicated, and the Emergency Physician is comfortable with the procedure of US-guided vascular access. The depth of the axillary vein, commonly >3 cm, makes access difficult in patients who are not thin. The close proximity of the brachial plexus can result in significant injury if the needle penetrates it. The length of the catheter may be too short to reach the superior vena cava if placed in the left axillary vein.

FEMORAL VEIN CANNULATION

Contraindications to femoral line placement include infection, venous thrombosis, or significant trauma to the ipsilateral lower extremity or groin area. Abdominal trauma may result in an interruption of the inferior vena cava, allowing any infused fluid or blood to flow into the abdomen rather than into the central circulation. During CPR, blood return below the diaphragm is reduced and a femoral catheter must end near the level of the diaphragm for medications to be most effective.

Catheterization via the internal jugular vein or subclavian vein is usually easier if the purpose of central venous access is pulmonary artery catheterization or transvenous cardiac pacing. These procedures often require fluoroscopy when they are performed through the femoral vein. Central venous pressures measured through a femoral vein catheter may be inaccurate unless the patient is perfectly supine.

EQUIPMENT

- Sterile gloves and gown
- Face mask and cap
- Povidone iodine or chlorhexidine solution
- Sterile drapes or towels
- Local anesthetic solution
- 25 gauge needle
- 5 mL syringes
- "Finder" needle, usually 22 gauge for an adult
- 5 mL syringe with a nonlocking hub
- Thin-walled introducer needle or catheter-over-the-needle
- Guidewire
- Gauze 4 × 4 squares
- Central venous line
- Dilator
- #11 scalpel blade
- Nylon or silk suture, 3-0 or 4-0
- Sterile saline
- Needle driver
- Tape and catheter site dressing material
- Catheter clamp, if supplied with the kit

A variety of standard kits are commercially available (**Figure 49-9**). They contain all required equipment except local anesthetic solution and sterile gloves. The appropriate catheter should be chosen based on the patient's needs. The optimal catheter lengths for patients of different ages are summarized in **Table 49-3**.

Catheters with between one and four lumens are available. Multiple-lumen catheters are available in a variety of sizes and allow simultaneous venous pressure measurement, administration of numerous medications, and venous sampling without disconnecting the infusion apparatus. Disadvantages of multiple-lumen catheters over single-lumen catheters include smaller lumen sizes for a given catheter's outside diameter, greater cost, and the need to maintain unused lumens to prevent them becoming thrombosed. There is probably no increased risk of infection in using triple-lumen versus single-lumen catheters.[29–31] Some comparisons between these devices are summarized in **Table 49-4**.

Percutaneous sheaths are intended primarily for the introduction of intravascular devices, such as pulmonary artery catheters and transvenous pacing wires. They are most often used in the Emergency Department as a large-bore line for the rapid resuscitation of hypotensive and hypovolemic patients. Sheaths are available in many sizes and configurations. Many models have an adjustable hemostasis valve that may be removed and a side port that allows infusion while the main lumen is being used for monitoring.

The equipment required for subclavian vein cannulation is the same as that for internal jugular vein cannulation. Subclavian vein catheters must be slightly longer or inserted farther than internal jugular vein catheters. Left-sided catheters must be a few centimeters longer or inserted farther than right-sided catheters. The longer needle should be used for subclavian vein cannulation if the kit used has two different lengths of introducer needles.

PATIENT PREPARATION

Explain the procedure, its risks, and its benefits to the patient and/or their representative. Obtain an informed consent for the procedure unless it is being performed emergently. Place the patient in the Trendelenburg position if catheterization of the internal jugular vein is being attempted. Position the patient in at least 15° of Trendelenburg to prevent an air embolism. Slightly rotate the patient's head toward the side opposite that to be cannulated. A large degree of head rotation has been show to increase the overlap between the internal jugular vein and carotid artery, theoretically increasing the risk of carotid artery puncture.[32]

The subclavian vein is fixed to the surrounding tissues and will neither collapse nor distend. Therefore, the Valsalva maneuver or the extreme Trendelenburg position is not necessary. Head rotation is neither necessary nor helpful. Slightly abduct the patient's arm on the side to be cannulated. Avoid placing rolled towels between



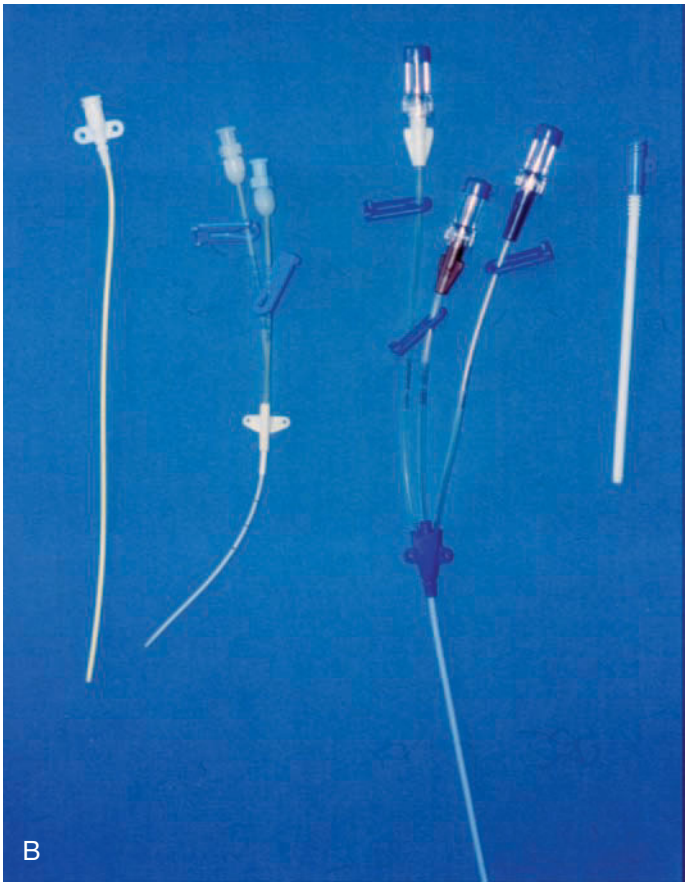


FIGURE 49-9. Equipment needed for central venous catheterization. **A.** A commercially available central venous line kit. **B.** Examples of different catheter types available. From left to right: single-lumen, double-lumen, triple-lumen, and introducer sheath (Cordis).

TABLE 49-3 Catheter Sizes, Types, and Characteristics

Catheter size (French)	Number of lumens	Patient size	Venous access site	Minimum catheter length (cm)*
2	1	Infant	Femoral, internal jugular, external jugular, or subclavian	5
3	1	<5 kg	Femoral, internal jugular, external jugular, or subclavian	5
4	1, 2	5–10 kg	Femoral	5
		10–15 kg	Femoral, internal jugular, external jugular, or subclavian	8–12
5	1, 2, 3	>15 kg	Femoral, internal jugular, external jugular, or subclavian	12–25
7	1 (sheath), 2, 3	>40 kg	Femoral, internal jugular, external jugular, or subclavian	15–25
8 and larger	1 (sheath), 2, 3, 4	Adult	Femoral, internal jugular, or subclavian	15–25

*The longer end of the catheter length range is for use in the subclavian veins, with the longest catheters needed for the left subclavian vein.

TABLE 49-4 Comparisons Between Central Venous Catheter Types

	Single-lumen	Multiple-lumen	Sheath (Cordis)
Minimum outer diameter	Smallest	Intermediate	Largest
Infusion rate	Moderate	Lowest (resuscitation catheters with larger lumen available)	Fastest (for central lumen; side port is slower)
Simultaneous infusions, or infusion while monitoring	No	Yes	Yes, if central lumen and side port both used
Length	Varies, fairly long	Long	Short
Allows device insertion (pulmonary artery lines and transvenous pacemakers)	No	No	Yes

the shoulder blades as this can decrease the distance between the clavicle and first rib, compress the subclavian vein, and make the procedure more difficult.[33]

Place the patient supine or in slight reverse Trendelenburg if femoral vein catheterization is being attempted. The reverse Trendelenburg position will increase the cross-sectional area of the femoral vein.[34] The Trendelenburg position is contraindicated due to the risk of venous air embolism. Slight external rotation and abduction of the extremity may increase the amount of femoral vein accessible for cannulation.[35] It is easier for a right-handed Emergency Physician to perform the procedure standing on the patient's right side, regardless of which femoral vein is being accessed. The opposite is true for those that are left-handed.

Identify the anatomic landmarks for the procedure after positioning the patient. Clean any dirt and debris from the area of the puncture site. Apply povidone iodine or chlorhexidine solution and allow it to dry.[36] **It is recommended to prepare the entire neck and clavicular area if the internal jugular or subclavian routes are attempted so that, if access to one site is unsuccessful, another site may be accessed without re-prepping and draping. Due to the risk of inducing a pneumothorax, attempts at contralateral internal jugular or subclavian vein cannulation after an unsuccessful attempt must be delayed until a chest radiograph is checked to prevent bilateral pneumothoraces.**

Infiltrate the subcutaneous tissues at the needle puncture site with a generous volume of local anesthetic solution, including any areas that will be used for suturing the catheter in place. This allows the local anesthetic to diffuse throughout the area and take effect before the main procedure begins. Any distortion of anatomic landmarks caused by anesthetic infiltration decreases as the anesthetic is absorbed into the subcutaneous tissues.

Apply electrocardiographic monitoring, pulse oximetry, and noninvasive blood pressure monitoring to the patient and administer supplemental oxygen. Electrocardiographic monitoring during insertion of a central line is recommended due to the risk of ventricular dysrhythmias should the guidewire or catheter enter the right ventricle. It is preferable to have a designated person—physician or nurse—whose only job is to watch the monitoring equipment. The patient's face and chest will be draped for the internal jugular or subclavian vein cannulation procedure. The Emergency Physician will be focused on the procedure and unaware of any sudden patient deterioration, ventilator disconnect, or other irregularities. Resuscitation equipment should be immediately available. A postinsertion chest radiograph to verify line placement and the lack of a pneumothorax must be immediately available.

Prepare for the procedure. Apply sterile gloves, a sterile gown, and a face mask. Some Emergency Physicians prefer to double-glove. If one glove becomes contaminated, it can be discarded and the procedure continued without interruption. Open the desired venous access kit using aseptic technique on a bedside table. Perform a quick inventory and identify all necessary equipment before beginning the procedure. Set up a sterile field next to the patient and within easy reach. Place the equipment that must be immediately at hand on the sterile field. This includes a sterile drape, syringe, large-bore hollow needle, guidewire, and gauze squares. Any other equipment, including the catheter itself, may be temporarily left in the kit. **Never use the patient as a table.** If they move, everything can fall onto the floor. A needlestick injury can occur from the falling needles or if the instinct to grab the falling equipment occurs.

INTERNAL JUGULAR VEIN CATHETERIZATION TECHNIQUES

CENTRAL APPROACH TO THE INTERNAL JUGULAR VEIN

While an internal jugular vein cannula can be inserted using the over-the-needle and through-the-needle techniques, the Seldinger technique is often preferred.[37,38] See Chapter 47 and **Table 49-5** for a more complete discussion. The Seldinger technique uses a flexible guidewire, inserted through a special thin-walled hollow needle, to guide a catheter of any desired length through the skin and into the central circulation. This technique is described below and summarized in **Table 49-6**.

Clean, prep, and drape the area as described previously. Place the patient in the Trendelenburg position with their head down 15° to 30°. Slightly rotate the patient's head away from the side that will be cannulated. Excessive rotation will distort the anatomic landmarks and may bring the internal jugular vein closer to the carotid artery.

Several cardinal rules for the insertion of the catheter should be observed. Always occlude the open hub of a needle or catheter in a central vein to prevent an air embolism. Never let go of the guidewire, so as to prevent its embolization into the central venous circulation. Never apply excessive force to the guidewire on insertion or removal. Doing so may injure the vessel, break the guidewire, and/or embolize the guidewire.

Attach the thin-walled introducer needle to a 5 mL syringe containing 1 mL of sterile saline or local anesthetic solution. The specially designed introducer needle included with the catheter should be used, as it has a relatively thin wall and a larger internal diameter relative to its external diameter. It has a shorter bevel than a conventional hypodermic needle. It also has a tapered hub to guide the guidewire into the needle proper.

If there is doubt about the exact location of the vein, it may first be located with a small "finder" needle. Insert a 25 or 27 gauge needle attached to a 5 mL syringe through the skin puncture site previously chosen. Advance the needle at a 30° to 60° angle to the skin while applying negative pressure to the syringe. A flash of blood signifies that the tip of the needle is within the vein. Note the depth and location of the vein. Remove the finder needle. Alternatively, the finder needle may be left in place for reference.

Insert the introducer needle at a 30° to 60° angle at the apex of the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle and the clavicle (**Figure 49-4**). This point is just lateral to the carotid artery pulse. Direct the introducer needle

TABLE 49-5 Comparison of Central Venous Catheterization Methods

	Seldinger	Catheter-over-the-needle	Catheter-through-the-needle
Insertion needle	Small	Large	Largest
Speed	Slowest	Fastest	Fast
Number of steps	4+	1	2
Risk of catheter shear	None	Low	Highest
Catheters and lumens available	Single- or multiple-lumen, sheath/introducer	Single-lumen only	Single-lumen only
Rate of infusion	Highest (with sheath)	Moderate	Low to moderate

TABLE 49-6 Summary of the Seldinger Method of Central Venous Cannulation*

Step	Action	Tips and caveats
1	Prep and drape the skin puncture site.	For internal jugular vein, prepping down to the clavicle and up to the jaw will enable an attempt at the ipsilateral subclavian vein (or vice versa).
2	Anesthetize the puncture site if not already done.	Anesthetize the suture sites also.
3	Uncap the distal lumen.	Additional lumens may be flushed at this point or after insertion, as desired.
4	Locate the vein using the finder needle and aspirating syringe.	Internal jugular vein should be reached within 3 cm. Stop advancing after 4–5 cm if the vein is not located.
5	Remove the finder needle, noting the direction and depth of the internal jugular vein. Or withdraw the needle slightly so it is outside the internal jugular vein and leave it in place as a guide	A few drops or a line of blood may be left on the skin as the finder is withdrawn to show the proper direction.
6	Insert introducer needle on a syringe along the "finder's" path until venous blood is aspirated. Alternatively, an introducer catheter and needle assembly can be used to cannulate the internal jugular vein; the needle is then withdrawn.	Syringe must have a nonlocking hub. A little saline in the syringe allows any occluding skin plug to be ejected. The vein is often located on withdrawal of the needle, since the friction of the large needle in the tissues can compress the internal jugular vein.
7	Disconnect the syringe from the needle, immediately occluding the open needle hub to prevent air embolism.	Do not move the needle at all! Keep the hand holding the needle in contact with the patient's skin to prevent movement.
8	Insert the guidewire through the introducer needle and into the vein.	Do not move the needle! Do not force the guidewire—it should pass easily!
9	Advance the guidewire into the vein to the desired depth or until ventricular ectopy is seen on the ECG monitor.	The guidewire must be securely in the vein, not just in the subcutaneous tissue.
10	Withdraw the introducer needle a few millimeters and use the scalpel to enlarge the puncture site slightly.	Keeping the needle in place eliminates any possibility of cutting the guidewire.
11	Remove the introducer needle.	Never let go of the guidewire!
12	Thread the dilator over the guidewire until it can be grasped outside the hub, then insert and withdraw the dilator.	Always keep a firm grip on the guidewire!
13	Thread the catheter tip over the guidewire and withdraw the guidewire from the skin until it can be grasped at the infusion hub.	Never let go of the guidewire.
14	Insert the catheter to the desired depth; most catheters are marked in centimeters, with larger markings every 5 and 10 cm. Introducer sheaths should be inserted completely.	The tip of the catheter should be in the superior vena cava, at the level of the manubriosternal angle.
15	Holding the catheter in place, remove the guidewire. Occlude the open hub with a gloved finger to prevent air embolism.	Do not apply excessive force to the guidewire. If it is trapped, withdraw the catheter a few centimeters and try again. Do not break the wire!
16	Attach a syringe to the catheter hub and aspirate blood, taking samples as desired; then flush the lumen with saline and begin the desired venous infusion.	Other lumens may be aspirated, flushed, and clamped.
17	Verify intravenous placement before suturing the catheter in place	If the patient's blood travels up the intravenous tubing, the catheter is in the carotid artery!
18	Remove the patient from the Trendelenburg position.	
19	Suture the catheter to the skin with sutures and tape.	Take care not to puncture the catheter or to occlude it with a tight suture
20	Apply a dressing to the catheter site.	
21	Verify catheter tip position by chest X-ray.	Catheter tip must be in the superior vena cava, not in the right atrium. Tip should be above the azygos vein and the carina, with the tip parallel to the vessel wall.

*The central approach to the internal jugular vein is used as an example, although the same technique is used for other approaches and central veins.

toward the ipsilateral nipple. Shallower angles make it necessary to traverse a greater amount of subcutaneous tissues and structures before entering the vessel. Steeper angles make insertion of the catheter over the guidewire difficult, as the guidewire tends to kink. Shallower angles are generally necessary in children whose vessels are smaller. Inject a small amount of the fluid in the syringe to remove any skin plug that may block blood return once the vein has been penetrated.

Apply negative pressure to the syringe by withdrawing the plunger. Advance the introducer needle into the vein (**Figure 49-10A**). If the vein is not located within 3 to 5 cm of the skin—this distance will vary depending on the patient's size and the target vessel's location—stop advancing the introducer needle. Withdraw the needle slowly while continuing to aspirate. Often, the vessel will have been completely traversed and no blood will return due to collapse of the vein by the pressure of the skin being forced inward as the introducer needle passes through it. Under normal physiologic conditions, veins have very low pressures within them and are easily collapsed by external pressure. If no blood is aspirated while withdrawing the needle, withdraw the introducer needle to the subcutaneous plane and redirect it slightly medially. Avoid putting continuous pressure on the carotid artery pulse, as even gentle pressure may collapse the internal jugular vein (**Figure 49-3B**).

Stabilize and hold the introducer needle perfectly still with the nondominant hand once blood returns in the syringe. The carotid artery has been entered if the blood is bright red and/or forces

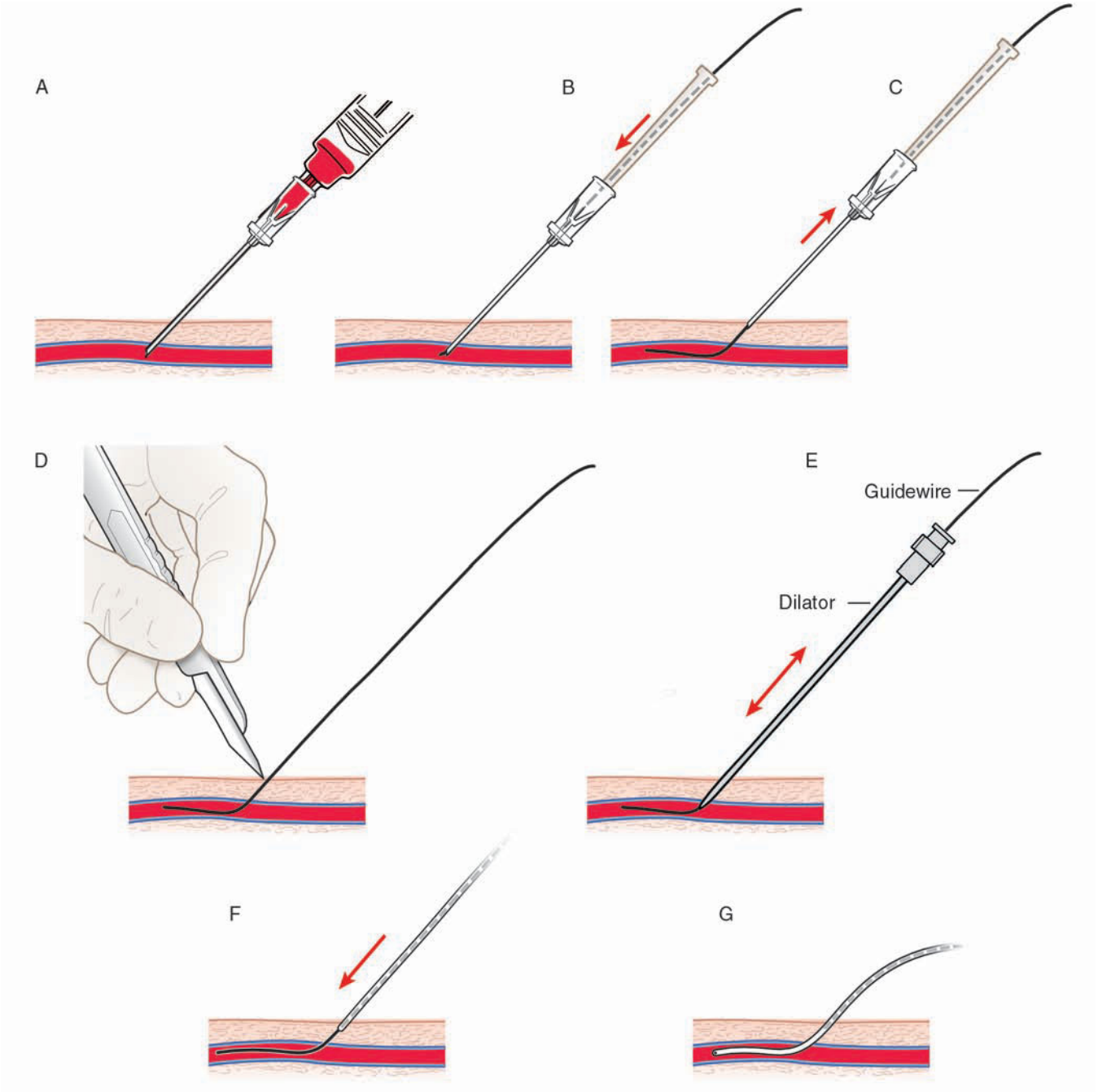


FIGURE 49-10. The Seldinger technique. **A.** The vein is punctured by the introducer needle and blood is aspirated. **B.** The syringe has been removed. The guidewire is inserted through the introducer needle and into the vein. **C.** The introducer needle and guidewire sleeve are withdrawn over the guidewire. **D.** The skin puncture site is enlarged. **E.** The dilator is advanced over the guidewire until the hub is against the skin; then it is removed. **F.** The catheter is advanced over the guidewire and into the vein. **G.** The guidewire is withdrawn through the catheter.

the plunger of the syringe back. Remove the syringe. Blood should flow slowly and freely from the hub of the needle. The introducer needle is in the carotid or subclavian artery if blood squirts out the introducer needle hub. If blood dribbles out or does not flow from the hub and the patient has spontaneous circulation, reattach the syringe and reposition the introducer needle until free flow is obtained. Occlude the open hub of the introducer needle with the thumb of the nondominant hand while keeping the small finger of the hand in contact with the patient's skin. The Emergency Physicians proprioceptive reflexes will prevent movement of the introducer needle by maintaining contact with the patient's skin. Even a millimeter of movement may result in failure of the needle tip to stay within the lumen of the vein.

Prepare the guidewire (**Figure 49-11**). Grasp the guidewire and its sleeve with the dominant hand. The tip of the guidewire has a "J" shape when the sleeve is retracted (**Figure 49-11A**). Slide the sleeve forward to straighten out the "J" of the guidewire (**Figure 49-11B**). Insert the wire sleeve into the hub of the introducer needle (**Figures 49-10B & 49-11C**). Advance the guidewire through the sleeve and into the introducer needle. **Never let go of the guidewire! One end of the wire must always be held to prevent loss of the wire and embolization into the central circulation.**

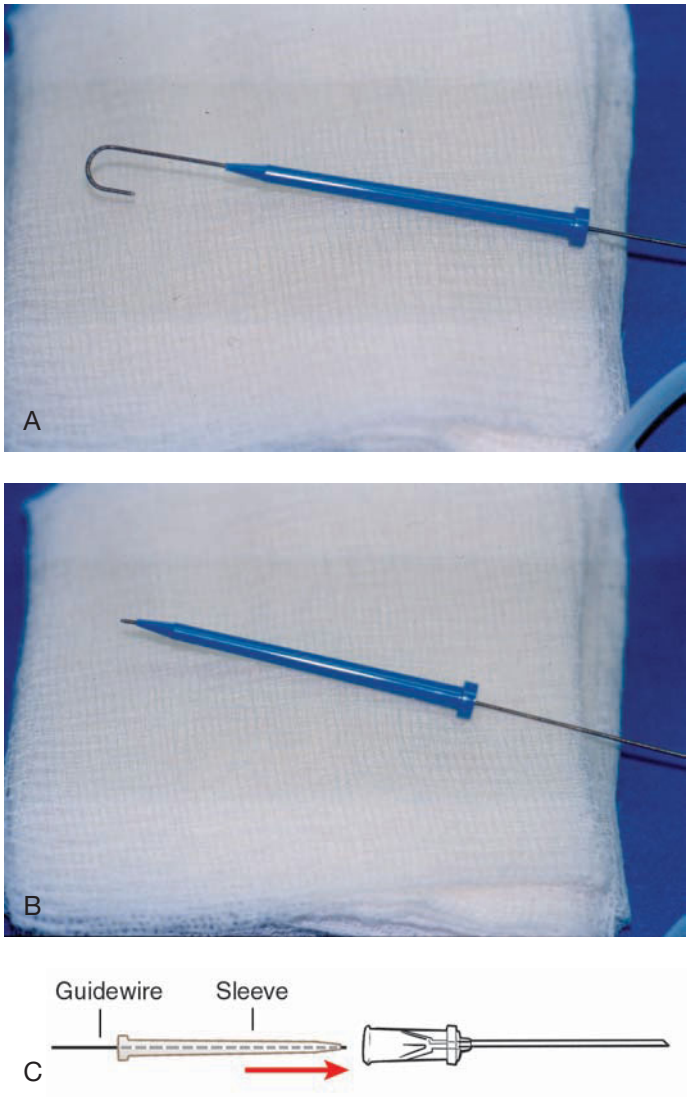


FIGURE 49-11. Guidewire preparation. **A.** The plastic sleeve is retracted, showing the "J" tip. **B.** The plastic sleeve is advanced to cover the guidewire tip, allowing the wire to be threaded into the introducer needle. **C.** The sleeve is inserted into the hub of the introducer needle.

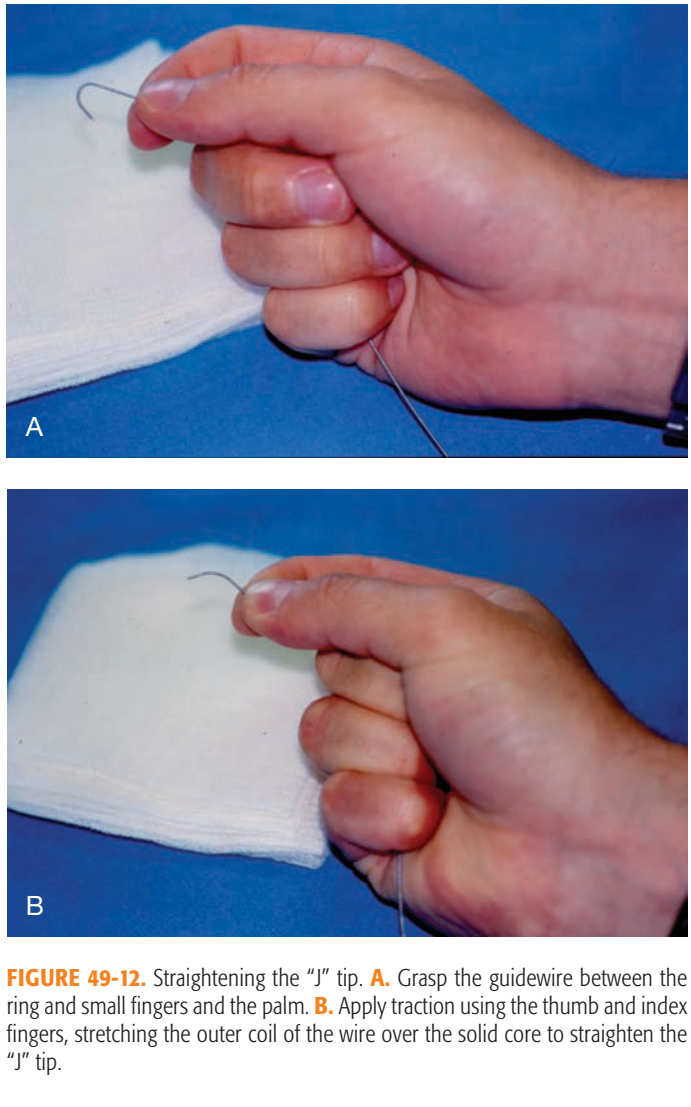


FIGURE 49-12. Straightening the "J" tip. **A.** Grasp the guidewire between the ring and small fingers and the palm. **B.** Apply traction using the thumb and index fingers, stretching the outer coil of the wire over the solid core to straighten the "J" tip.

Do not simply reverse the guidewire if the sleeve used to straighten the curved end of the guidewire is lost. The straight end of the guidewire can puncture the wall of the vein. Grasp the guidewire between the fourth and fifth fingers and the palm of the dominant hand (**Figure 49-12A**). Apply gentle traction on the curved guidewire tip with the thumb and the second and third fingers in order to straighten the guidewire (**Figure 49-12B**). The guidewire can then be inserted into the introducer needle hub without the use of the sleeve.

Advance the guidewire through the introducer needle and into the vein (**Figure 49-10B**). The guidewire should advance easily into the vein. **Never force the guidewire.** Guidewire resistance may indicate that the introducer needle is not within the vein, is against the wall of a vessel, or is caught as the vessel bends. Slightly withdraw the guidewire, rotate it slightly, and readvance it. **The use of force will kink the guidewire and may cause it to damage the vein and adjoining tissues.** Advance the guidewire 5 to 10 cm into the vessel or until ectopic beats are seen on the cardiac monitor. Withdraw the introducer needle and guidewire sheath while securely holding the guidewire (**Figure 49-10C**). Grasp the guidewire with the nondominant hand as soon as the guidewire is visible between the tip of the introducer needle and the skin. Finish removing the needle over the guidewire.

Make a small incision in the skin adjacent to the guidewire using a #11 scalpel blade (**Figure 49-10D**). Place the dilator over the straight end of the guidewire (**Figure 49-10E**). Advance the dilator over the guidewire, through the skin, and into the vein. A slight twisting motion of the dilator as it is advanced may aid in its insertion. Continue to advance the dilator until its hub is against the skin. **Do not release hold of the guidewire at any time.** Remove the dilator over the guidewire.

Place the catheter tip over the guidewire. Advance the catheter over the guidewire and into the vein to the desired depth (**Figure 49-10F**). **Do not release hold of the guidewire.** Gently rolling or twisting the catheter between the thumb and the forefinger may aid in its advancement. Hold the catheter securely in place and remove the guidewire (**Figure 49-10G**). Occlude the open catheter lumen with a sterile-gloved finger to prevent an air embolization and excessive blood loss.

Attach a syringe to the catheter hub and aspirate blood to confirm that the catheter is within the vein. Withdraw any necessary blood samples from the catheter. Attach infusion tubing or a heparin lock to the port and flush the catheter to prevent a blood clot from obstructing the lumen. If a multilumen catheter is inserted, flush any other lumens after first withdrawing any air (**Figure 49-13**).

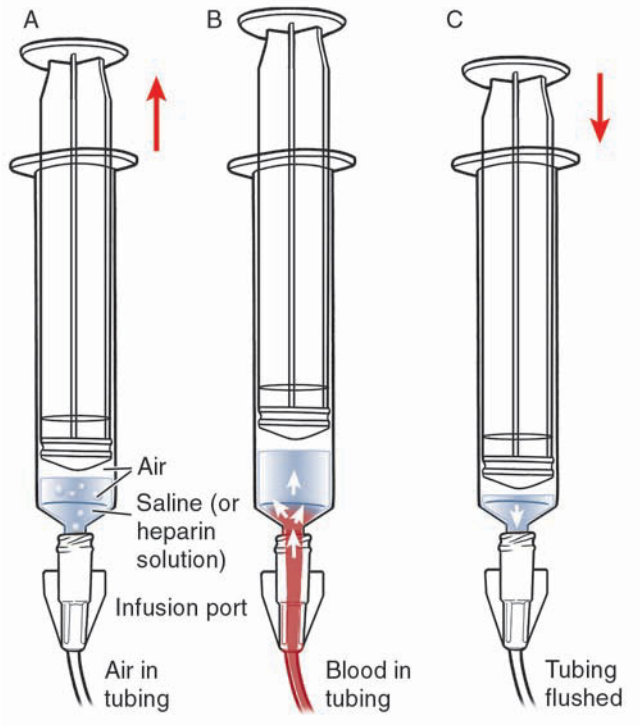


FIGURE 49-13. Aspiration and flushing of catheters. **A.** Any air in the lumen of the tubing is aspirated into the syringe of flush solution. The syringe must be held upright, as shown. **B.** Stop aspirating once all the air is removed from the catheter and blood begins to enter the syringe. **C.** Flush solution is injected until the lumen is filled and contains no blood. This usually requires 2 to 4 mL of flush solution.

Securely attach the catheter to the skin with nylon or silk sutures. Cover the skin puncture site with a sterile dressing.

ANTERIOR APPROACH TO THE INTERNAL JUGULAR VEIN

The skin puncture site is at the anterior border of the sternal head of the sternocleidomastoid muscle, just lateral to the carotid artery and at the level of the cricoid cartilage (**Figure 49-5**). Enter the skin at a 45° to 60° angle. Direct the introducer needle toward the ipsilateral nipple. The internal jugular vein in an adult should be encountered within 3 to 5 cm. If the vein is not encountered by 5 cm, withdraw the tip of the introducer needle to the subcutaneous space and redirect it slightly medially. The remainder of the procedure is as described for the central approach above and in **Table 49-6**.

POSTERIOR APPROACH TO THE INTERNAL JUGULAR VEIN

Enter the skin at the posterior edge of the sternocleidomastoid muscle, one-third of the way from the clavicle to the mastoid process (**Figure 49-6**). Alternatively, the point where the external jugular vein crosses the lateral border of the sternocleidomastoid muscle can be used. Direct the introducer needle under the sternocleidomastoid muscle at a 30° to 45° angle to the skin and toward the sternal notch. Place the index finger of the nondominant hand in the sternal notch to provide a landmark with the patient draped. In an adult, the internal jugular vein should be encountered within 5 cm. This approach is not recommended in children. The remainder of the procedure is as described for the central approach above and in **Table 49-6**.

TABLE 49-7 Comparison of Subclavian Vein Cannulation Routes

	Infraclavicular approach	Supraclavicular approach
Entry site	Just inferior to the clavicle at the midclavicular line	1 cm lateral to the clavicular head of the sternocleidomastoid muscle, 1 cm posterior to the clavicle
Needle orientation	Keep as close to the coronal plane as possible	Tip aimed 10° anterior to the coronal plane
Needle bevel and "J" wire directed	Medially and caudally	Medially
Aim toward	Just posterior to the sternal notch	Contralateral nipple, needle bisects angle formed by the clavicle and the clavicular head of the sternocleidomastoid muscle
Distance from skin to subclavian vein	3–4 cm	2–3 cm

SUBCLAVIAN VEIN CATHETERIZATION TECHNIQUES

The technique is identical to that described above for internal jugular vein cannulation except for the puncture site. Two techniques, infraclavicular and supraclavicular, are described below and summarized in **Table 49-7**.

INFRACLAVICULAR APPROACH TO THE SUBCLAVIAN VEIN

The infraclavicular approach to the subclavian vein is most often used. It is commonly thought to be easier to perform and less likely to result in a pneumothorax than the supraclavicular approach, although data for this belief are lacking.[39] Some Emergency Physicians prefer not to use a finder needle for infraclavicular subclavian vein cannulation as there is no danger of penetrating the carotid artery. This also makes as few needle passes near the pleura as possible in order to decrease the risk of an iatrogenic pneumothorax. Estimate the distance from the skin puncture site to the superior vena cava (i.e., the manubriosternal junction).

Several different skin entry sites are described in the literature. Some feel that the preferred entry site is 1 cm caudal to the junction of the medial and middle thirds of the clavicle. The subclavian vein lies just posterior to the clavicle at this site (**Figure 49-14**). The first rib lies between the pleural dome and the subclavian vein. Direct the introducer needle just superior and posterior to the suprasternal notch while staying as close to the frontal (coronal) plane as possible. The needle and syringe should be parallel to the bed (**Figure 49-14A**). Placing the nondominant index finger in the sternal notch will help to guide placement (**Figure 49-14A**).

Some Emergency Physicians prefer to enter the skin inferior to the clavicle at the deltopectoral groove, or the point just lateral to the midclavicular line along the inferior surface of the clavicle. This is the point where the skin may be maximally depressed. Direct the introducer needle parallel to the bed and toward the sternal notch. This entry site may make it easier to keep the introducer needle in the coronal plane. The distance before entering the subclavian vein is longer than in the preceding approach and the protection offered by the first rib is lost.

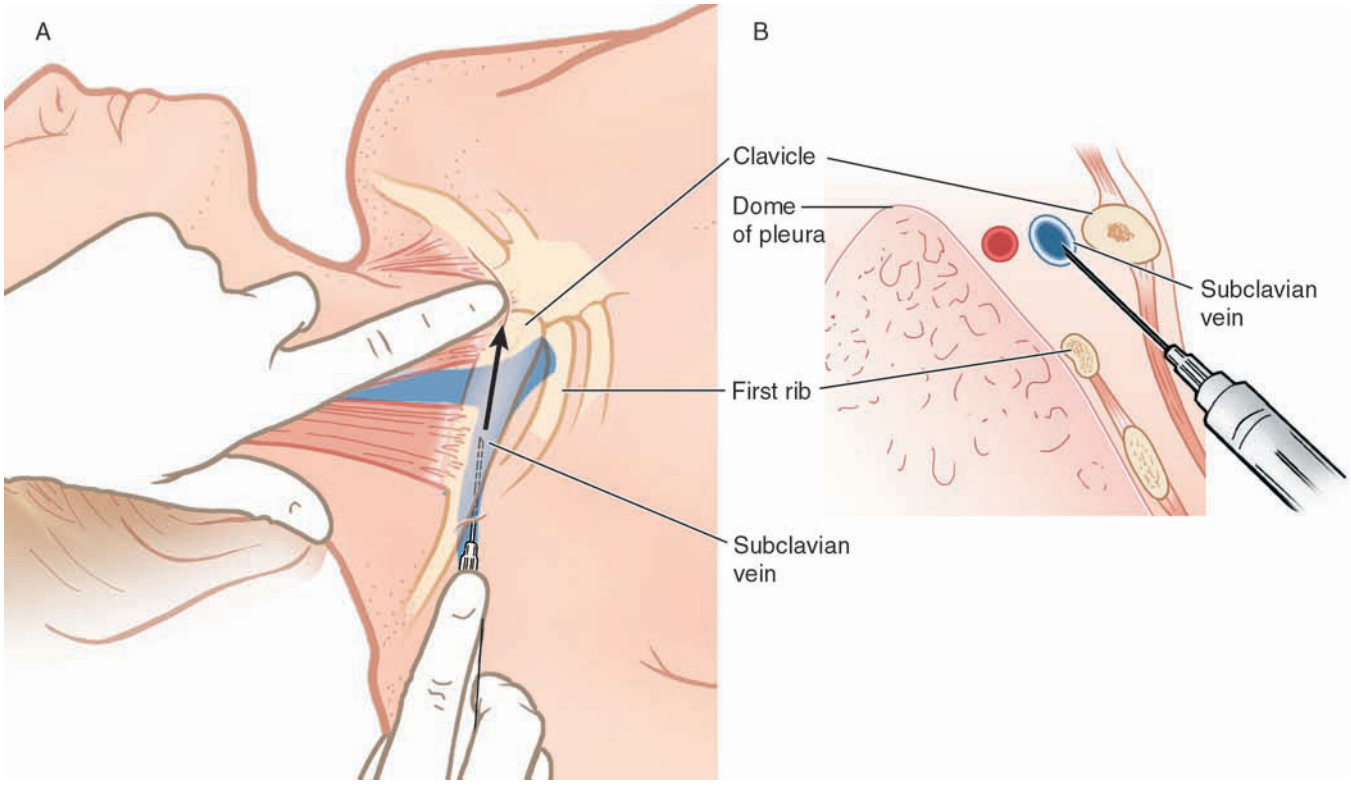


FIGURE 49-14. Infraclavicular approach to subclavian vein cannulation. **A.** Frontal (oblique) view of the procedure. **B.** Sagittal section through the medial third of the clavicle. Note the proximity of the pleura and subclavian artery.

One additional landmark can be used to identify the skin puncture site. Palpate the bony tubercle, or protrusion, on the inferior surface of the clavicle and approximately one-third to one-half the length of the clavicle from the sternoclavicular joint. The advantage of this site is that it is a definitive landmark and avoids approximating distances, as described for the other sites above. Insert the introducer needle parallel to the bed and aimed just posterior to the sternal notch.

The bevel of the introducer needle should be oriented caudally, as should the "J" in the guidewire (**Figure 49-15**). This position will allow the guidewire to enter the innominate vein and superior vena cava rather than being directed upward into the internal jugular vein or across to the contralateral subclavian vein (**Figure 49-15**). Once venous blood is aspirated, the Seldinger technique for catheter insertion is otherwise the same as previously described for internal jugular vein cannulation. Aspiration of bright red blood under pressure indicates subclavian artery puncture, which will be incompressible. Remove the introducer needle and observe the patient for signs of significant hemorrhage over the next several hours. Aspiration of air indicates penetration of the pleura. Observation with serial chest radiographs for at least the next 6 to 24 hours is essential to evaluate the size of the potential resulting pneumothorax.

SUPRACLAVICULAR APPROACH TO THE SUBCLAVIAN VEIN

While most Emergency Physicians are more comfortable with the infraclavicular approach to the subclavian vein, the supraclavicular approach offers some distinct advantages. The supraclavicular subclavian vein is closer to the skin. The route from a right-sided skin puncture site to the superior vena cava is more direct. It allows easier access to the superior vena cava while avoiding the hazards of a left-sided puncture (i.e., the thoracic duct). The skin entry site is

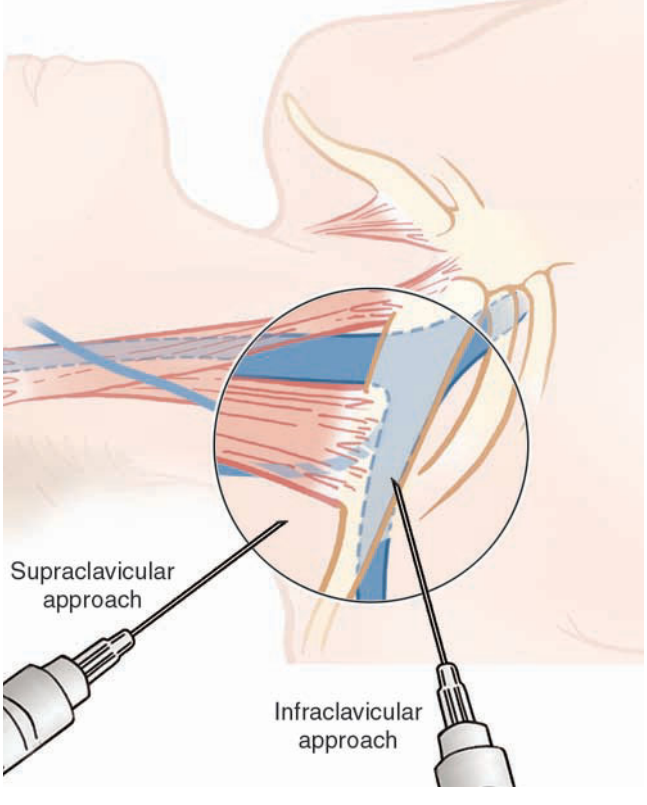


FIGURE 49-15. Introducer needle bevel orientation for subclavian vein cannulation. Varying the orientation of the introducer needle bevel for infraclavicular and supraclavicular techniques helps guide the "J" shaped guidewire into the superior vena cava.

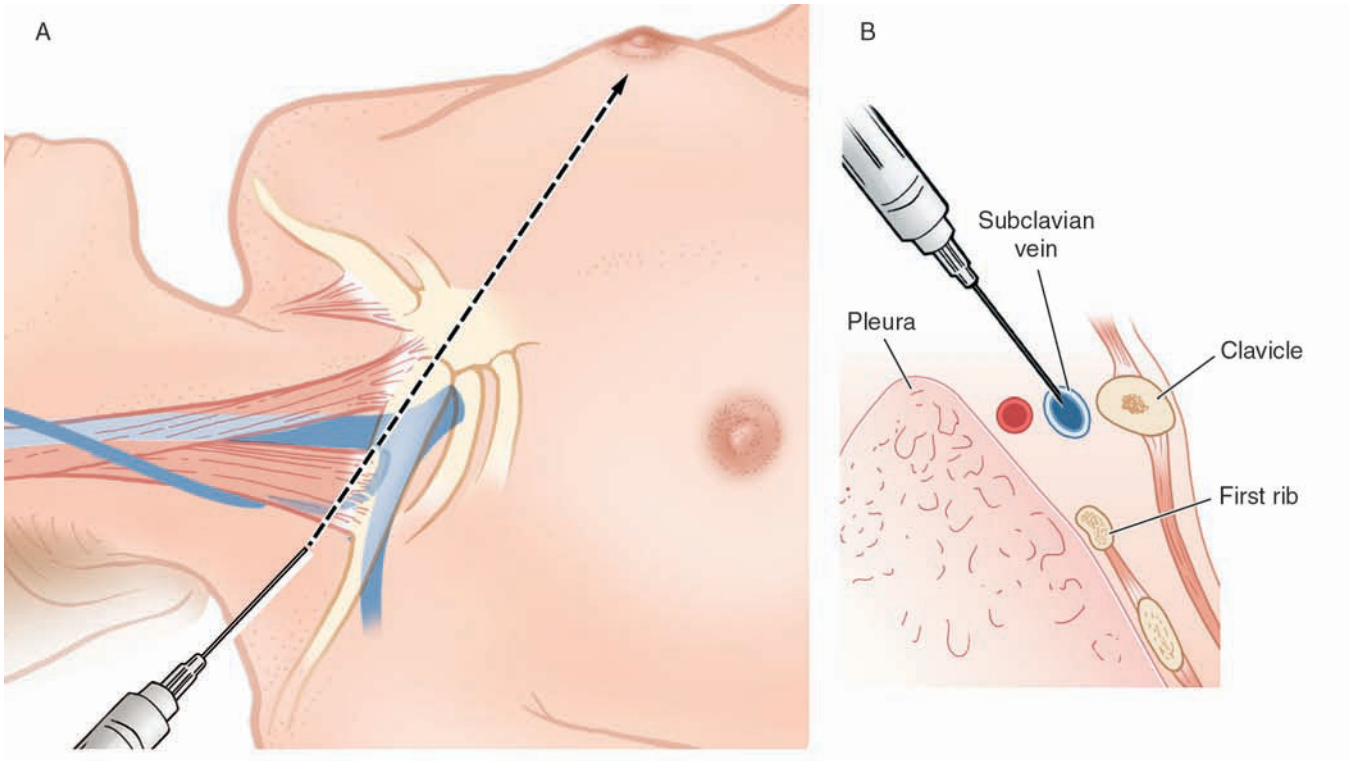


FIGURE 49-16. Supraclavicular approach to subclavian vein cannulation. **A.** From the insertion point 1 cm superior to the clavicle and 1 cm lateral to the border of the sternocleidomastoid muscle, direct the introducer needle tip at a 45° angle to the transverse and sagittal planes and slightly anterior toward the contralateral nipple. **B.** Sagittal section through the medial third of the clavicle. Note that the introducer needle track must be directed anteriorly to avoid the subclavian artery and the dome of the pleura.

more accessible during CPR and requires less interruption of external chest compressions.[40] With experience, the complication rate for the supraclavicular approach is probably lower than that for the infraclavicular approach.[39,41]

Estimate the distance from the skin puncture site to the superior vena cava to guide the catheter insertion depth. The skin is entered at a point 1 cm lateral to the lateral border of the clavicular head of the sternocleidomastoid muscle and 1 cm superior to the clavicle (**Figure 49-16**).[42] The introducer needle should bisect the angle formed by the clavicle and the lateral border of the sternocleidomastoid muscle (**Figure 49-16A**). Direct the introducer needle toward the contralateral nipple or a point just superior and posterior to the sternal notch. Orient the introducer needle bevel medially (**Figure 49-15**). The subclavian vein should be entered within 2 to 3 cm in an adult. The length of catheter inserted will be 2 to 4 cm less than that for the infraclavicular approach.

Alternative skin entry sites and approaches have been described. Enter the skin 1 cm medially and 1 cm superiorly to the midpoint of the clavicle with the introducer needle directed toward the ipsilateral sternoclavicular joint.[43] The skin can be entered just posterior to the clavicle, at the junction of the medial and middle third of the clavicle, with the introducer needle directed toward the ipsilateral sternoclavicular joint and parallel to the coronal plane.[44] This last approach is probably the simplest, although the study cited was performed on cadavers rather than live patients.

AXILLARY VEIN CATHETERIZATION TECHNIQUE

The axillary vein must be accessed using US guidance and not blindly using landmarks. Place the patient supine with their arm abducted in a comfortable position. A recent US study demonstrated no benefit of arm abduction in increasing axillary vein size or decreasing arteriovenous overlap.[16] Locate the axillary vein using a high frequency, 5 to 10 MHz, US probe. Place the US probe, with the marker pointing cephalad, just below the clavicle at approximately its middle third. Identify the axillary artery, axillary vein, and the pleura to obtain proper orientation. Manual compression and color flow Doppler can be used to differentiate between the vein and the artery. Follow the axillary vein laterally on the chest until overlap with the artery is minimized and the pleura is out of the view of the probe. Rotate the US probe into a parallel orientation in respect to the axillary vein with the probe marker toward you to obtain a long axis view of the axillary vein. Gently pivot the US probe in a cephalad and caudal direction to clearly differentiate the axillary vein from the axillary artery. Slight movements of the probe will alter the US image between the vein and artery. It is recommend to stabilize the US probe by resting your distal forearm and wrist against the anterior chest. Note the depth of the vein to ensure that the central venous catheter needle will be able to puncture the vessel. The remaining details of the technique are as described in Chapter 50 (US-Guided Vascular Access).

FEMORAL VEIN CATHETERIZATION TECHNIQUE

This technique is often performed blind using landmarks. It can also be performed under US guidance. The use of an ECG monitor is still recommended even though the short guidewire may not reach the heart. Particular care must be taken if the patient has a preexisting left bundle branch block, as complete heart block may result if the guidewire or catheter enters the right ventricle.[28] Premeasuring from the insertion site to the xiphoid process will give the maximum depth of catheter insertion.

The introducer needle should enter the skin 2 to 4 cm inferior to the midpoint of the inguinal ligament and 1 cm medial to the

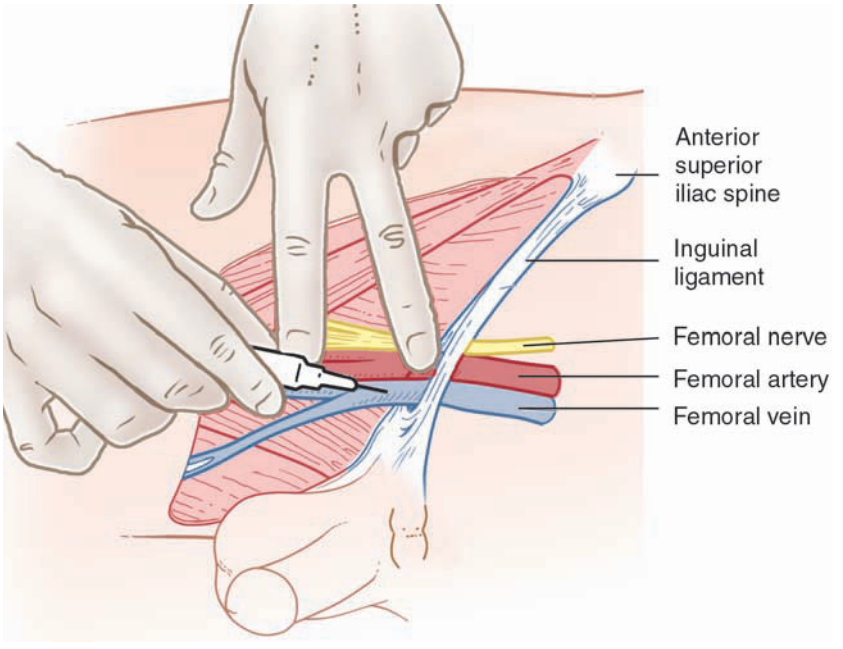


FIGURE 49-17. Femoral vein cannulation. The skin puncture site is 1 cm medial to the femoral artery pulse and 2 to 4 cm inferior to the inguinal ligament. Direct the introducer needle posteriorly at a 45° to 60° angle while aspirating.

femoral artery pulse (**Figure 49-17**). In an infant or young child, the introducer needle should enter the skin 1 to 2 cm inferior to the inguinal ligament and 0.5 cm medial to the femoral artery pulse. The cannulation technique is as described previously for the internal jugular vein.

Two site-specific considerations deserve mention. The use of a finder needle is unnecessary, since there are no vital structures in the area other than the femoral artery that is compressible if it is punctured. The introducer needle is directed at a 45° to 60° angle to the skin and parallel to the long axis of the thigh. Shallower angles may be necessary in very small and thin patients. **Use caution to avoid puncturing the posterior wall of the vein above the inguinal ligament, since this can result in a retroperitoneal hemorrhage.**

ALTERNATIVE TECHNIQUES

USE OF THE SELDINGER-HUB INTRODUCER CATHETER

Some central venous access kits include a catheter-over-the-needle with a tapered hub that can be used in place of the thin-walled introducer needle. This technique has the advantage of allowing the introducer catheter to remain in place while venous placement is verified. It provides less likelihood of the vein being lost as the aspiration syringe is removed and the guidewire advanced. A guidewire advanced through the introducer catheter cannot become sheared off, as when it is inserted through the needle.

The vein is entered with the catheter-over-the-needle assembly attached to an aspirating syringe, as described previously. Once the flashback of blood is obtained, advance the catheter-over-the-needle 2 mm further into the vein. This will ensure that the tip of the introducer catheter is within the vein. Hold the hub of the needle securely. Advance the catheter into the vein until its hub is against the skin. Withdraw the needle. If necessary, the introducer catheter may be attached to a pressure transducer and the venous waveform verified to confirm venous rather than arterial placement. Blood gas measurements may also be performed. Advance the guidewire through the introducer catheter and into the vein. The remainder of the procedure is as previously described.

MULTIPLE-LUMEN CATHETERS

Prior to skin puncture, remove the cap from the distal port's injection hub. It is usually marked "distal." The other lumens may be flushed with saline or heparin solution and recapped or left capped and flushed later (**Figure 49-13**). Heparin concentrations no higher than 100 U/mL should be used to avoid temporarily anticoagulating the patient.[45]

The introducer needle and guidewire are inserted as described previously. Place the multiple-lumen catheter tip over the guidewire. Advance the catheter until the guidewire emerges from the distal port hub (**Figure 49-18**). Insert the catheter to the desired depth. Remove the guidewire. Flush the distal lumen and connect it to the desired infusion. If not done previously, aspirate and flush the other lumens with the desired solution (**Figure 49-13**).

PERCUTANEOUS INTRODUCER SHEATH (CORDIS)

The insertion technique differs slightly from those described above (**Figure 49-19**). Locate the vein, insert the needle followed by the guidewire, and remove the needle leaving the guidewire in place as described previously. Insert the plastic dilator into the lumen of the sheath. The entire assembly must be advanced over the guidewire as a unit rather than utilizing separate dilation and insertion steps (**Figure 49-19C**). A correspondingly larger skin nick must be made with the scalpel, since the sheath is usually of larger diameter than a catheter. Advance the dilator–sheath unit over the guidewire (**Figure 49-19C**) and into the vein (**Figure 49-19D**). A twisting motion may aid in its advancement. Continue to advance the unit until the hub of the sheath is against the skin (**Figure 49-19E**). Remove the guidewire and dilator as a unit (**Figure 49-19E**). The remainder of the procedure is as described previously.

US-GUIDED CENTRAL VENOUS ACCESS

The use of bedside US to guide central venous access is becoming more common. The availability of US, its low cost, portable units, and training during residency are making its use standard procedure for central venous line placement. Please refer to Chapter 50 for the complete details of US-guided vascular access.

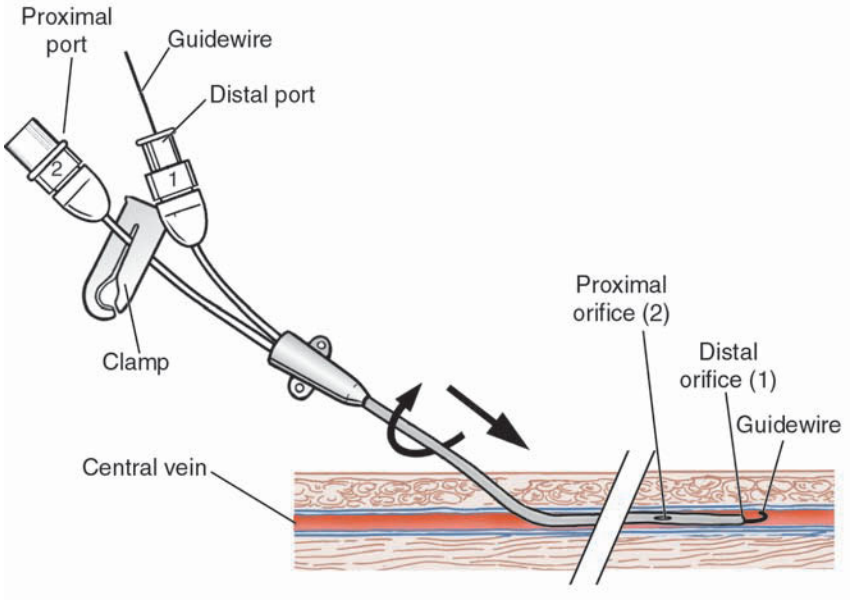


FIGURE 49-18. Inserting a multiple-lumen catheter. The guidewire exits through the uncapped distal port. The proximal port(s) must be clamped or capped to prevent air embolism.

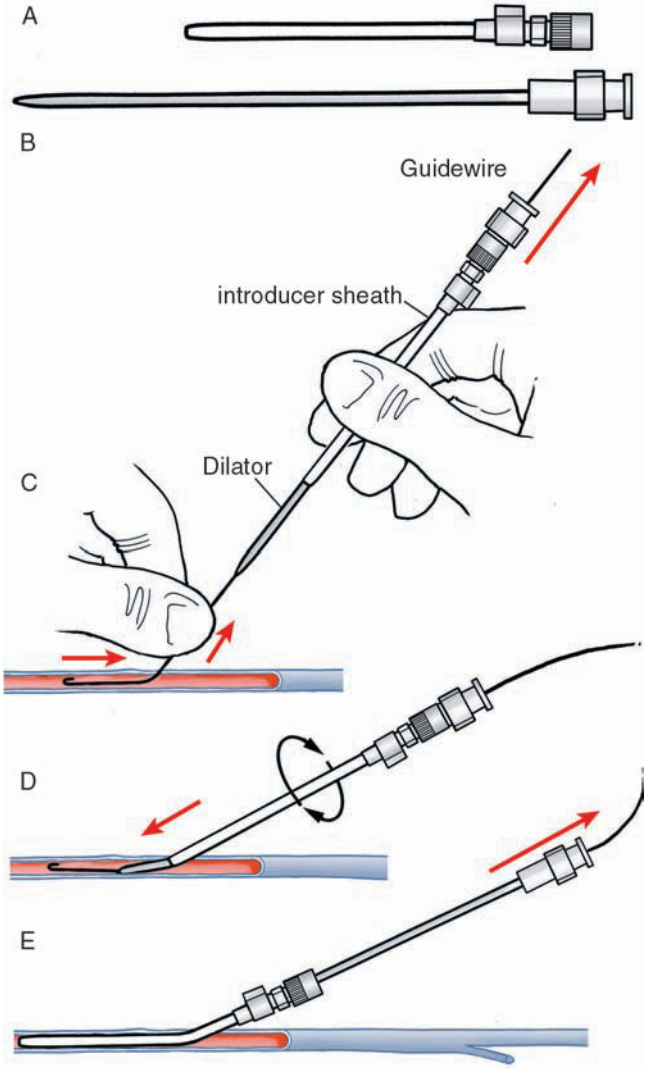


FIGURE 49-19. Inserting an introducer sheath. **A.** The sheath. **B.** The dilator. **C.** The dilator is inserted into the sheath and the unit is threaded over the guidewire. **D.** Advance the unit over the guidewire and into the vein using a twisting motion (*arrow*). **E.** The dilator and guidewire are removed as a unit, leaving the sheath in place.

PEDIATRIC CONSIDERATIONS

The anterior or central approach to the internal jugular vein is preferred for children. Appropriate catheter sizes and lengths are shown in **Table 49-3**. The child must be sedated and immobilized prior to attempts at cannulation of the internal jugular or subclavian vein. The femoral vein is the vein of choice if central venous access is needed in a combative child who cannot be completely restrained. The patient need not be in the Trendelenburg position, the consequences of a misdirected needle are less severe, and the procedure is less threatening as the face is not draped. A shallower angle of skin entry than in an adult is necessary to access the femoral vein. Enter the skin 1 to 2 cm inferior to the inguinal ligament and 0.5 mm medial to the femoral artery. Subclavian vein access in the small child can be difficult due to the anatomic relationships of the vessels as previously described. Despite this, the subclavian vein, in addition to the femoral vein, can be safely and effectively accessed in children less than 1 year of age.[46]

ASSESSMENT

Examine the patient. Examine the lung fields carefully to exclude a significant iatrogenic pneumothorax. Recheck the patient's vital signs frequently after the procedure. Obtain a portable anteroposterior chest radiograph to verify line tip placement in the superior vena cava and rule out an iatrogenic pneumothorax. Check the catheter site for hematoma formation or hemorrhage along the dilated catheter track. Control any hemorrhage with direct pressure.

US, if immediately available, can be used postinsertion to determine the presence or absence of an iatrogenic pneumothorax. Detection of an anterior pneumothorax in a supine patient has been shown to more sensitive using US than standard plain radiographs.[47,48] **The use of US does not negate the need to determine catheter location by plain radiographs.** US may be a useful tool when postline chest radiographs are delayed or the patient suddenly decompensates during or immediately after central line placement.

Check the function of the catheter by aspiration and infusion through all ports, as discussed above. A proximal lumen may be extravascular if it fails to aspirate blood easily. A catheter may be exchanged over a guidewire as long as the distal tip of the catheter is definitely intravascular. Do not attempt to advance the catheter once the guidewire has been removed.

Check the position of the catheter tip on the chest radiograph. The catheter must not be in the heart due to the risk that erosion through the thin right atrial wall will result in a pericardial hemorrhage and tamponade.[49,50] Landmarks for an internal jugular or subclavian vein catheter tip include the following: above the level of the carina, above the azygos vein, and at/above the manubriosternal junction. The tip of the catheter should be parallel to the vein to prevent erosion through the wall of the vein. If the catheter crosses over to the opposite subclavian vein and the patient cannot tolerate an attempt at repositioning, it may be used for intravenous infusion. Lines placed from the subclavian vein into the jugular system must be replaced. Catheters in or below the right atrium must be pulled back immediately to prevent any arrhythmias and perforation of the myocardium.

It is important to ensure that the catheter is within a vein and not an artery. This can be accomplished by US as described in Chapter 50. An arterial line monitoring setup can be attached to the catheter to measure intravascular pressures. This is time consuming, expensive, and takes some time to prepare. A device was recently approved by the FDA to assist in this evaluation. The Compass Vascular Access pressure measurement device (Mirador Biomedical, Seattle, WA) is a disposable, single patient use, digital manometer that attaches between the syringe and introducer needle. It provides a digital pressure measurement through the needle when it is within the blood vessel. It also provides pressure measurements while the guidewire is being inserted through the needle.

Most femoral vein catheters can be fully inserted. Premeasurement is recommended to make sure that the catheter tip will not reach the right atrium. If there is any doubt about the catheter position, postinsertion abdominal and chest radiographs should be obtained. The tip of the catheter must be at or below the xiphoid process of the sternum. Reassess the distal neurovascular status of the lower extremity after line placement.

AFTERCARE

The catheter must be sutured in place to prevent malpositioning of the line. Tie a surgeon's knot at the skin, then secure the suture to the hole(s) provided in the catheter wings. The straight needle contained within most central venous access kits can be difficult to use and it poses a needlestick risk. One option is to use nylon suture on a curved needle and a laceration repair kit. This requires additional equipment and at an additional cost. Another option is to use a needle cap or syringe contained within the kit to protect against the advancing straight needle puncturing your finger.[51,52] Use the cap to apply counter pressure against the skin as the straight needle tip exits the skin. A catheter clamp is often provided in the kit for longer catheters. It too should be sutured in place. The clamp holds the catheter in place by friction. It is not a guarantee that the catheter will not move. The catheter depth should be checked daily by inspection and by frequent chest radiographs. Movement of the patient's head and neck may move the tip of the internal jugular vein catheter by as much as 4 cm.[53]

Introducer sheaths have large lumens and present a significant risk of causing an air embolism. Cap the main lumen if it is not being used for an infusion. Any built-in diaphragm is not a reliable means of preventing an air embolism.[54] Do not use the dilator as an occluder or infusion port, as the stiff plastic can easily erode through the wall of the vein. An occlusive dressing can be used if no occluder is available.

The skin puncture site should be checked regularly for signs of infection. Cellulitis or purulent drainage requires a new central venous line at another site. Remember to restrain any patient who is uncooperative so as to prevent inadvertent removal of the central line.

While the short-term infection rate of femoral lines compares favorably with that in other central lines, some precautions are necessary to prevent soilage of the site.[20,55] Consider the judicious use of bladder catheterization in patients who are incontinent of urine and of rectal tubes in patients with loose stools. Patients with percutaneous femoral vein catheters must be confined to bed to prevent catheter dislodgment and hemorrhage around the catheter. Frequent assessment for venous thrombosis in the lower extremity is essential. It is recommended that femoral lines be discontinued when an alternative venous access site is available or within 3 days, whichever is sooner.[56]

REMOVAL OF THE CENTRAL VENOUS CATHETER

It has been, and sometimes still is, routine policy in some institutions to change all central venous lines placed in the Emergency Department when the patient arrives in the Intensive Care Unit. It was believed that these lines placed in the Emergency Department were "dirty" and at a higher risk of infection. This practice results in an additional procedure, the additional time and cost of the procedure, the associated discomfort or pain of the procedure, and the potential for complications. A recent study demonstrated that the infection rate of central venous lines placed in the Emergency Department using aseptic technique was no different than those placed in the Intensive Care Unit.[57]

When removing a central venous catheter from the internal jugular or subclavian vein, place the patient in the Trendelenburg position. To remove a femoral vein catheter, place the patient supine. Remove the dressing overlying the skin puncture site. Cut the suture securing the catheter to the skin. Ask the patient to exhale and hold their breath. Briskly remove the catheter and cover the puncture site with a gauze dressing. The track from the skin surface to the vein can be a source of a fatal venous air embolism.[58] If the catheter had a large diameter or remained in place for more than 2 to 3 days, apply an occlusive dressing to the site for the first 1 to 2 days after the catheter has been removed. The skin puncture site should be observed for signs of infection twice a day for 48 hours.

COMPLICATIONS

Mechanical complications can occur. The needle and/or guidewire may puncture the lateral or posterior wall of the vein.[59–62] This can result in a hematoma formation, arterial puncture, arterial cannulation, and an arteriovenous fistula. The use of US guidance does not prevent these complications.[59–61] The guidewire or catheter can break, fragment, or become knotted intravascularly. The guidewire can become a venous embolus if it completely enters the vein.

INTERNAL JUGULAR VEIN CATHETERIZATION

Internal jugular venous access has a myriad of potential complications.[49,63–66] Infection can be either at the local site or in a systemic line due to bacteremia and sepsis. A pneumothorax can occur during line placement. A hemothorax may be life-threatening, especially if a venopleural fistula is created. A chylothorax occurs if the thoracic duct is lacerated. Occasionally, carotid artery puncture can result. It may be complicated by a stroke if the blood supply to the brain is interrupted or if a plaque embolizes. Airway compromise can occur due to the formation of a hematoma and compression of the airway. An air embolism can occur if the catheter lumens are left open to the air during insertion or if connections loosen and separate at a later time. Right ventricular irritation from the catheter tip can cause cardiac dysrhythmias. Puncture of the right atrial wall can lead to pericardial tamponade and death. The guidewire can

become entrapped, necessitating surgical or interventional radiology removal. Embolization of the guidewire or catheter parts occurs with improper use of the equipment. Anaphylactic reactions to antibiotic-impregnated catheters have been reported. The cardiac monitors should be observed during the procedure to prevent the death of a critically ill patient from being unnoticed while the catheter is being inserted. Thrombosis of the catheter or vein may lead to pulmonary embolism.

Many of these complications can be prevented or minimized with the use of US guidance. Karakitsos et al. showed a statistically significant difference between the blind and US-guided techniques with regard to arterial puncture, hematoma formation, hemothorax, pneumothorax, and infection rate.[67] All of these were in favor of the US-guided study arm. Multiple smaller studies have shown similar results in favor of the US-guided technique.[2,68–72] There is no specific report of complication rates involving the thoracic duct, nerve injury, or thyroid injury. This is likely due to the extremely rare incidence of damage to these structures. **Overall, US guidance has been shown to significantly reduce complications and improve patient safety for internal jugular vein access.** Complications during catheterization occur in proportion to the operator's inexperience.[64] If the patient is unlikely to survive a mistake, the most experienced person available should perform the procedure!

SUBCLAVIAN VEIN CATHETERIZATION

Complications of subclavian vein cannulation are similar to those of internal jugular vein cannulation, as described above. While there is no risk of carotid artery injury if the procedure is performed correctly, the subclavian artery can be lacerated if the needle is advanced too deeply. Malposition of the catheter tip, usually due to overinsertion of the catheter, is common. Lacerations of the thoracic duct can be avoided by performing the procedure on the right side, avoiding overpenetration with the introducer needle, and avoiding directing the needle too superiorly toward the junction of the subclavian vein and internal jugular vein. Other complications, such as injury to the brachial plexus and phrenic nerve, are uncommon but possible.[73] They can be prevented by avoiding over-insertion of the needle during the procedure and avoiding needle paths superior and posterior to the subclavian vein.

A pneumothorax is a very real risk with subclavian vein catheterization. The procedure should not be performed unless personnel are immediately available who can deal with this complication.[74] The risk of a pneumothorax is probably higher in obese patients, who may have distorted anatomic landmarks and in whom a more acute angle is required to enter the subclavian vein. Patients with emphysema and COPD may have higher pleural domes and less pulmonary reserve in the event of a pneumothorax.

FEMORAL VEIN CATHETERIZATION

Deep venous thrombosis of the femoral and more distal veins is a recognized complication of femoral venous lines.[56] Inadvertent cannulation of the femoral artery may occur. This is particularly true during an episode of severe hypotension or cardiac arrest. If such an episode goes unrecognized, infusion of vasopressors into the artery may result in ischemic injury to the distal limb.

Even though US guidance for femoral vein cannulation does not currently have large studies with robust data in the literature, anatomical visualization can be useful in multiple situations. Recent research depicting the anatomical variation and overlap between the femoral artery and the femoral vein in normal patients brings to question the safety of blind or landmark based venous cannulation. In a stable patient with a palpable pulse, US guidance may aid in identifying a very small femoral vein and/or significant arteriovenous overlap. In either situation, correction with reverse Trendelenburg or proper leg positioning under US guidance may allow the Emergency Physician a better target for cannulation and reduce complications. During periods of severe hypotension or cardiac arrest, palpation of the femoral artery may not be feasible. This can lead to failed access or arterial cannulation. Hilty et al. demonstrated a higher rate of success and a decreased rate of arterial cannulation with US guidance during CPR.[75] US guidance for femoral vein cannulation may not yet be a standard practice, but it may be a useful technique that can reduce the rates of complication of central venous cannulation.

SUMMARY

Central venous access is often necessary in critically ill patients and in those with poor peripheral veins. Mastery of these techniques is essential for anyone who will be caring for acutely ill and unstable patients. While all approaches to the central circulation have acceptably low complication rates (1% to 5%) when performed by experienced providers, they all carry real risks to the patient.[39,49] Be certain that there is no safer peripheral access alternative before placing a central venous line.

The internal jugular vein is a good choice for central venous access in nonambulatory patients. The right internal jugular vein provides easy access to the superior vena cava for monitoring and for infusion of solutions too concentrated or irritating for peripheral veins. This route poses a slightly lower risk of complications than the subclavian route.[64,66]

The subclavian vein provides easy access to the central circulation. Subclavian vein catheters are more easily tolerated by awake and ambulatory patients than are internal jugular or femoral catheters. Subclavian vein cannulation does present very real risks to the patient that must be balanced against the need for the procedure and other alternatives. Subclavian vein access is the least preferred route in young children due to their small size, the proximity of the pleura, and the proximity of the subclavian artery.

Femoral vein cannulation is an essential emergency skill. It allows the easiest central venous access in most patients with the lowest risk of catastrophic immediate complications compared to jugular and subclavian access procedures.

US guidance for central venous access, specifically the internal jugular vein has rapidly become integrated into the practice of Emergency Medicine. Familiarity with US guidance is become a mandatory skill for the Emergency Physician when placing central venous lines. Refer to Chapter 50 regarding the complete details of US-guided central venous access.

50 Ultrasound-Guided Vascular Access

Srikar Adhikari

INTRODUCTION

Central venous catheterization is essential in the management of critically ill patients seen in the Emergency Department (ED). It allows for fluid resuscitation, central venous pressure monitoring, pacemaker placement, and administration of vasoactive medications. Complications such as arterial puncture, hematoma, pneumothorax, hemothorax, and air embolus have been reported to occur in 5% to 20% of patients.[1–3] Unsuccessful cannulation has

been reported in up to 20% of cases.[4,5] Central venous catheterization has traditionally been performed using surface anatomic landmarks as a guide to locate the veins. Catheterization is not always successful using the landmark method due to anatomical variations or obscured landmarks. Other factors such as obesity, shock, dehydration, intravenous drug abuse, congenital deformities, thromboses, and scarring can complicate the procedure. Ultrasound (US)-guided vascular access is widely supported in current medical practice. The use of US guidance for central venous cannulation has been endorsed by several medical societies and supported by numerous trials in the literature. **US guidance has been shown to improve cannulation success rates, reduces mean insertion attempts, and reduce placement failure rates.**[6–11] US guidance allows the Emergency Physician to more precisely locate target vessels and also provide real time visualization of needle placement.

Peripheral venous access is more commonly performed in the ED than central venous cannulation. Patients with a history of chronic kidney disease, intravenous drug abuse, vascular disease, organ transplantation, and obesity lack easily located peripheral venous sites. Obtaining peripheral intravenous (IV) access in these patients can be a challenge, even for the most experienced medical personnel. Multiple studies have shown US-guided peripheral IV access is safe and successful in these patients.[12–17] US-guided peripheral IV access prevents the need for central venous catheterization and the pain of multiple needle sticks in many "hard-to-stick" patients.

ANATOMY AND PATHOPHYSIOLOGY

It is important to recognize the differences in sonographic appearance between arteries and veins when performing US-guided vascular access. Arteries and veins can be distinguished by their size, shape, location, ability to be compressed, Doppler mode signal, and spectral Doppler waveforms. Arteries have relatively thick and hyperechoic (white) walls and anechoic (black) lumens. Veins have relatively thin and hypoechoic (gray) walls and anechoic (black) lumens. The thin-walled veins are usually oval, easily compressible, and have no pulsations on Doppler mode (**Figures 50-1 & 50-2**). Arteries are typically round in appearance and pulsatile on Doppler mode (**Figure 50-1**). Arteries and veins are often found adjacent to each other. Veins are usually larger in diameter than arteries in a well-hydrated patient (**Figure 50-1**). The anatomy relevant to the sonographic evaluation of central and peripheral veins is described in the following sections.

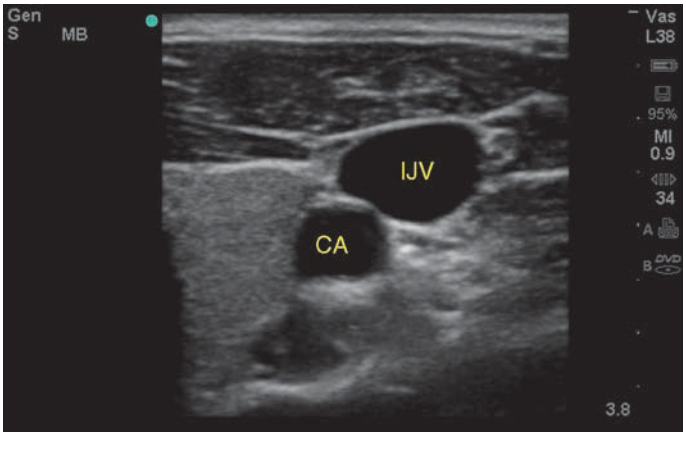


FIGURE 50-1. US image of the neck vessels. The internal jugular vein (IJV) is thin-walled and oval. The carotid artery (CA) is thick-walled and round.

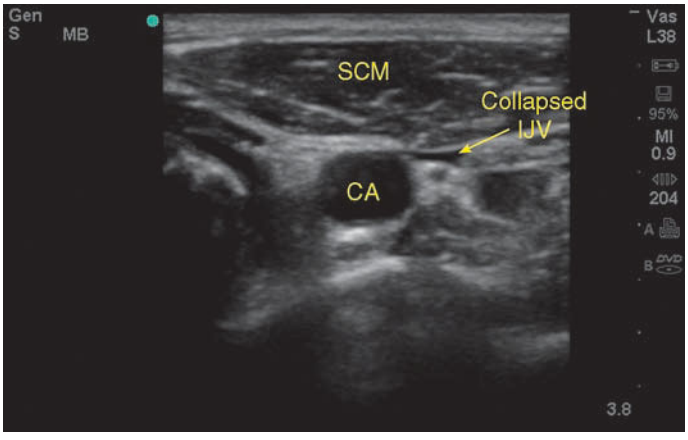


FIGURE 50-2. The US probe is used to apply external pressure to the soft tissues of the neck. The internal jugular vein collapses with gentle compression (CA, carotid artery; IJV, internal jugular vein; SCM, sternocleidomastoid muscle).

CENTRAL VEINS

The internal jugular and femoral veins are commonly used for US-guided central venous catheterization. US-guided subclavian vein cannulation is technically more challenging because the vein runs for a significant distance under the clavicle. The clavicle obstructs the US beam and produces a large acoustic shadow, which makes US visualization of this area difficult.

The internal jugular vein traverses the neck and is unopposed by bone, making it an ideal vein to visualize with US. The internal jugular vein lies underneath the bifurcation of the sternal and clavicular heads of the sternocleidomastoid muscle. It continues to run vertically downward in the neck, lying at first lateral to the internal carotid artery, and then lateral to the common carotid artery. It eventually enters the subclavian vein (**Figure 49-2**).

The common femoral vein lies medial to the common femoral artery and inferior to the inguinal ligament. In the upper thigh, the superficial femoral and deep femoral veins unite to form the common femoral vein. The greater saphenous vein joins the anteromedial aspect of the common femoral vein below the inguinal ligament (**Figure 50-3**). The common femoral vein becomes the external iliac vein after it passes under the inguinal ligament.

PERIPHERAL VEINS

The three veins of the upper extremity that are most commonly used for US-guided vascular access are the basilic, cephalic, and brachial veins. The venous drainage of the upper extremity consists of a deep system and a superficial system. The deep system includes radial and ulnar veins in the forearm that unite to form the brachial vein, which is the deep vein in the upper arm. The brachial vein lies next to the pulsatile and noncompressible brachial artery (**Figure 50-4**). It is not uncommon to find paired superficial and deep brachial veins. The two major superficial veins of the upper arm are basilic and cephalic veins. The cephalic vein arises from the radial aspect of the dorsal hand venous network, ascends proximally along the anterior border of the brachioradialis muscle, runs lateral to biceps muscle and joins axillary vein. The basilic vein begins in the ulnar side of the dorsal hand venous network, ascends along medial aspect of forearm and upper arm, and unites with the brachial veins to form the axillary vein.

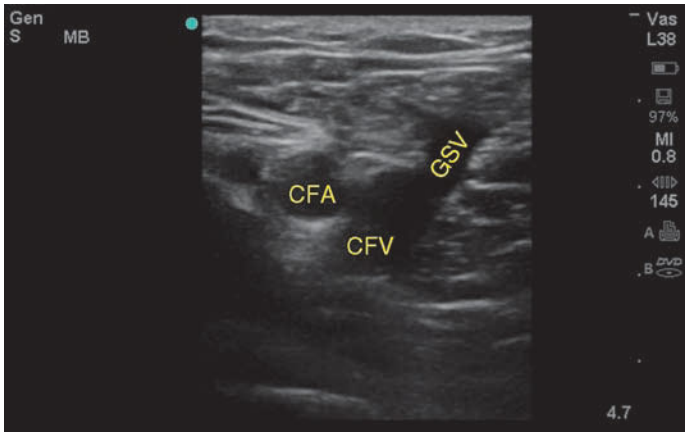


FIGURE 50-3. US image of the femoral vessels. The common femoral vein (CFV) lies medial to the common femoral artery (CFA). The superficially located greater saphenous vein (GSV) enters the common femoral vein 2 to 3 cm below the inguinal ligament.

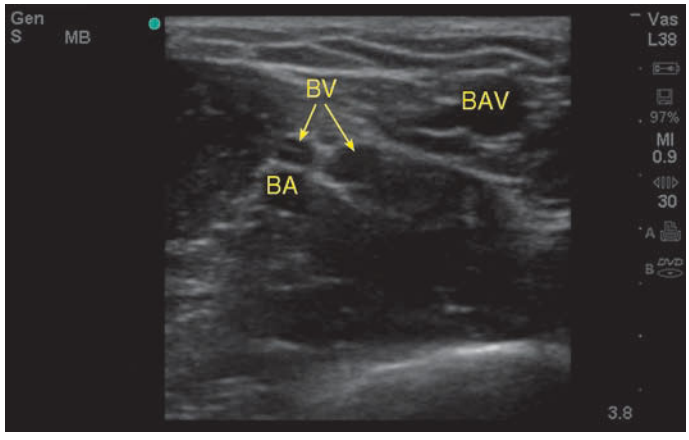


FIGURE 50-4. Transverse US view of the upper arm veins (BA, brachial artery; BAV, basilic vein; BV, paired brachial veins).

STATIC APPROACH TO VASCULAR ACCESS

The static approach to vascular access involves confirming the location of the vein prior to performing the cannulation. Place the US transducer perpendicular to the course of the vein to visualize the vein and verify compressibility. Adjust the probe so that the target vein is in the center of the US monitor screen. This places the vein directly under the center of the US probe. Place a mark on the skin at the midpoint of the US probe to mark the vein location. To assess the path of the vein, repeat this process at a point 2 cm away and along the vein. These two points marked on the skin will serve as a guide to direct the needle. Determine how deep the vein is located. Look at the depth markers on the side of the US monitor screen. Remove the probe and prepare the patient as usual.

Proceed with the catheterization. Insert the needle approximately 0.5 cm above or below the mark. Advance and direct the needle to the appropriate depth underneath the skin markings. If the patient changes position after marking the skin but before needle puncture, the patient must be re-imaged and the skin markings repeated prior to inserting the needle. The advantages of the static approach are its simplicity and that the US probe does not need to be prepared for the sterile portion of the procedure. The disadvantage of this technique is that the needle is not visualized in real time while performing the procedure.

DYNAMIC APPROACH FOR VASCULAR ACCESS

The dynamic approach to vascular access involves inserting the needle into the vein under real time US guidance. Two techniques are used for the dynamic approach and they refer to the orientation of the US probe and target vein during the venipuncture. The short axis approach visualizes the vein in a cross section. The long axis approach visualizes the vein longitudinally.

Each approach has its own advantages and disadvantages. The short axis approach provides better medial to lateral orientation of the needle in relation to the target vein and also allows for visualization of adjacent structures in the same image. Novice sonographers can learn the short axis approach more quickly and it can be performed in anatomic locations where space is limited such as the neck or the groin in an obese patient. One potential danger with the short axis approach is unseen penetration of the posterior wall of the target vein and adjacent structures. The long axis approach allows better depth and needle slope information. The entire needle can be tracked with this approach. The long axis approach provides much better visualization of the tip of the needle and its trajectory, thus avoiding inadvertent puncture of the posterior wall of the vein. The long axis approach requires more hand–eye coordination and is technically more difficult to learn.

INDICATIONS

US can be used to mark the site of needle entry or provide real time guidance. Ideally, US guidance should be used for all internal jugular and femoral vein cannulations if the equipment is available. It should also be used for peripheral IV access in all "hard-to-stick" patients or when a peripheral vein is not visible or palpable. The use of US-guided peripheral IV access in the patient with difficult peripheral IV access can prevent the need for central venous access. It is highly recommended in the patient with poor anatomic landmarks, coagulopathies, anticoagulant use, a history of difficult IV access, DIC, thrombocytopenia, prior surgical interventions or radiation in the area, scarring on the skin above veins, intravenous drug abuse, obesity, hypotension, and severe dehydration.

CONTRAINDICATIONS

There are no absolute contraindications to the use of US for central or peripheral venous access except lack of US training and experience.

EQUIPMENT

- Ultrasound machine
- Ultrasound gel
- High frequency, 5 to 10 MHz linear array US probe
- Sterile US probe cover (clear plastic cover, US gel, and rubber bands)
- Povidone iodine or chlorhexidine solution
- Equipment for peripheral IV access (Chapters 47 and 48)
- Equipment for central venous access (Chapter 49)
- Water-soluble lubricant, sterile
- Translucent dressing (e.g., Tegaderm)
- 2 to 3 inch (in) long catheter-over-the-needle, various sizes

PATIENT PREPARATION

CENTRAL VENOUS ACCESS

Position the patient the same as if performing central venous catheterization using the landmark method (**Figure 50-5**). Place the US machine across from where you will be standing to minimize the body movement required to view the US image. For internal jugular vein access, stand at the head of the patient with the US machine at the patients hips (**Figure 50-5A**). Place the patient in the Trendelenburg position with their head turned to the contralateral side or kept in a neutral head position (**Figure 50-5A**). The relationship of the internal jugular vein to the carotid artery changes with head position. In the neutral position, the internal jugular vein assumes a more lateral position to the carotid artery. This minimizes the risk of arterial puncture while accessing the target vein. For femoral vein access, stand at the bedside adjacent to the patient's hip with the US machine above the patient's shoulder (**Figure 50-5B**). Place the patient in the reverse Trendelenburg position with their hip abducted and externally rotated (**Figure 50-5B**). This position enhances the success rate of catheterization by increasing the surface area of the femoral vein available for cannulation.[18]

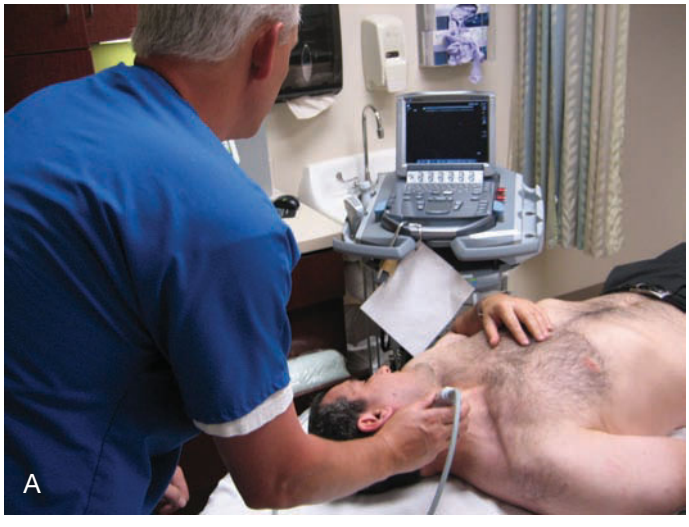




FIGURE 50-5. Patient and US machine positioning for central venous access. **A.** Internal jugular vein access. **B.** Femoral vein access.

Perform a preliminary scan prior to preparing the patient for the sterile procedure. Survey the underlying vasculature to confirm the patency of the target vein, determine the optimal site for venipuncture, and adjust the US machine settings to optimize the image. The ability of the vein to be compressed distinguishes artery from vein, confirms the patency of the vein, and reduces the risk of cannulating a thrombosed vein. Do not assess compressibility in the long axis. The US probe may slide off the vein and be seen as the vein lumen disappearing and misinterpreting it as being compressible. Clean and prep the skin at the access site as if performing a traditional central line placement. **Follow strict aseptic technique and all barrier precautions during the procedure.**

The procedure can be performed by either one person (the Emergency Physician) or two people (the Emergency Physician and an assistant). Using the two-person technique, one person stabilizes the US probe over the vein and the other performs the procedure. Prepare the US probe as discussed below.

US PROBE PREPARATION

A high frequency, 5 to 10 MHz, linear array US probe is typically used for US-guided vascular access. These US probes produce linear images and are ideal for visualization of superficial structures such as veins. **Always use a sterile US probe cover and sterile US gel when performing central venous catheterization.** Set up a sterile field on a bedside table. Open the US probe cover set onto the sterile field.

Instruct an assistant to hold the US probe upright and place standard or sterile US gel on the footprint of the US probe (**Figure 50-6A**). Apply the sterile probe cover over the US probe (**Figure 50-6B**). Smooth all the air bubbles away from the footprint of the US probe to prevent imaging artifacts. Secure the cover with rubber bands to prevent it from sliding off the US probe (**Figure 50-6C**). Place the US probe on the sterile field (**Figure 50-6D**). Apply sterile US gel onto the cover over the probe footprint just before scanning.

US PROBE ORIENTATION

Orient the US probe. In the short axis approach, the marker on the US probe and the marker on the US machine screen should be aimed in the same direction (**Figure 50-7**). If the needle moves to the right side of the US probe, the needle also moves to the right on the US machine screen. This helps to accurately move the needle right to left while directing the needle towards the vein. This makes performing the procedure less complicated. In the long axis approach, it is important to know which way the probe marker is directed (cephalad or caudad) so that the Emergency Physician knows which side of the screen the needle will come from (i.e., the right or left of the image).

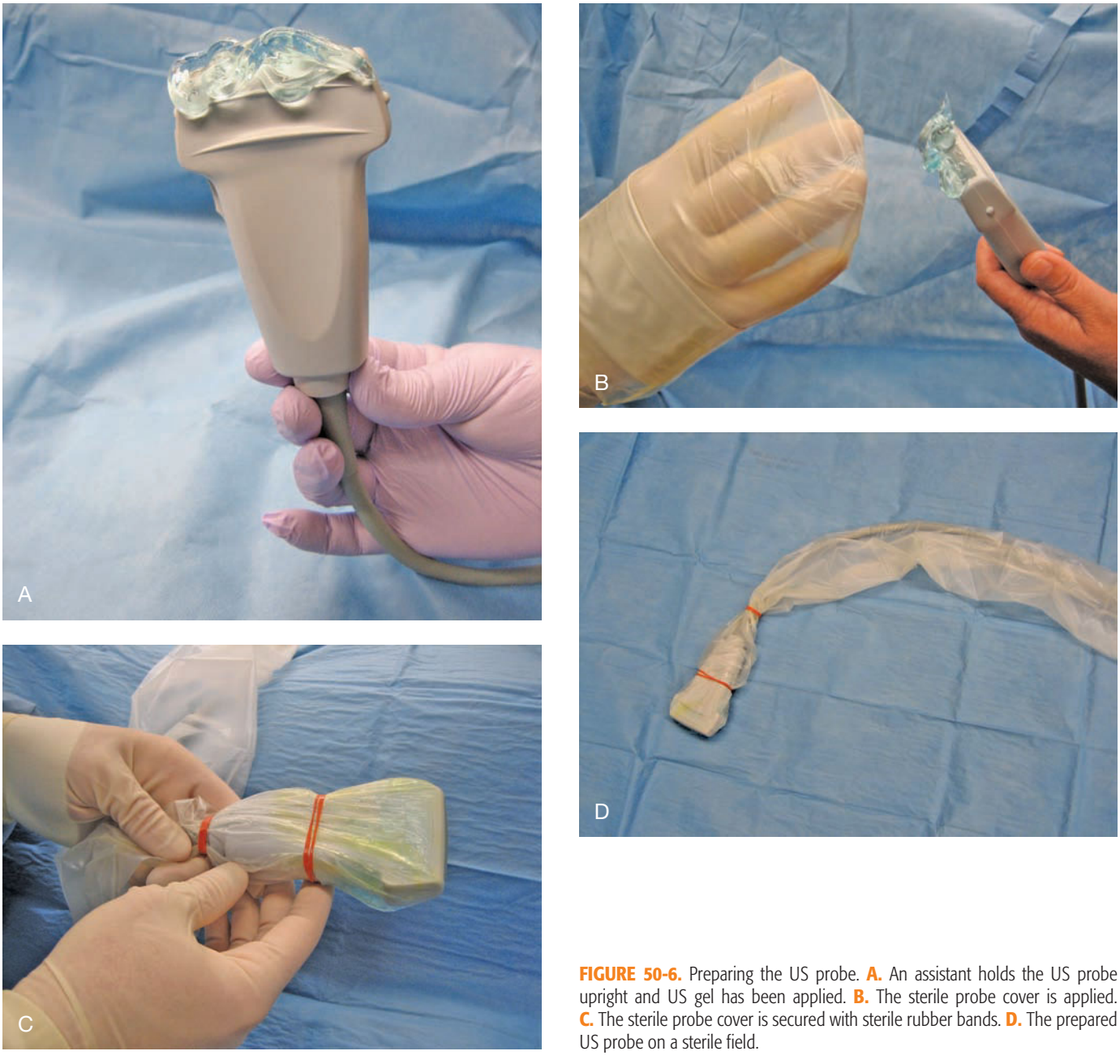


FIGURE 50-6. Preparing the US probe. **A.** An assistant holds the US probe upright and US gel has been applied. **B.** The sterile probe cover is applied. **C.** The sterile probe cover is secured with sterile rubber bands. **D.** The prepared US probe on a sterile field.

IDENTIFICATION OF VEINS

Identify and verify the vein depth, direction, and patency prior to the procedure. To locate the internal jugular vein, place the US probe in the triangle formed by the two heads of sternocleidomastoid muscle and clavicle (**Figure 50-8A**). Scan from the apex of the triangle to the clavicle. Visualize the internal jugular vein, carotid artery, and thyroid gland (**Figure 50-8B**). The internal jugular vein is an irregular and oval-shaped structure lateral to the carotid artery (**Figures 50-8B & C**). Visualize the internal jugular vein and identify its widest diameter, the depth from the skin surface, and its relationship to the carotid artery. Instruct the patient to perform a Valsalva maneuver to increase venous flow and distend the internal jugular vein while observing the US machine screen to note the changes in the US appearance of the vein.

To locate the common femoral vein, scan below the midpoint of inguinal ligament (**Figure 50-9A**). The common femoral

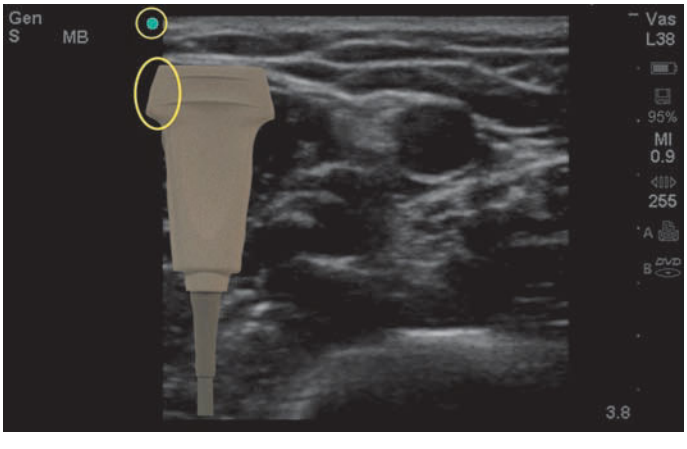
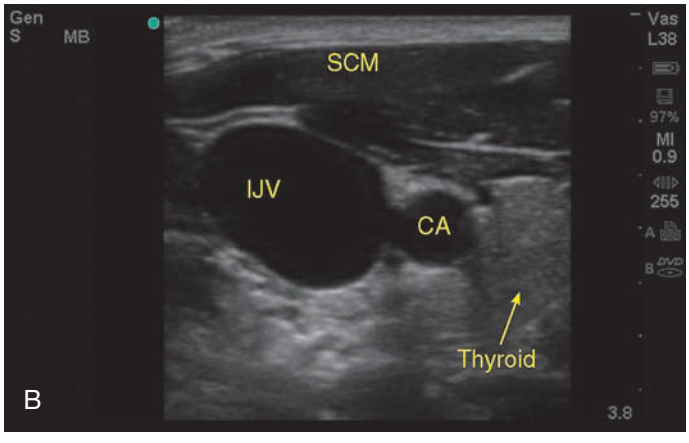


FIGURE 50-7. The US probe marker and the marker on the US machine screen are aimed in the same direction.





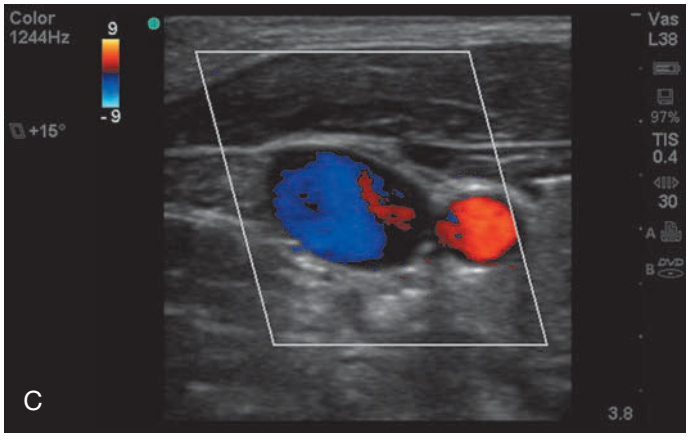


FIGURE 50-8. Identification of the internal jugular vein. **A.** Patient and US probe positioning. **B.** US image of the transverse or short axis view in B-mode. **C.** Short axis view in color Doppler mode. The large blue internal jugular vein is clearly visible adjacent to the red carotid artery (CA, carotid artery; IJV, internal jugular vein; SCM, sternocleidomastoid muscle).

artery should be clearly visible next to the common femoral vein (**Figure 50-9B**). The greater saphenous vein merges with the common femoral vein on the medial aspect. Visualize the common femoral vein and identify its widest diameter, the most superficial location, the depth from the skin surface, and a location that does not overlap with the common femoral artery.



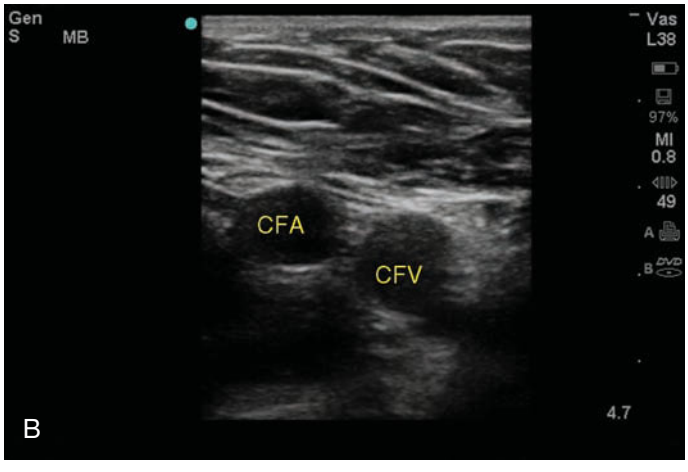


FIGURE 50-9. Identification of the common femoral vein. **A.** Patient and US probe positioning. **B.** US image of the transverse or short axis view in B-mode (CFA, common femoral artery; CFV, common femoral vein).

Do not apply excessive pressure with the US probe when assessing the vein. Excessive pressure can collapse the vein and makes it difficult to identify. Verify that the identified vessel is compressible and truly a vein (**Figure 50-2**). **The ability of the vein to be compressed distinguishes artery from vein, confirms the patency of the vein, and reduces the risk of cannulating a thrombosed vein.** Do not assess compressibility in the long axis. The US probe may slide off the vein and be seen as the vein lumen disappearing and misinterpreting it as being compressible.

Doppler US can be used to identify vascular structures. Color Doppler ensures the patency of blood vessels (**Figure 50-8C**). Spectral Doppler distinguishes blood flow patterns. Spectral Doppler demonstrates continuous venous flow in the internal jugular and femoral veins (**Figure 50-10A**). Triphasic pulsatile flow is seen on spectral Doppler in the carotid and femoral arteries (**Figure 50-10B**).

TECHNIQUES

SHORT AXIS APPROACH TO CENTRAL VENOUS ACCESS

The short axis approach allows visualization of the vein in cross section. This view is obtained by placing the US probe

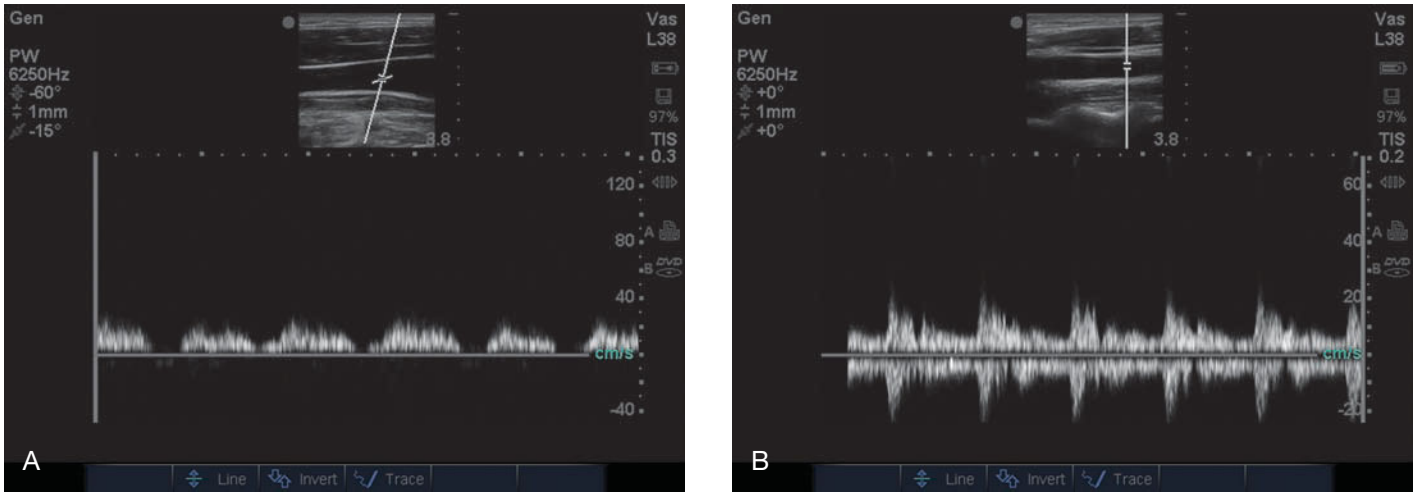


FIGURE 50-10. Long axis US images of spectral Doppler waveforms. **A.** The internal jugular vein. **B.** The carotid artery.

perpendicular to the long axis of the vein. The vein appears oval-shaped in this view (**Figures 50-1, 50-8B, & 50-9B**). Place sterile US gel on the skin above the vein and on the footprint of the sterile US probe. Grasp the US probe with the nondominant hand and the needle with the dominant hand. As described previously, reidentify the vein and the optimal site of needle insertion. Adjust the US probe to center the target vein on the US machine screen. The midpoint of the US probe now becomes the reference point for needle insertion.

Select the skin entry site to maximize the chances that the tip of the needle punctures the vein as well as intersect the US probe scan plane. The geometry of the Pythagorean Theorem ($a^2 + b^2 = c^2$) can be used to assess the distance to insert the needle into the skin and away from the US probe (**Figure 50-11**). Measure the distance from the skin surface to the center of the vein. This distance is equal to the distance from the probe to where the needle punctures the skin at a 45° angle. For example, if the distance from the skin surface to the center of the vein is 1 cm, make the skin puncture 1 cm from the midpoint of the US probe along the trajectory of the vein (**Figures 50-11A & B**). Insert and advance the needle at a 45° angle. The vein will then be punctured after the needle is inserted 1.4 cm. **It is very useful to assess the distances using this method before venipuncture to avoid complications.** If the vein is not punctured within the expected inserted needle length, the needle trajectory is not accurate and should be reassessed.

It is important to understand that the US beam is very narrow and only 1 to 2 mm wide despite the US probe being approximately 1 cm wide. **The needle will be visualized only when it is within this narrow beam width. The cross section of the needle in the short axis approach will be seen only when it crosses the US scan plane that is oriented perpendicular to the needle.** The needle tip or shaft will appear as a hyperechoic dot within the vein (**Figure 50-12A**). It will be seen in association with either an acoustic shadow (black) or a reverberation or ring down artifact (white echoes) posterior to the needle (**Figure 50-12B**).

Clean, prep, and anesthetize the skin after estimating the distance to the vein. Insert and advance the needle at a 45° angle (**Figure 50-13**). During the initial portion of the needle path, its location can only be identified by signs of it pushing through the tissue as soft tissue movement. This is because the needle has not yet crossed the US probe scan plane. Small, rapid, and in-line

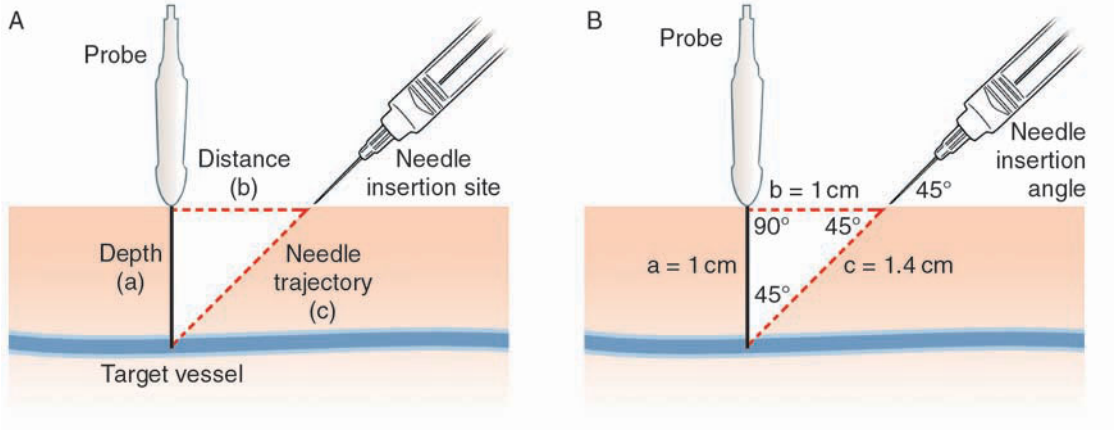
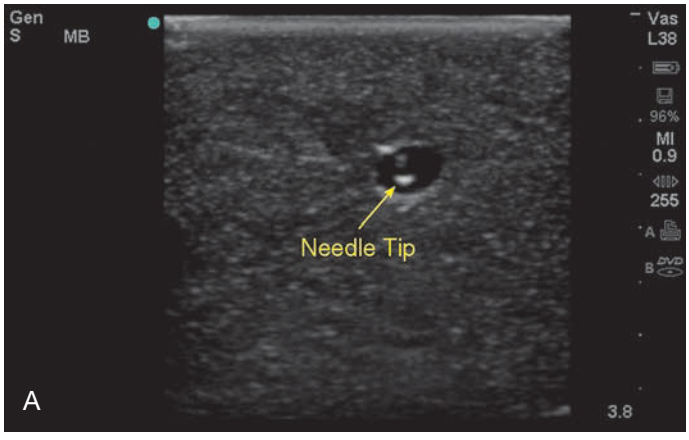


FIGURE 50-11. The short axis approach needle insertion based on the Pythagorean theorem. **A.** The depth (a) equals the distance from the US probe (b) to insert the needle at a 45° angle. **B.** A sample calculation where $a^2 + b^2 = c^2$.



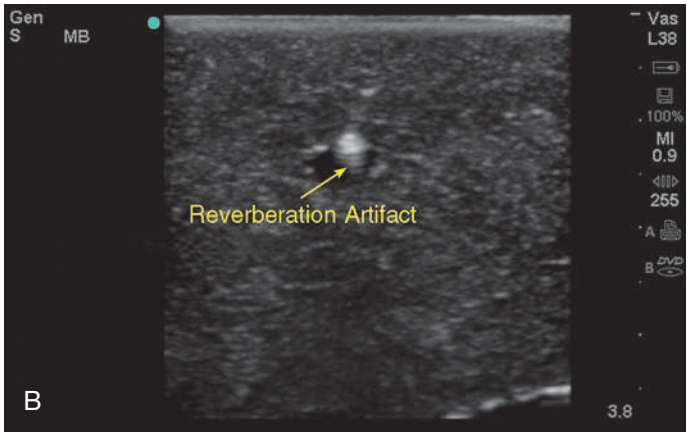


FIGURE 50-12. Short axis US image of a needle within a vein. **A.** The needle tip is visible as a hyperechoic dot inside the lumen. **B.** The reverberation or ring down artifact from the needle.

movements of the needle are helpful to locate the needle tip on the US image. **Do not mistake the needle shaft for the needle tip.** Always try to locate the needle tip by angling or fanning the US probe. As the needle contacts the anterior vein wall, it will tent or buckle the vein wall (**Figure 50-14**). The wall of the vein will first collapse downward as it is being punctured and then return to normal after the wall is punctured. Visualize the hyperechoic needle tip within the lumen of the vein to confirm the needle entered the vein (**Figure 50-12**). A concurrent flash of blood will be seen in the syringe. Place the US probe back onto the sterile field. The remainder of the procedure is as described for the landmark technique of central venous access (Chapter 49).

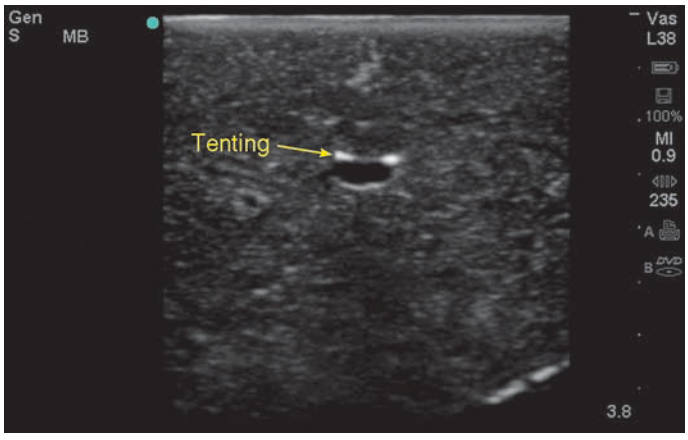


FIGURE 50-14. Short axis US image demonstrating tenting of the anterior wall of the vein as it is penetrated by the needle.

LONG AXIS APPROACH TO CENTRAL VENOUS ACCESS

The long axis approach targets the vein along its length in the longitudinal plane. Grasp the US probe in the nondominant hand and the needle with the dominant hand. Locate the target vein using the short axis approach. Verify it is compressible. Slowly rotate the US probe to visualize the vein in the long axis. The US probe should be positioned directly over the vein so that its long axis is parallel to the long axis of the vein (**Figure 50-15**). Adjust the US probe to visualize the vein at its greatest anteroposterior diameter.

Insert the needle through the skin at approximately a 30° angle adjacent to one end of the US probe (**Figures 50-15 & 50-16**).



FIGURE 50-13. The short axis approach for venous access.

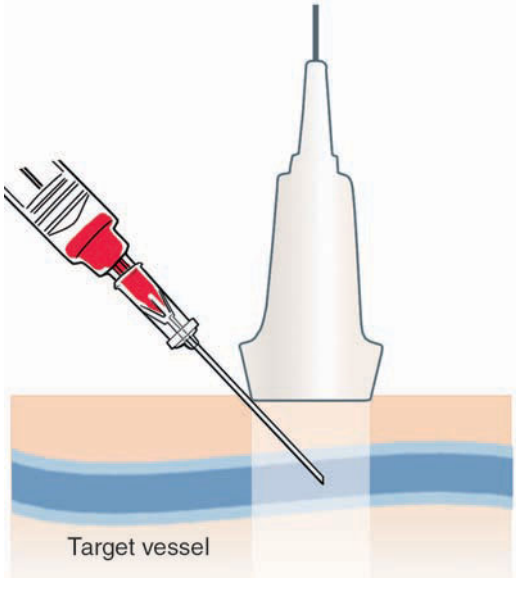


FIGURE 50-15. The long axis orientation and needle insertion.

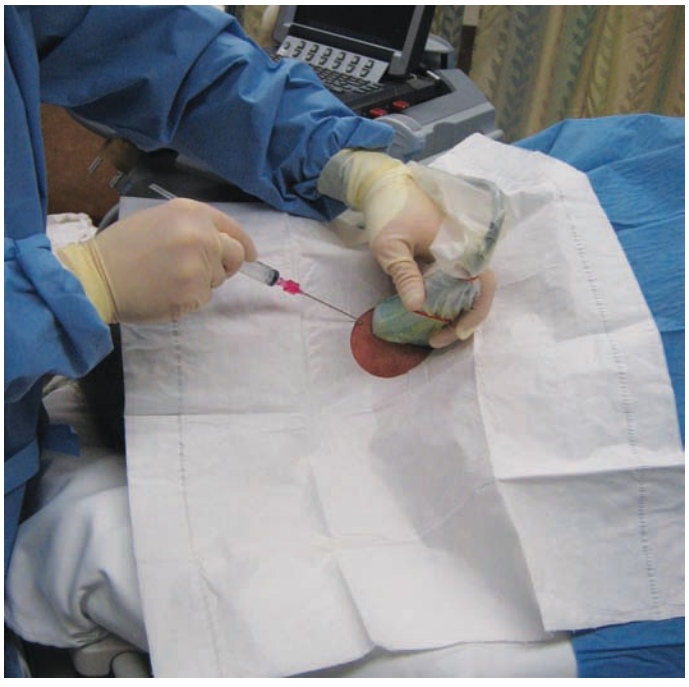


FIGURE 50-16. The long axis approach for venous access.

The needle should be in the plane that is in-line with the long axis of the US probe and in the exact same plane as the US beam. With this approach, it is crucial to keep the US probe steady and over the vein. Advance the needle. The needle tip and shaft will be visualized in real time as it travels through the subcutaneous tissues and into the lumen of the target vein (**Figure 50-17**). If it is not visualized in the US image, the needle plane and US probe scan plane are not aligned. Do not advance the needle any further. Withdraw the needle toward the skin and redirect it to align it with the US beam and the long axis of the vein.

PERIPHERAL VENOUS ACCESS

Place the patient supine with their upper extremity abducted to expose the anteromedial aspect of the upper arm (**Figure 50-18**).



FIGURE 50-18. Patient and US machine positioning for upper extremity peripheral venous access.

Place a tourniquet on the upper arm, just below the axilla, to distend the veins. Sit or stand at the patient's bedside facing the patient. Position the US machine so that the screen is easily visible (**Figure 50-18**). To locate the veins and find the ideal venipuncture site, scan the entire upper arm from just below the tourniquet to the elbow. Identify the basilic vein along the medial aspect of the upper arm (**Figure 50-19**). Move the US probe slightly laterally to visualize the brachial vein adjacent to the brachial artery. Scanning further laterally will identify the cephalic vein. Peripheral veins collapse very easily. Minimize the pressure placed upon the skin surface with the US probe. Too much pressure can collapse these veins and make them difficult to identify. Identify the segment of vein that is widest in diameter, closest to the skin surface, and not adjacent to an artery. Verify that the vein is compressible and patent as described previously.

Prepare the skin insertion site similar to peripheral IV placement. There is no need to follow any special precautions such as a sterile US probe cover. Apply a large transparent dressing (e.g., Tegaderm) onto the footprint of the linear array US probe. Make sure that no air bubbles are trapped between the transparent

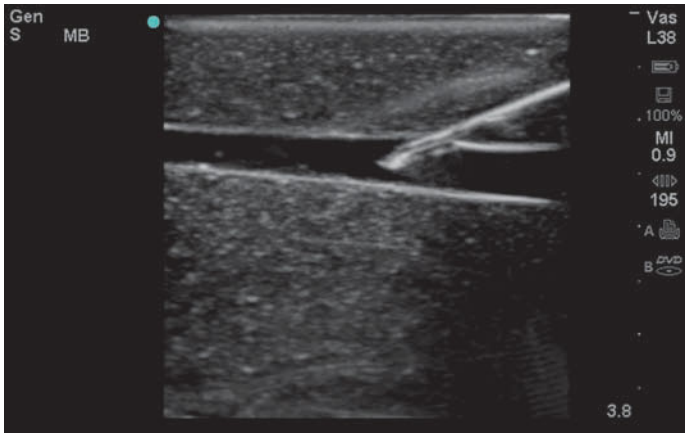


FIGURE 50-17. Long axis US image of the needle shaft in the subcutaneous tissues and the tip inside the lumen of the vein.

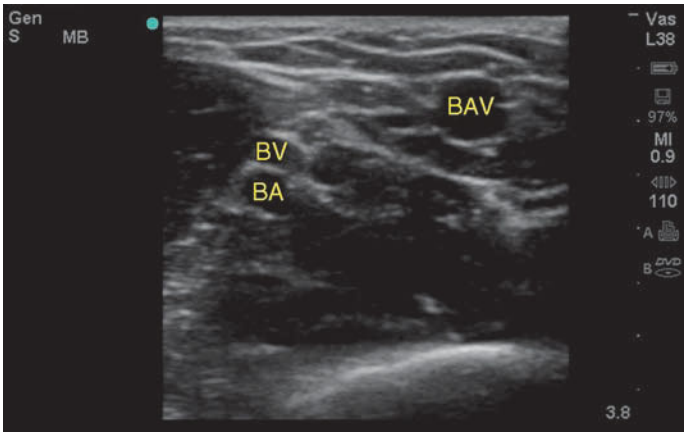


FIGURE 50-19. Short axis US image of the basilic and brachial veins (BA, brachial artery; BAV, basilic vein; BV, brachial vein).

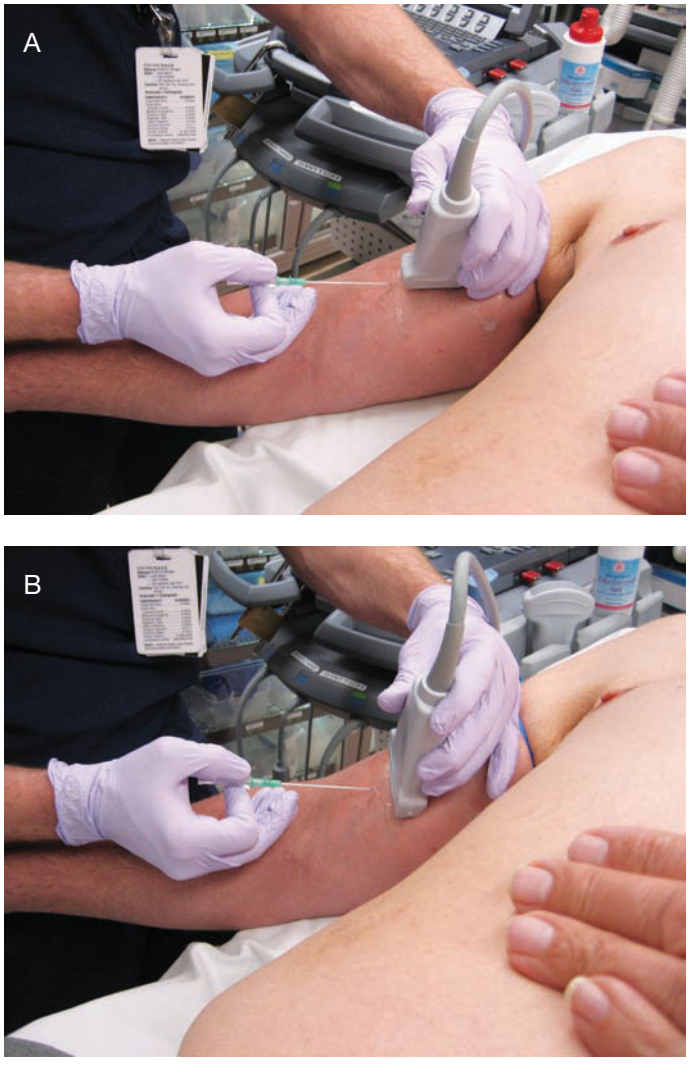


FIGURE 50-20. US probe and needle insertion for upper extremity venous access. **A.** Long axis approach. **B.** Short axis approach.

dressing and the US probe. The transparent dressing keeps the field sterile and prevents contamination of the US probe with blood. Use a water-soluble lubricant (e.g., Surgilube) instead of US gel for scanning. Use a 2.5 to 3.0 in long catheter-over-the-needle for US-guided peripheral IV access. Standard length peripheral IV catheters are too short to reach or stay within the lumen of the vein. Identify the vein in either the long axis (**Figure 50-20A**) or the short axis (**Figure 50-20B**) using the methods described previously. Insert the catheter-over-the-needle under US guidance. Once the tip of the needle is within the lumen of the vein, advance the catheter into the vein (**Figure 50-21**). Put down the US probe. Withdraw the needle, attach IV tubing onto the hub of the catheter, and secure the catheter.

ARTERIAL ACCESS

US guidance can be used to assist in obtaining an arterial blood gas and the placement of an arterial catheter. Identify the artery by its round shape, relatively thicket walls, noncompressibility, and pulsatile contractions. The procedure of cannulating an artery is the same as described above for a vein. Refer to Chapter 57 for the complete details regarding arterial puncture and cannulation.

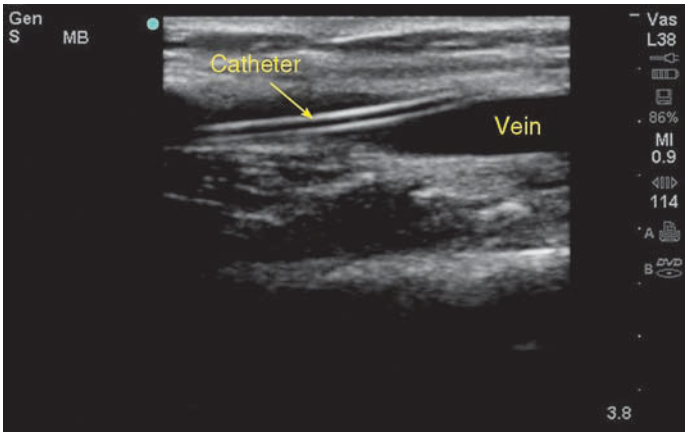


FIGURE 50-21. Long axis US image of a cannulated peripheral vein. The catheter is visible inside the lumen of the vein.

ASSESSMENT

Scan along the length of the cannulated vein in both the long axis view and the short axis view. Confirm the placement of the catheter within the lumen of the vein (**Figure 50-21**).

AFTERCARE

No specific aftercare is required following the US guidance. The aftercare procedures are related to the central venous line (Chapter 49) and peripheral IV (Chapters 47 & 48) placement.

COMPLICATIONS

Complications related to using US for vascular access are generally due to a poor technique or misinterpretation of images. An artery can be misinterpreted as a vein. There is no exposure to ionizing radiation. No increased risk of infections has been reported with the use of US when aseptic technique was followed. US guidance can be more time consuming when used for routine peripheral IV access. Its use may actually save time in the patient with difficult venous access. Using too short of a peripheral IV catheter can result in it being pulled out of the vein and the infusion solution extravasating. This can be prevented by using a longer (2 to 3 in) catheter-over-the-needle and/or inserting the catheter at a steeper angle to minimize the distance it travels in the subcutaneous tissues.

SUMMARY

US-guided vascular access is widely supported in current clinical practice. It can be used for both central and peripheral IV access. US guidance has been shown to reduce failure rates and many of the complications associated with the traditional landmark technique. The benefits of US guidance include precise localization of the target vein, visualization of adjacent structures, identification of anatomic variations, avoidance of veins with thromboses, and real time visualization of venipuncture. Knowledge of the sonographic anatomy and basic US technology combined with hand–eye coordination are essential to perform this procedure. Understanding the principles discussed in this chapter will enhance the success rate of vascular access.

51 Troubleshooting Indwelling Central Venous Lines

James J. McCarthy

INTRODUCTION

Indwelling central venous lines are an essential part of the care of both the acutely and chronically ill patients. These patients may require implanted venous access devices due to their poor peripheral venous access or for long-term intravenous therapies. When an indwelling central venous line is malfunctioning, the Emergency Physician must act quickly and thoughtfully to diagnose and correct the malfunction without further damaging the device. Understanding the different etiologies and a thorough assessment are critical to the successful management of a central venous catheter malfunction.

ANATOMY AND PATHOPHYSIOLOGY

Indwelling central venous catheters allow access to the central venous circulation from a peripheral site. This access to the central circulation is via the end of a partially implanted catheter that protrudes from the body or through the skin into a subcutaneous reservoir of a fully implanted catheter.[1,2] The proximal tip of the central venous line will typically reside in either the superior vena cava, the inferior vena cava (less commonly), or the right atrium.

Indwelling central venous access devices can malfunction for a variety of reasons. The two most common types of vascular catheter complications are thrombotic occlusions and infections.[3] The etiology of the malfunction can be divided into two main categories: external to the catheter and internal to the catheter. External malfunctions are for the most part mechanical malfunctions. Examples include catheter migration, the catheter tip abutting a vessel wall, a mural thrombus, and kinked catheters. Internal malfunctions can be further divided into thrombotic (e.g., intraluminal thrombus, fibrin sheath, and fibrin tail) and nonthrombotic (e.g., drug/drug precipitate, insoluble salts, lipid precipitate, and drug/solution precipitate).[3–5] Phenytoin and diazepam cannot be given through silicone indwelling lines as they can crystallize and permanently obstruct the catheter lumen.[4] Calcium and phosphate can form an insoluble precipitate within the catheter lumen. Infused lipids can form waxy casts within the catheter lumen.

INDICATIONS

Any catheter that cannot be easily flushed or aspirated requires further investigation. If peripheral venous access is readily available, and the patient is not acutely ill due to catheter sepsis or central venous thrombosis, catheter troubleshooting may be deferred to the Primary Care Provider. It is important to consider that delaying troubleshooting may make management more difficult and therefore necessitate line replacement. However, the Emergency Physician will have to address the problem if emergent or urgent access to the patient's central vascular system is required.

CONTRAINDICATIONS

Any device that is obviously displaced from the central circulation is not salvageable and should not be used. Dislodging a clot or septic thrombus from a catheter tip can lead to a fatal pulmonary embolism. Catheter manipulation should be avoided if signs of sepsis or central venous thrombosis are present.[6] The use of indwelling dialysis lines for purposes other than dialysis is discouraged. Manipulation of a dialysis line should only be undertaken in a true emergency or if the line is malfunctioning and is needed for hemodialysis.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile alcohol prep pads
- Thrombolytic agent
- Syringes, 5 mL and 10 mL
- 18 gauge needles
- Noncoring (Huber) needle
- 70% ethanol solution
- 0.1 N hydrochloric acid (HCl) solution
- Sterile saline
- Heparinized saline flush solution (100 U/mL)
- Sterile gauze squares
- Sterile gloves

Repair kits are available to repair some externally damaged partially implanted catheters. The kits avoid the need to remove the device and implant a new catheter. If the external tubing of the device is damaged, apply a smooth catheter clamp proximal to the damaged area and arrange to have the device repaired. The use of these kits is beyond the scope of this chapter.

THROMBOLYTIC AGENTS

The use of a specific thrombolytic agent is institution-specific and physician-specific. Streptokinase, recombinant tissue plasminogen activator (t-PA), Reteplase, and urokinase have all been successfully used to dissolve a clot within a central venous catheter.[4,7–12] Volumes and doses of the drugs differ significantly and careful attention should be paid to the medication administration. Urokinase and recombinant tissue plasminogen activator are most commonly used. Streptokinase is more likely to lead to a hypersensitivity reaction, especially if the patient has prior exposure to it, and is therefore not recommended. Urokinase is the thrombolytic agent used by most institutions because it is much less expensive than t-PA. Urokinase may be purchased in concentrations of 5000 U/mL and 250,000 U/5 mL (50,000 U/mL). The concentration of 5000 U/mL is used for dissolving a clot within a catheter. Some institutions prefer to use t-PA for this process. The Pharmacist dilutes a 50 mg vial of t-PA with 50 mL of sterile water to produce 25 syringes containing 2 mg of t-PA in 2 mL (1 mg/mL). The syringes of t-PA are then frozen until needed. It is also available from the manufacturer in 2 mg single use vials. Standard dosing for catheter obstructions is 1 mL of urokinase (5000 U/mL), 2 mL of t-PA (1 mg/ml), or 0.4 units of Reteplase.[15]

PATIENT PREPARATION

Discuss the procedure with the patient and/or their representative. Most patients with indwelling central venous access devices are very familiar with their use and idiosyncrasies. The patient will often be able to tell the Emergency Physician if the line has had problems in the past and the method used to correct the problem. Some patients will be able to suggest postural changes (e.g., raising an arm or lying in the Trendelenburg position) that will help the catheter function better. Obtain a posteroanterior and lateral chest radiograph to confirm that the tip of the catheter is in a proper location.

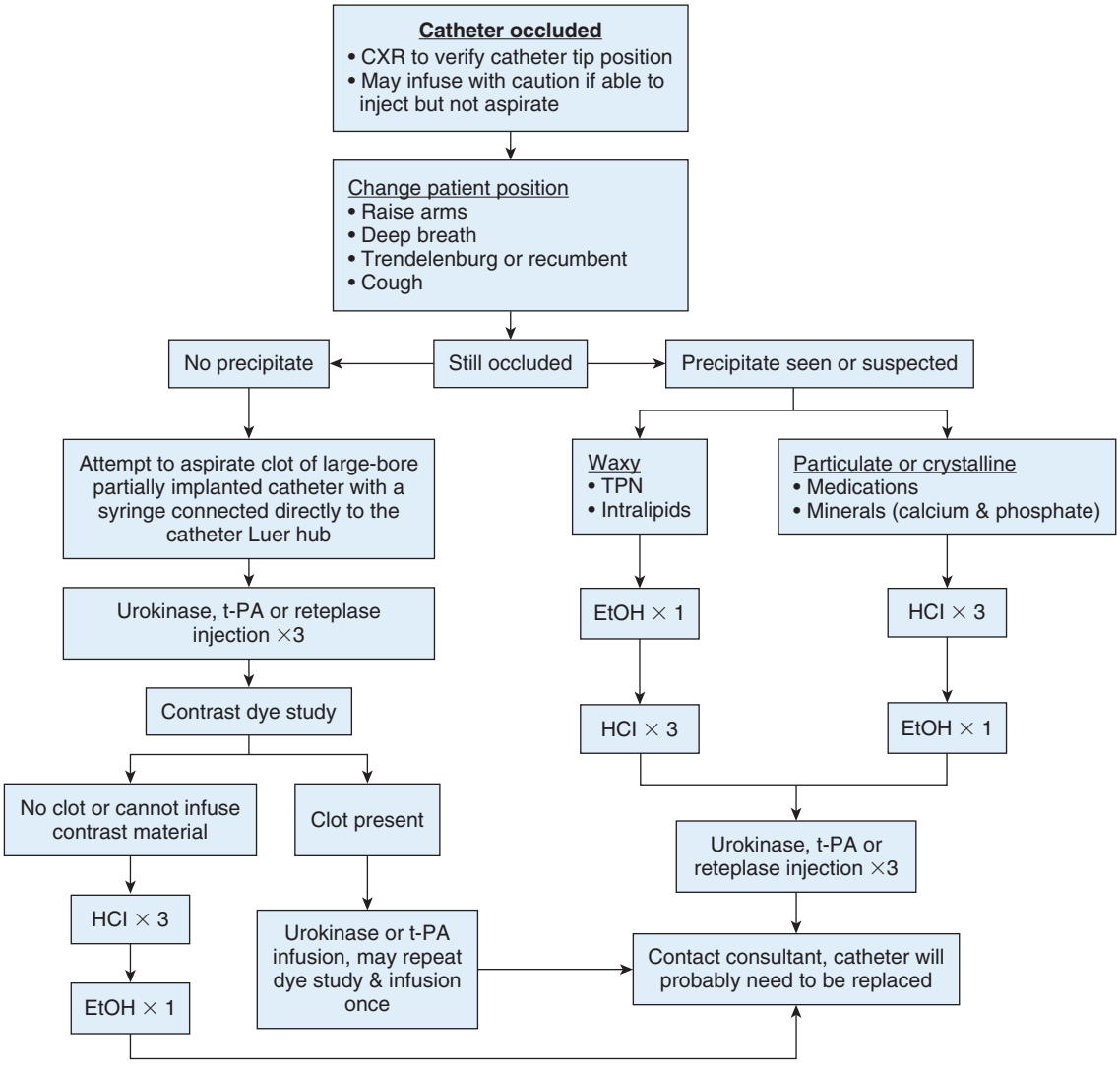


FIGURE 51-1. An algorithmic approach to the occluded central venous catheter. Continue to work down the protocol until the occlusion is resolved (CXR, chest radiograph; EtOH, 70% ethanol in water; HCl, 0.1 normal hydrochloric acid solution; TPN, total parenteral nutrition).

The chest radiograph is a good screening tool that allows the Emergency Physician to often diagnose catheter complications. A malpositioned catheter or one with the tip abutting the vessel wall must be removed and replaced. A catheter whose flow changes with patient arm position may be subject to the "pinch-off" phenomenon. This may be visible as a kinking of the catheter as it passes between the clavicle and first rib. A series of chest radiographs with the arm at the patient's side and elevated may reveal the kinking or pinching-off of the catheter. These catheters require removal. A catheter may migrate intravascularly so that it is within the contralateral subclavian vein. An Interventional Radiologist may be able to insert a wire or snare into the femoral vein to grasp and reposition the catheter. Arrhythmias associated with a catheter tip positioned within the heart require the catheter to be removed and a new one inserted. The distal catheter can curve upward so that it lies within the jugular vein. An Interventional Radiologist may be able to reposition it. Otherwise, it must be removed and replaced.

Any manipulation, injection, or aspiration of a central venous line must be done using strict aseptic techniques. Clean any dirt and debris from the distal port of a partially implanted device or the skin overlying the reservoir of a fully implanted device. Apply povidone iodine or chlorhexidine and allow it to dry. Wipe off the iodine (if used) with a sterile alcohol prep pad. **This process must be performed every time a needle is inserted into a central venous access device.**

TECHNIQUES

An algorithmic approach to the occluded indwelling central venous catheter is summarized in **Figure 51-1**.[9,14] **The key principle is that forced irrigation of the catheter, especially with a 1 mL syringe, is never performed as the catheter may rupture.**

A catheter that flushes easily but cannot be aspirated may have a fibrin sheath around the catheter tip forming a one-way valve. The tip may also be lodged against the wall of the superior vena cava or the right atrium. Repositioning the patient may alleviate the problem. The catheter may be cautiously used for an infusion if there are no signs of infection (e.g., new heart murmur, fever, erythema, or discharge at the catheter or subcutaneous reservoir

site) and the catheter tip is in good position. Refer the patient to their Primary Care Provider or a consultant for follow-up of the malfunction.

The problem is more serious if the catheter does not easily flush. Attempt to obtain peripheral intravenous access while attempting to correct the problem with the central venous catheter. If there are no signs of infection, and the catheter is not ruptured or malpositioned, the Emergency Physician must decide if a prolonged effort at resolving the occlusion is necessary. If so, proceed as described below and in **Figure 51-1**.

PARTIALLY IMPLANTED CATHETERS

A clot or small amount of precipitate within the partially implanted catheter may be able to be aspirated if the catheter bore is large enough to permit passage. Remove the Luer-lock cap from the catheter. Connect a 10 mL syringe with 2 to 3 mL of sterile saline directly to the occluded port's Luer adapter. Any clot large enough to occlude the catheter will not pass through a needle. Apply negative pressure to the syringe. The catheter is probably occluded by a clot or a precipitate if the obstruction cannot be aspirated. Remove the syringe and attach a new Luer-lock cap.

If a precipitate is seen in the catheter aspirate, determine if it is waxy or solid. Waxy precipitates are due to the lipid component of parenteral nutrition fluids. Waxy precipitates may be dissolved with a solution of 70% ethanol in water. Inject 1 to 2 mL of this alcohol–water solution and allow it to dwell in the catheter for 1 hour. Aspirate the catheter to determine patency. If still occluded, inject 1 to 2 mL of 0.1 N hydrochloric acid solution. Allow the solution to dwell in the catheter for 20 minutes. Aspirate the catheter to determine patency. Attempt to infuse 0.1 N hydrochloric acid solution two more times. The next step is to infuse a thrombolytic agent, as described below, or to replace the catheter.

Solid precipitates are due to precipitation of medications or minerals. Dilute 0.1 hydrochloric acid solution may be used to dissolve precipitated calcium and phosphate crystals. Infuse 1 to 2 mL of 0.1 N HCl and allow it to dwell in the catheter 20 minutes. Aspirate the catheter to determine patency. The process may be repeated up to three times. If still occluded, inject 1 to 2 mL of 70% ethanol in water and allow it to dwell in the catheter for 1 hour. Aspirate the catheter to determine patency. The next step is to inject a thrombolytic agent, as described below, or to replace the catheter.

If no precipitate is present, or if efforts to clear the precipitate fail, a clot may be present within the catheter lumen. Clots probably form to some extent in the majority of implanted central venous catheters. The clots may obstruct the catheter lumen.[13] Thrombosis of the central veins, superior vena cava, or right atrium may also occur. Suspect a major vein thrombosis if there is swelling, pain, or edema of anatomic structures that are drained by the cannulated vein(s).

Small clots may be dissolved by a bolus or infusion of a thrombolytic agent. Inject 1 mL of urokinase (5000 U/mL), 2 mL of t-PA (1 mg/mL), or 0.4 units of Reteplase into the catheter. Allow the solution to dwell in the catheter for 30 minutes. Aspirate the catheter to determine patency. This process may be repeated up to three times. For catheters with multiple occluded ports, the medication dosing should remain the same but divided into equal doses between the ports. If still occluded, inject 2 mL of intravenous contrast dye under fluoroscopy or inject the dye and obtain a radiograph. If no clot is present or if the contrast material will not infuse, attempt to clear the catheter with hydrochloric acid solution (up to three times) and 70% ethanol in water.

If a clot is present within the catheter, a continuous thrombolytic infusion may be considered. The infusion should occur through an intravenous line equipped with a 0.22 micron or 0.45 micron filter. A urokinase infusion may be begun over a 24-hour period. Administer the urokinase at a dose of 200 U/kg-hr mixed to run at a rate of at least 20 mL/h.[8,9] A continuous t-PA infusion may also be started. Use 2 mg/20 mL as a low dose for ports, 4 mg/20 mL as a high dose for ports, or 5 mg/50 mL as a high dose for tunneled catheters. Set the t-PA infusion rate at 10 mL/h for low and high doses for ports or 20 mL/h for high dose tunneled catheters. Thrombolytic infusions should be undertaken in consultation with the patient's Primary Care Provider as the patient will require hospital admission.

Consider consulting an Interventional Radiologist if these methods do not successfully clear the catheter or if a thrombolytic infusion is contraindicated. They can perform percutaneous fibrin sheath stripping, exchange over a wire, or removal and replacement of the malfunctioning catheter. Alternatively, the Emergency Physician may place a new central venous catheter at another site if the patient requires immediate vascular access.

FULLY IMPLANTED CATHETERS

The procedure is the same for a fully implanted central venous access device with one exception. The subcutaneous reservoir will not be able to be initially cleared by aspiration. Any clot or precipitates large enough to occlude a catheter will not pass through a noncoring (Huber) needle. **Always use a noncoring (Huber) needle when aspirating or injecting through a fully implanted catheter.**

AFTERCARE

Indwelling central venous lines must be flushed with saline, followed by the appropriate heparin solution if necessary, after clearing the obstruction. Refer to Chapter 49 for the complete details. Patients given thrombolytics must be assessed for bleeding at the catheter site and elsewhere prior to discharge, if they do not require hospital admission. The success rate for thrombolytics restoring catheter patency are greater than 80%.[16,17] Patients receiving prolonged thrombolytic infusions should be admitted for the infusion and for monitoring of potential bleeding complications. Patients and their care providers must be made aware of any catheter malfunctions and the attempts made at restoring catheter patency.

COMPLICATIONS

The complications associated with attempts to de-occlude a catheter include catheter rupture, disconnection of the catheter from any implanted reservoir, hemorrhage, and contamination of the catheter with subsequent infection. No major bleeding episodes or deaths have been associated with intracatheter thrombolysis.[15–17] Assessment for these complications is discussed in Chapter 49.

SUMMARY

In the course of their treatment, a number of patients with indwelling central venous access devices will present to the Emergency Department with malfunctioning catheters. Familiarity with the strategies for diagnosing and correcting the catheter dysfunction will enable the Emergency Physician to restore the function of some, but not all, indwelling lines. Early consultation with the patient's Primary Care Provider, Vascular Surgeon, or Interventional Radiologist is essential if the procedures outlined do not promptly restore the catheter's function.

52 Accessing Indwelling Central Venous Lines

Lisa Freeman Grossheim

INTRODUCTION

Venous access for medication administration, nutritional support, hemodialysis, and blood sampling is essential for the management of many chronic diseases. A variety of indwelling central venous access devices have been developed to avoid repeated venipunctures and permit direct access to the central circulation. These devices may be partially or completely implanted under the patient's skin. The Emergency Physician must be able to access these devices to administer medications and withdraw blood samples without damaging the device or causing it to clot off. The necessary procedures for successfully accessing indwelling central venous lines are described in this chapter.

ANATOMY AND PATHOPHYSIOLOGY

Indwelling central venous lines allow access to the central venous circulation from a peripheral site.[1,2] This is accomplished through either the end of a partially implanted catheter or through the skin into a subcutaneous reservoir of a fully implanted catheter (**Figure 52-1**). The proximal tip of the central venous line may lie in the superior vena cava or in the right atrium. Catheters designed for right atrial placement are made of softer and more pliable material than are catheters used for short-term transcutaneous central venous access. These catheters are unlikely to erode through or perforate the thin right atrial wall.

The internal jugular, subclavian, and femoral veins can all be utilized as a route for a central venous line to access the superior vena cava or right atrium. The subclavian veins are most commonly used to maximize patient comfort and mobility. When the line is initially inserted, the vein is punctured transcutaneously, the catheter is inserted into the vein, and its distal end is tunneled under the skin. If the line is partially implanted, the distal end of the catheter is brought external to the skin through a small puncture (**Figure 52-1A**). If the line is fully implanted, its distal end is connected to a subcutaneous reservoir that is placed in a pocket dissected under the skin of the chest wall (**Figure 52-1B**).

PARTIALLY IMPLANTED CATHETERS

Partially implanted central venous catheters (**Figures 52-1A & 52-2**) are those whose distal end emerges from the skin via a subcutaneous tunnel.[3] This tunnel helps prevent the spread of skin flora along the outside of the catheter and toward the central circulation. Most partially implanted catheters use a subcutaneous Dacron cuff to further insulate the proximal catheter from skin flora and help anchor the catheter in place.[4]

A variety of models are in use, including the Broviac,[5] Hickman,[6] and Groshong[7] catheters. All are available in single-lumen or multiple-lumen versions. Broviac and Hickman catheters must be flushed with heparin solution twice weekly. The Groshong catheter is unique in that it has a slit valve at its proximal end that prevents blood from reentering the catheter once it has been flushed (**Figure 52-3**). Groshong catheters need only a weekly saline flush to prevent clot formation.

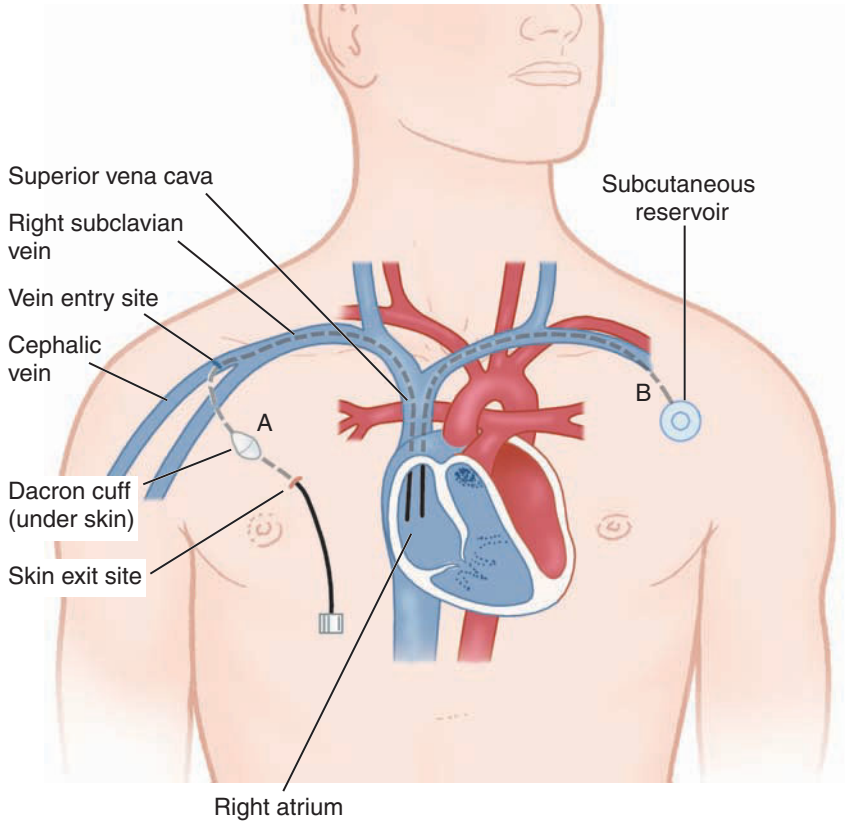


FIGURE 52-1. Indwelling central venous lines. **A.** The partially implanted central venous line. The distal end of the line emerges from the chest wall. Contamination of the implanted portion is prevented by a subcutaneous tunnel and a Dacron cuff around the catheter. **B.** The fully implanted central venous line. The catheter is connected to a reservoir that is contained in a subcutaneous pocket.

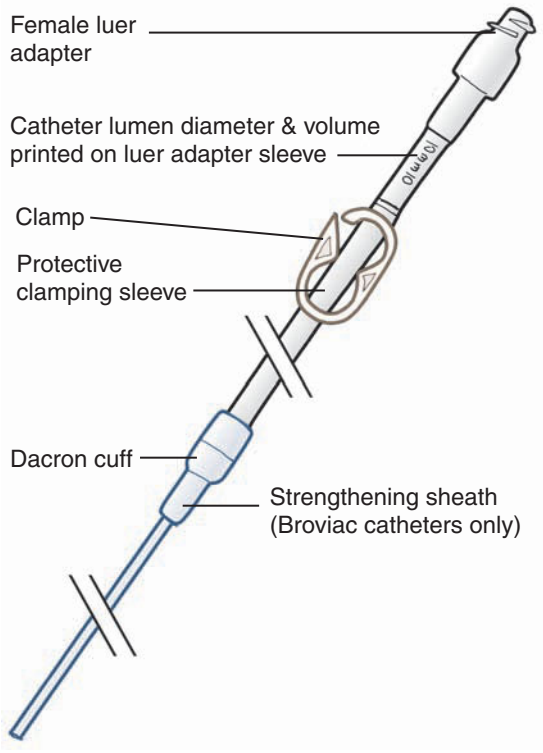


FIGURE 52-2. The partially implanted central venous catheter. A single-lumen (Hickman or Broviac) line is shown schematically. The Dacron cuff lies in the subcutaneous tissue just proximal to the skin entry site. The catheter tip lies in either the proximal superior vena cava or the right atrium.

The Hemocath or Permacath is the largest bore of the right atrial catheters. It is manufactured by Quinton and is used for hemodialysis, plasmapheresis, long-term nutritional support, and analgesia. These catheters are typically flushed during dialysis, but otherwise should be flushed three times per week with heparinized saline.

FULLY IMPLANTED CATHETERS

Fully implanted central venous catheters are those that are entirely embedded and do not exit the skin (**Figures 52-4 & 52-5**). The

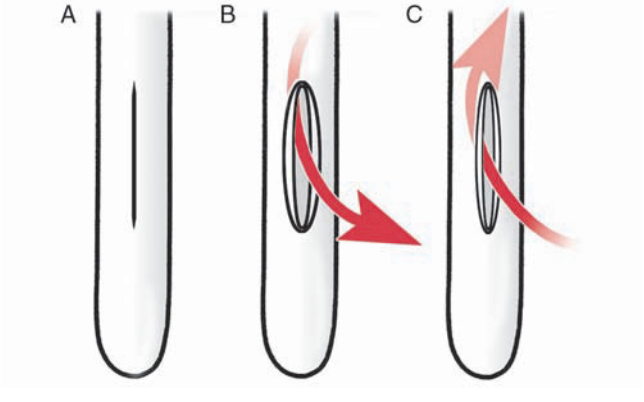


FIGURE 52-3. The Groshong central venous catheter tip. Detail of the Groshong three-position slit valve that prevents venous blood from passively entering the catheter when it is not in use. **A.** The closed or resting position of the slit valve. **B.** The valve opens outward from positive pressure when the catheter is flushed or infused. **C.** The valve opens inward from negative pressure when the catheter is aspirated.

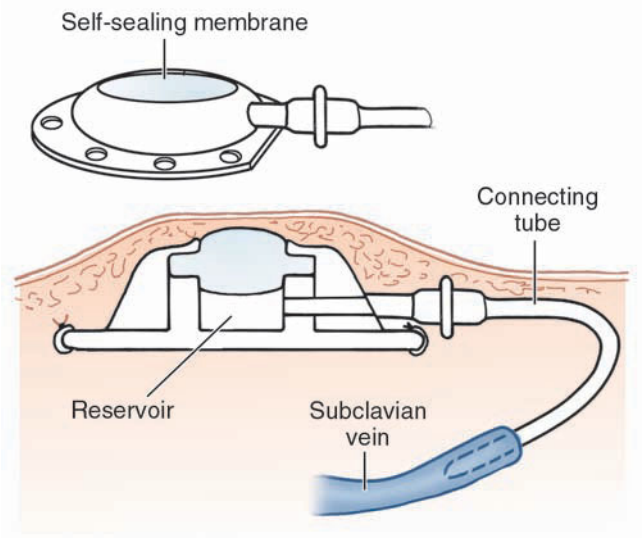


FIGURE 52-4. The fully implanted central venous catheter. The reservoir lies in the subcutaneous tissue and is anchored with sutures to keep the diaphragm facing the skin surface.

catheter's distal end is attached to a subcutaneously implanted reservoir.[4] Various catheters, including Hickman and Groshong catheters, can be attached to a subcutaneous reservoir. Most fully implanted central venous access systems are known by the brand names Port-A-Cath and Infusaport. Most manufacturers recommend that these catheters must be flushed with a heparin solution monthly when not in use.[7] However, there are some data that suggest that flushing of the port system can be done every 3 months without any increase in complications.[7] The reservoir's infusion port is covered with a self-sealing silicone rubber membrane (**Figures 52-4 & 52-5**). **Specially designed noncoring or Huber**

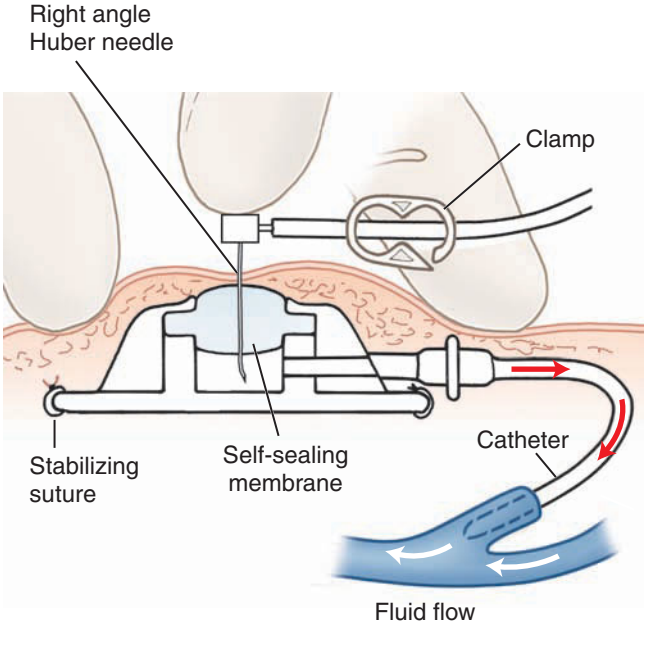


FIGURE 52-5. Accessing the fully implanted central venous catheter system. The reservoir is stabilized between the fingers of the Emergency Physician's nondominant hand as a noncoring (Huber) needle is used to penetrate the skin and reservoir.

needles must be used when accessing the subcutaneous reservoir to avoid permanently damaging the self-sealing membrane.

PERIPHERALLY INSERTED CENTRAL CATHETERS

Peripherally inserted central catheters are also known as PICC lines. They are inserted into the brachial, cephalic, or antecubital vein of the upper extremity and advanced into the subclavian vein. The greatest drawback for the use of PICC lines is the 50% risk of catheter-related thrombosis. PICC lines are made of either silicone or polyurethane. They are 50 to 60 cm long and have an outside diameter of 2 to 7 French, with the 5 French being most commonly used. They are available in both single-lumen and double-lumen versions. Some PICC catheters are equipped with a Dacron cuff similar to the Broviac and Hickman catheters.

PERCUTANEOUS CENTRAL VENOUS CATHETER

A device similar to the PICC is known as the percutaneous central venous catheter (PCVC). This catheter is often used in neonates in the neonatal intensive care unit and not in the Emergency Department. It is available in three sizes (1.1, 1.9, and 2.8 French). The 2.8 French size is used more often because the smaller sizes tend to become occluded with a thrombus. This device is only mentioned for completeness.

INDICATIONS

PATIENTS REQUIRING INDWELLING CENTRAL VENOUS LINES

Patients of all ages and with a variety of diagnoses may present with an indwelling central venous line. Some examples of such presentations are chronic painful conditions requiring parenteral analgesia (e.g., sickle cell disease), chronic infections requiring long-term parenteral antibiotics (e.g., endocarditis, osteomyelitis), the need for prolonged hyperalimentation, patients with difficult peripheral intravenous access, and cancer patients required chemotherapy and blood sampling. Any patient who will require several weeks of repeated intravenous blood sampling and/or drug administration is a candidate for an indwelling central venous line.

ACCESS OF INDWELLING CENTRAL VENOUS LINES

Fully or partially implanted central venous access devices may be accessed routinely when phlebotomy is required, medications must be administered, or intravenous fluids must be administered.

CONTRAINDICATIONS

Do not access an indwelling central venous device if peripheral intravenous access can be obtained. The use of bedside ultrasound may facilitate peripheral intravenous access and avoid accessing the indwelling device. Fully implanted devices should not be accessed through infected skin. Partially implanted catheters known or suspected to be infected should be used cautiously, as they may be a source of septic emboli, although it is sometimes possible to treat catheter sepsis without removing the device.[8,9] Phenytoin and diazepam cannot be given via silicone indwelling central venous lines as they can crystallize and permanently obstruct the catheter lumen.[10]

Devices used for hemodialysis should be accessed only in a true emergency and if no other method of venous access can be readily obtained. This guideline is intended to prevent loss of the patient's dialysis access due to device damage, clotting, or an infection. An inability to dialyze the patient will lead to significant morbidity and mortality. There are a finite number of veins available for dialysis access.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gauze, 4 × 4 squares
- 10 mL syringes
- 20 gauge needles
- Sterile saline, 0.9%
- Heparinized saline flush (100 and 1000 U/mL)
- Adhesive tape
- Luer-lock caps
- Blood collection tubes
- Infusion set
- Any intravenous fluids or medications to be injected
- Huber needle, noncoring right angle or straight angle
- Topical anesthetic (EMLA cream, ethynyl chloride spray, or ice)
- Injectable anesthetic without epinephrine, 1% lidocaine
- Sterile alcohol prep pads
- Sterile gloves
- Sterile drapes

PATIENT PREPARATION

Discuss the necessary procedure with the patient and/or their representative. Obtain an informed consent for accessing the device. Patients with indwelling central venous lines are usually very familiar with their care and use. They can often advise the Emergency Physician on the correct procedure, the appropriate flush solution, and any anatomic manipulations necessary to optimize flow through the line (e.g., raising the arms, turning the head, etc.). **Aseptic technique is required at all times when accessing indwelling central venous catheters.**

TECHNIQUES

PARTIALLY IMPLANTED CATHETERS

Accessing a partially implanted central venous catheter is simple and similar to accessing a heparin-locked peripheral intravenous catheter.[7,10] Remove any adhesive tape and gauze wrapped around the distal end of the lumen to be accessed. Fasten the catheter clamp on the desired lumen (**Figure 52-2**). Clean the catheter cap and Luer adapter with povidone iodine or chlorhexidine solution and allow it to dry. The technique for accessing the catheter will vary depending on whether blood sampling with or without a subsequent infusion is required. Both techniques are described below.

BLOOD SAMPLING FROM PARTIALLY IMPLANTED CATHETERS

Blood samples may be withdrawn through the catheter cap using a 20 gauge hypodermic needle attached to a 10 mL syringe if blood is to be sampled without beginning an infusion. Insert the needle through the Luer cap. Open the catheter clamp. Withdraw 5 mL of blood from the catheter. Discard the blood sample, needle, and syringe. This blood sample is diluted by the catheter contents (i.e., saline or heparinized saline) and does not truly represent the circulating blood. This step is essential when accessing dialysis catheters

as they contain a dose of concentrated heparin (1000 U/mL). If unable to aspirate blood, gently flush the catheter with 2 to 3 mL of sterile saline. **Avoid using a syringe smaller than 5 mL to inject as pressure high enough to damage the catheter can be generated.** Refer to Chapter 51 for troubleshooting instructions if the catheter does not flush easily.

Withdraw the required blood samples using a new needle and syringe. Transfer the blood samples into collection tubes for the laboratory. The catheter must now be flushed to prevent it from clotting off. Flush the catheter with the appropriate solution in a 10 mL syringe armed with a 20 gauge needle. Inject 3 to 5 mL of heparinized saline (100 U/mL) into Broviac and Hickman catheters. Inject 5 mL of normal saline into a Groshong catheter. Inject dialysis catheters with the volume printed on the catheter, usually ≤2 mL, of heparinized saline (1000 U/mL). Wipe off the cap with an alcohol pad.

Secure the free end of the catheter. Tape the catheter to the patient's chest wall to prevent accidental traction on the catheter. Evaluate the skin puncture site. Reapply a dressing over the skin puncture site if necessary.

BLOOD SAMPLING AND INFUSION THROUGH PARTIALLY IMPLANTED CATHETERS

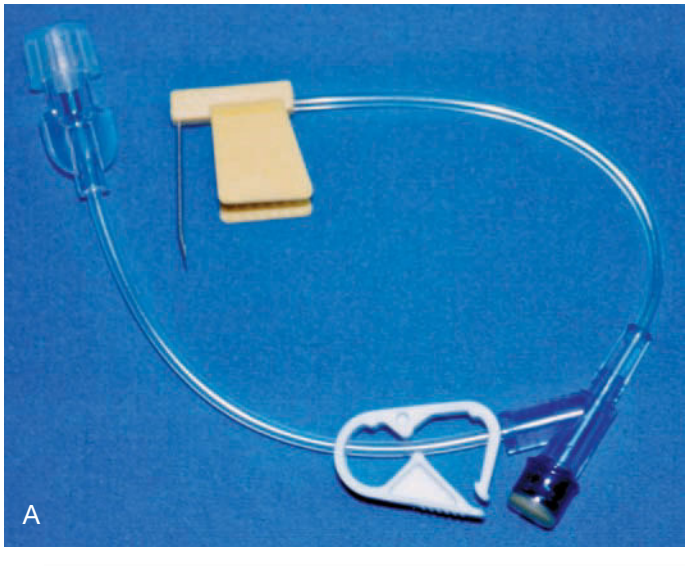
The Luer catheter cap can be removed entirely and the catheter lumen accessed directly with a Leur-hub syringe if an infusion is to be subsequently started. **Ensure that the catheter clamp is securely closed.** Remove the cap from the catheter. Attach a 10 mL syringe to the hub of the catheter. Open the catheter clamp. Withdraw 5 mL of blood into the syringe. Close the catheter clamp. Remove and discard the syringe with the original blood sample. Apply a new syringe, open the catheter clamp, and withdraw the blood sample. Close the catheter clamp. Remove the syringe. Continue this sequence of events until all required blood samples are obtained. **It is imperative to make sure that the catheter is clamped when the cap or syringe is removed to prevent an air embolism.** Securely attach primed intravenous tubing to the hub of the catheter, open the catheter clamp, and begin the infusion.

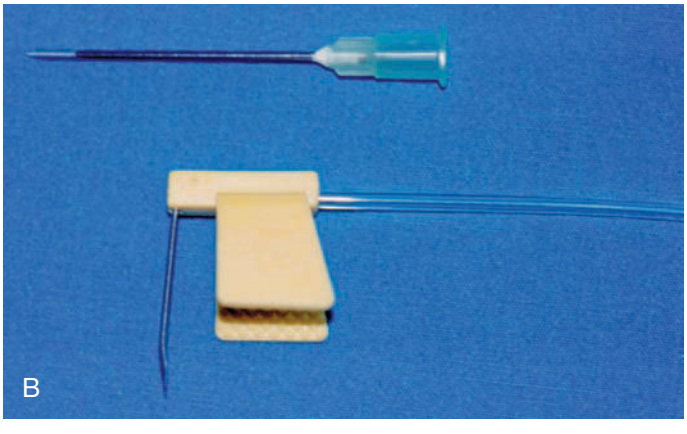
Clamp the catheter lumen when terminating the infusion or if no infusion is to be started. Remove the intravenous tubing or the syringe from the catheter. Attach a syringe containing the appropriate flush solution, open the catheter clamp, and flush the catheter. Close the catheter clamp. Remove the syringe. Apply a new sterile cap onto the hub of the catheter. **Never use "needle-less" caps, as they are a potential source of air emboli.** Open the catheter clamp to prevent catheter damage from long-term clamping. Secure the catheter to the patient's chest wall.

FULLY IMPLANTED CATHETERS

A noncoring Huber-type needle must be used to access subcutaneous injection ports (Figures 52-5 & 52-6). A small-gauge standard hypodermic needle can be used only in a dire emergency if a noncoring needle is not available. **The diaphragm covering the injection reservoir can be damaged by a standard hypodermic needle, leading to subcutaneous hemorrhage and necessitating surgical replacement of the implanted device.**

Clean and prep the skin overlying the injection port with povidone iodine or chlorhexidine solution and allow it to dry.





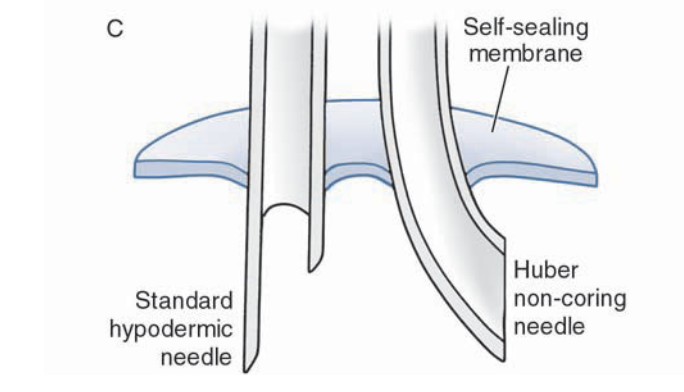


FIGURE 52-6. The Huber needle. **A.** Photo of a complete right-angle Huber needle set, including the extension tubing and clamp. **B.** Photo showing the right-angle Huber needle compared with a standard hypodermic needle. **C.** Drawing showing the key difference between a standard hypodermic needle and the Huber needle. The hypodermic needle tip can cut a cylindrical core of subcutaneous tissue and the diaphragm sealing the subcutaneous reservoir. The Huber needle pushes the subcutaneous tissue and the diaphragm material aside without removing any of it.

TABLE 52-1 Volumes and Concentrations of Heparin Flushes for Pediatric Indwelling Devices

	Children < 6 months old	Children > 6 months old
Partially implanted device	3 mL heparin (10 U/mL)	5 mL heparin (100 U/mL)
PICC line	3 mL heparin (10 U/mL)	5 mL heparin (100 U/mL)
Fully implanted device	3 mL heparin (10 U/mL)	5 mL heparin (100 U/mL)

The application of a topical or injectable anesthetic over the reservoir is optional but greatly appreciated by the patient. Remove the iodine solution (if used) with an alcohol swab. Flush the Huber needle and extension tubing with normal saline using a 10 mL syringe. Leave the syringe attached. Locate the center of the self-sealing membrane (diaphragm). Stabilize the reservoir with the nondominant hand (**Figure 52-5**). Slowly and steadily insert the needle through the skin and into the reservoir (**Figure 52-5**). Stop advancing the needle when it touches the far wall of the device. Gently flush 2 to 3 mL of saline through the needle. Refer to Chapter 51 for troubleshooting instructions if the catheter does not flush easily.

If the catheter can be flushed easily, secure the Huber needle in place by stabilizing it with gauze squares and tape. Withdraw 5 to 10 mL of blood. Close the clamp on the extension tubing (**Figure 52-5**). Remove and discard the syringe. Attach a new syringe, open the clamp, and withdraw the required blood samples. Clamp the extension tubing and remove the syringe. If an infusion is to be started, attach the primed intravenous tubing and begin the infusion. If no infusion is desired or when discontinuing an infusion, clamp the extension tubing and disconnect the intravenous tubing. Attach a 5 or 10 mL syringe containing heparinized saline (100 to 200 U/mL) to the Huber needle extension tubing. Open the clamp and flush the device with 3 to 5 mL of heparinized saline. Use only saline if a Groshong catheter is attached to the reservoir. Remove the Huber needle from the skin. Control any skin bleeding with direct pressure. Apply a sterile dressing.

PEDIATRIC CONSIDERATIONS

The management of pediatric indwelling devices is similar to those in adults with a few noted exceptions. The catheters, reservoirs, and tubing are often smaller than those used in adults or adolescents. The volumes and concentrations of heparin flushes differ in these smaller catheters (**Table 52-1**). The external portion of partially implanted devices and PICC lines must be secured with a dressing so that the child does not pull it out.

ASSESSMENT

Assessment of line function after accessing a central venous access device will not occur until the next access attempt. This procedure is described above. Troubleshooting nonfunctioning indwelling central venous lines is discussed in Chapter 51.

AFTERCARE

Secure the partially implanted catheter to the skin with tape so that the tubing will not get caught on the patient's clothing. The patient should be given a written record of how the access device was used and flushed in the Emergency Department to convey to their Primary Care Physician should problems with the line become evident at a later time. Patients must regularly assess their indwelling access sites for signs of infection (i.e., erythema, pain, purulent discharge, or serous discharge). Instruct the patient to immediately contact their Primary Care Provider or return to the Emergency Department if they develop a fever or other signs of an infection.

COMPLICATIONS

The most important elements after accessing indwelling lines are to not allow the central venous line to clot off and not to contaminate the line. Strict adherence to the procedures described above will minimize the chances of these problems occurring. Complications associated with the catheter include right atrial thromboses, right atrial erosion with pericardial tamponade (rare with implanted lines), catheter-related infections, and pulmonary embolism.[7,9,11,12] Fully implanted catheters may become disconnected from the subcutaneous reservoir or may leak into the subcutaneous tissue due to diaphragm failure. Any hematoma formation near the reservoir must be assessed promptly to prevent major hemorrhage. Infection and line sepsis can be prevented using strict sterile technique.

An air embolism should be suspected if the patient becomes confused, hypotensive, and/or tachycardic while accessing the central venous access device. This complication is 100% preventable by ensuring that the catheter tubing is clamped closed whenever the end of the tubing is without a cap. Immediately place the patient in the Trendelenburg position and on their left side (i.e., left lateral decubitus position). This will hopefully cause any air emboli to collect in the apex of the right ventricle and not enter the pulmonary artery.

Repair kits are available for damaged partially implanted catheters. These can serve to avoid the need to remove the device and implant a new catheter. If the external tubing of the partially implanted catheter is damaged, apply a smooth catheter clamp proximal to the damaged area and arrange to have the device repaired. Instructions for the use of these kits are beyond the scope of this chapter.

SUMMARY

The Emergency Physician will encounter many patients with indwelling central venous lines. Careful adherence to sterile technique as well as proper blood sampling and infusion techniques will allow access for phlebotomy, medication administration, and fluid administration while preserving the indwelling line for future use.

53 Pulmonary Artery (Swan-Ganz) Catheterization

Pratik Doshi

INTRODUCTION

The routine clinical catheterization of the pulmonary artery was made possible by the pioneering work of H.J.C. Swan and William Ganz. Together they developed the soft, balloon-tipped, flow-directed pulmonary artery catheter (PAC) that bears their names.[1] Prior to the work of Swan and Ganz, pulmonary artery catheterization was performed using a stiff catheter that required fluoroscopic guidance and was associated with a high complication rate. The Swan-Ganz PAC allows reliable and continuous measurement of hemodynamic parameters to be performed safely, even in critically ill patients.[2–4] While complications are uncommon, they can

occur. The optimal application of the PAC, both its insertion and interpretation of the data, requires appropriate training and skill.[5–7]

This chapter concentrates on the technique of PAC insertion. Obtaining central venous access is a necessary prerequisite for this technique and is discussed in Chapter 49. A detailed discussion of the interpretation of the abundant variety of data that the PAC may provide is beyond the scope of this chapter.[8] The interpretation of data is discussed primarily as it concerns PAC insertion and associated complications.

ANATOMY AND PATHOPHYSIOLOGY

The PAC is advanced into the right atrium from a venous access site in the neck, chest, upper extremity, or lower extremity. The balloon near the tip of the catheter is inflated during its insertion. The balloon follows the flow of blood through the right heart—from the right atrium through the tricuspid valve into the right ventricle, then up the right ventricular outflow tract through the pulmonic valve into the pulmonary artery, and from there into a branch of the pulmonary artery (**Figure 53-1**).

When the PAC is correctly positioned, inflating the balloon near its tip will occlude the forward blood flow to that arterial segment (**Figure 53-2**). The lumen opening at the tip of the PAC will therefore measure the downstream pressure in that vessel, rather than pulmonary artery pressure. Because the pulmonary circulation has no valves, the pressure that the PAC tip measures beyond the inflated balloon is equal to the pressure in the pulmonary capillaries. This pressure is, in turn, equal to the pressures in the pulmonary veins and the left atrium. During diastole, when the mitral valve is open, this pressure is equal to the left ventricular diastolic pressure. The left ventricular end-diastolic pressure is a very important parameter because it is the best clinical indicator of preload. Thus, measurement of the pulmonary capillary wedge pressure (or pulmonary artery occlusion pressure, as it is sometimes called) provides an excellent assessment of left ventricular filling without the need to catheterize the left side of the heart.

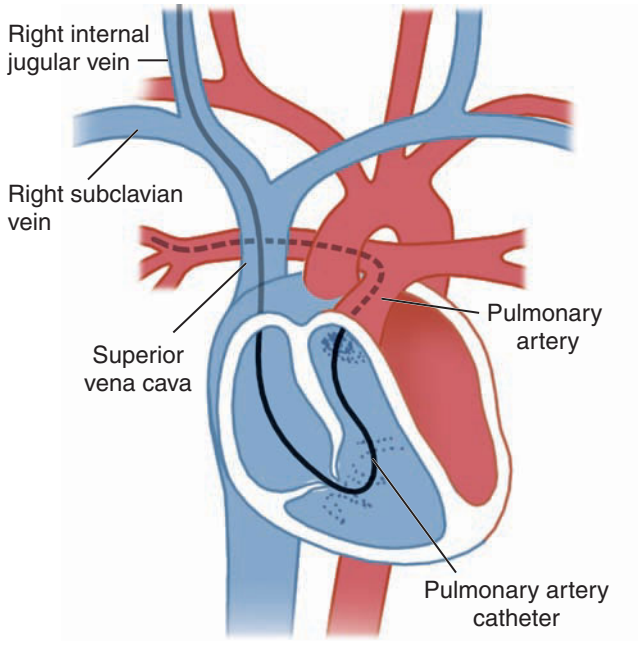


FIGURE 53-1. Cardiac anatomy as it pertains to pulmonary artery catheter insertion. The PAC enters the right atrium from the superior vena cava, crosses the tricuspid valve into the right ventricle, and then crosses the pulmonic valve into the pulmonary artery. The catheter tip lies in a branch of the right pulmonary artery.

The PAC may also be used to measure cardiac output using the thermodilution method. The tip of the PAC has a temperature-sensitive probe. When a given volume of cold saline is injected into the right atrial port of the PAC, it cools the temperature of the blood flowing past the catheter tip. If the cardiac output is high, the cold saline is mixed with and carried along by a larger flow of blood so that the temperature change detected at the PAC tip is smaller and

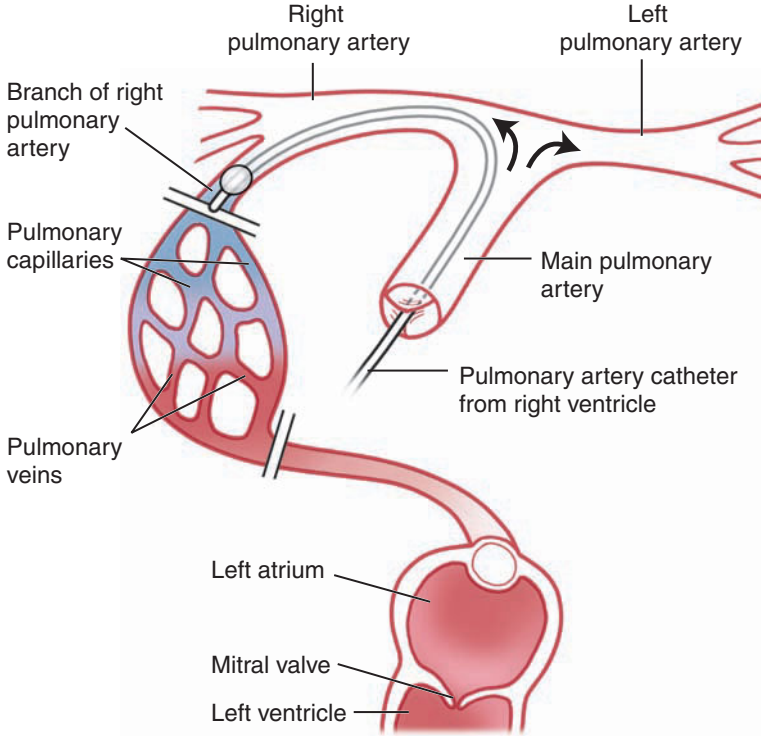


FIGURE 53-2. Diagram of the principle underlying pulmonary capillary wedge pressure. Balloon inflation blocks transmission of the forward pulmonary artery pressure to the tip of the catheter. The catheter tip therefore measures the downstream pressure of the pulmonary circulation. Because the pulmonary circulation has no valves, the pressure measured at the catheter tip is equal to the pressure in the left ventricle when the mitral valve is open (diastole).

dissipates faster. If cardiac output is low, the cold saline mixes with a smaller volume of blood and the temperature change is more apparent and slower to dissipate.

INDICATIONS

The major advantage of the PAC is that it provides accurate measurements of hemodynamic parameters such as pulmonary capillary wedge pressure and cardiac output. This is particularly useful in critically ill patients, as the clinical estimation of these parameters is frequently incorrect.[9–13] The PAC may be used for diagnostic or therapeutic purposes. Diagnostically, the PAC is usually used in situations where clinical judgment alone cannot reliably determine the physiologic basis for hemodynamic instability, pulmonary edema, or reduced urine output. Therapeutically, the PAC may help to direct therapy in patients in whom noninvasive clinical parameters are insufficient guides of treatment efficacy. The most common clinical indications for the PAC in medical and surgical patients are listed in **Table 53-1**.

It should be noted that despite the prevalence of PAC use, few prospective studies have documented improved clinical outcomes with the PAC except in perioperative surgical patients. Retrospective studies have suggested that the use of the PAC may be associated with worse outcomes.[14–17] Over the last 10 years, this question has been further studied in randomized controlled trials as a result of the retrospective data suggesting worse outcomes with the use of PAC. In all of these trials, PACs do not appear to improve survival or decrease length of stay. However, these trials also do not confirm the suggestion of worse outcomes with the use of PAC. As with any intervention, the Emergency Physician must carefully assess the potential benefits and risks in making the decision to place a PAC. There is an actual cost and potential complications associated with placement of these catheters.[21–28]

TABLE 53-1 Common Clinical Indications for Pulmonary Artery Catheter Placement in Medical and Surgical Patients

Cardiac

A. Complicated myocardial infarction
   i. Management of refractory hypotension or left ventricular failure
   ii. In the presence of hemodynamic deterioration due to a mechanical complication, to differentiate mitral regurgitation from acute ventricular septal defect
B. Other cardiac conditions
   i. Diagnose/manage cardiac tamponade
   ii. Distinguish cardiogenic from noncardiogenic pulmonary edema
   iii. Management of severe cardiomyopathy
   iv. Diagnose/manage severe pulmonary hypertension

Medical/Surgical

In the setting of sepsis, trauma, burns, multiple organ failure, pulmonary embolus, or drug overdose.

If any of the following is found to be unresponsive to conventional medical management:

A. Hypotension
B. Low urine output
C. Hypoperfusion (evidenced by cool skin, mental obtundation, and lactic acidosis)
D. Severe hypoxemia requiring high levels of PEEP (>10 cm)

Preoperative

A. High-risk cardiac surgery (e.g., CABG in elderly patients, multiple valve replacement, and ventricular aneurysm resection)
B. Complicated vascular surgery (dissecting aneurysm, resection of thoracic or abdominal aneurysm)
C. Other surgical patients with multiple risk factors
   i. Myocardial infarction within 6 months
   ii. Poor left ventricular function
   iii. Elevated Goldman or ASA score

CONTRAINDICATIONS

There are no circumstances in which PAC insertion is absolutely contraindicated. Insertion of a PAC may be relatively contraindicated in cases where the risks of obtaining vascular access (e.g., severe bleeding diathesis) or of passing the catheter (e.g., a mobile thrombus in the right heart or right-sided endocarditis) outweigh the potential benefits of obtaining the data the PAC provides.

A PAC is not indicated in situations where it will provide no diagnostic information that cannot be acquired by less invasive means. For example, while a PAC may be helpful in diagnosing or treating patients with mitral regurgitation or ventricular septal defects following myocardial infarction, echocardiography may be sufficiently diagnostic and may obviate the need for a PAC. The same can be true in cases of cardiac tamponade. The PAC may also be superfluous in situations where it will provide little or no therapeutic guidance. The insertion of a PAC is not necessary if a therapeutic trial of fluid administration restores urine output and blood pressure in a hypovolemic patient who has normal cardiac function. Other contraindications include patients with: cardiac dysrhythmias, implanted pacemakers or defibrillators, pulmonary hypertension, right-sided endocarditis, right-sided intracardiac valvular abnormalities, right-sided prosthetic heart valves, right-sided intracardiac thrombi, or severe hypotension. A PAC should not be inserted if the appropriate equipment is unavailable or if personnel experienced with the insertion and interpretation of the PAC data are not present.[19,20]

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves and gown
- Face mask and cap
- Saline or dextrose solution with or without heparin (1 to 2 U/mL)
- Pressure bag with manometer
- Pressure tubing
- Pressure transducer for distal port (CVP port optional)
- Stopcocks and occlusive caps for each port of PAC
- Fluid infusion tubing for sheath sideport and for PAC ports
- PAC
- Balloon inflation syringe
- Catheter sleeve
- Sterile dressing for site
- Electrocardiogram (ECG) and pressure monitor

The materials required to place a percutaneous introducer sheath are available in commercially prepared prepackaged kits. Refer to Chapter 49 for the details regarding the placement of the introducer sheath. Note that many PACs require an 8.5 French introducer sheath. In addition, it is desirable to use an introducer sheath that allows the sterile protective sleeve over the PAC to be affixed securely to the sheath.

The PAC consists of a balloon lumen that ends in a balloon just proximal to the catheter tip, a distal lumen that opens at the end of the PAC, a lumen that opens approximately 30 cm proximal to the tip, and a thermister (**Figure 53-3**). Many PACs have one or more additional lumens opening proximal to the tip. Some of these lumens are designed to accommodate a cardiac pacing wire. A 3 mL syringe with a safety stop at 1.5 mL is supplied with each PAC.

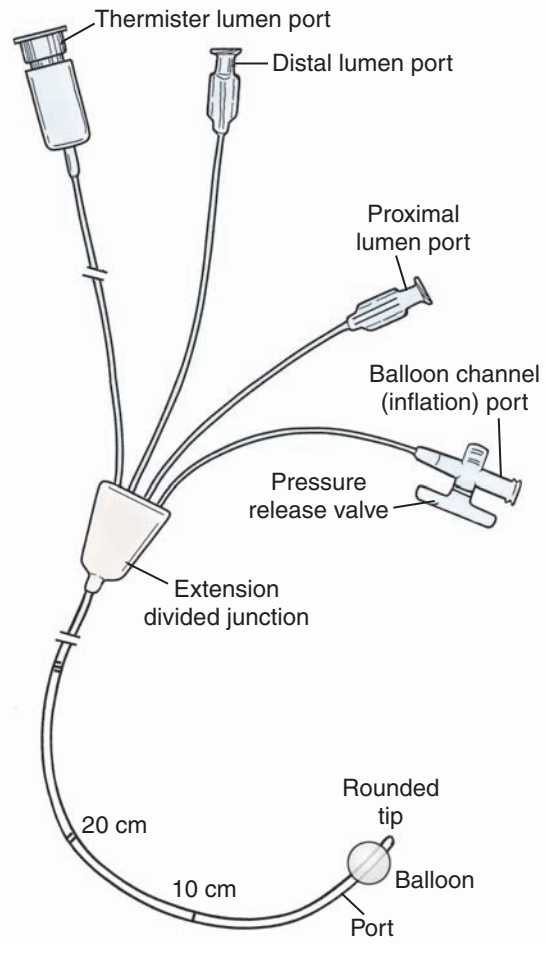


FIGURE 53-3. The pulmonary artery catheter.

This syringe is used to inject air into the balloon. Distances from the tip of the PAC are indicated by linear markings on the shaft. By the standard designation, each thin line represents 5 cm increments and each thick line 10 cm increments.

PATIENT PREPARATION

Routine laboratory studies are advisable prior to PAC insertion in nonemergent circumstances. Hematologic abnormalities (e.g., severe anemia, thrombocytopenia, and coagulation system deficiencies) can increase the risk or adverse consequences of bleeding. Electrolyte derangements (e.g., hyperkalemia, hypokalemia, and hypomagnesemia) that may predispose to arrhythmias should be identified and corrected when possible.

Explain to the patient and/or their representative the risks, benefits, and complications of the procedure. Obtain informed consent for the procedure if possible. The use of mild sedation may be advantageous in some patients. Place the patient supine if possible. Continuous ECG monitoring is essential. Pulse oximetry should be routinely monitored. Arterial pressure monitoring is often desirable in patients receiving a PAC. Apply supplemental oxygen. Equipment and personnel necessary for assisting with the PAC insertion procedure and for managing potential complications should be immediately available. This should include equipment for emergency airway management and emergency cardiac pacing.

The choice of which central venous access site to use for PAC insertion must be individualized. The preferred sites are the right internal jugular vein or the left subclavian vein. The PAC tends to float into the desired position more easily from these two sites. The left internal jugular vein and the right subclavian vein are acceptable alternatives. The femoral vein may also be used. The femoral approach may be quite difficult without fluoroscopic guidance of the catheter. The external jugular veins, basilic veins, and axillary veins are additional alternatives that carry the same difficulty.

It is essential that strict sterile technique be maintained throughout the insertion procedure. The Emergency Physician and their assistant should be wearing sterile gloves, a sterile gown, a face mask, and a cap. A large sterile field is necessary, as is close attention to the long PAC, which can easily become contaminated. It is also very important to take all necessary precautions with syringe needles, scalpel blades, and suture needles to prevent a needlestick injury.

Insert a percutaneous introducer sheath into the central venous system. Refer to Chapter 49 for the complete details regarding the insertion of the sheath. If the patient already has a single-lumen or multi-lumen central venous catheter inserted, it may be exchanged for an introducer sheath. Remove any bandages and dressings on the catheter and skin access site. Thoroughly prep the catheter, skin access site, and surrounding skin with povidone iodine or chlorhexidine solution and allow it to dry. Drape a sterile field. Discontinue any infusions through the catheter. Open an introducer sheath kit. Cut any sutures securing the catheter to the skin. Insert a guidewire through the hub of the distal port and into the central venous circulation. Withdraw the catheter over the guidewire. Insert and secure the percutaneous sheath over the guidewire as described in Chapter 49.

TECHNIQUE

Set up a bedside sterile table and open the PAC kit. Remove the protective sleeve. It allows later repositioning of the PAC while maintaining sterility. Place the sleeve over the catheter and slide it far back (>60 cm) from the catheter tip. Attach the balloon inflation syringe to the PAC. Inflate the balloon once to confirm the integrity of the balloon. It is a good idea to inflate the balloon in a full bowl of sterile saline and observe for air bubbles to ensure that there are no leaks or gross eccentricities. Allow the balloon to deflate passively. **Deflation by aspirating air from the balloon should be avoided as it places undue stress on the balloon.** Flush the PAC ports with sterile saline and attach a stopcock to each port. Attach the pressure tubing to the distal port. Flush the entire apparatus, including the PAC and the pressure monitoring system, with sterile saline to ensure that no air remains in any part of the system. Have an assistant set up, calibrate, and level the transducer. Hand the proximal end of the PAC to an assistant to attach to the ECG monitor. Finally, shake the tip of the PAC while observing the pressure waveform on the monitor to confirm that the monitoring system is operative.

Insert the PAC through the diaphragm on the introducer sheath, taking care to orient the natural curve of the catheter toward the right ventricular outflow tract. Continue to advance the PAC until it is inserted 10 to 15 cm and exits the sheath. This ensures that the balloon is not inflated within the sheath. Stop advancing the PAC. Inflate air into the balloon and lock the pressure release valve. **The PAC should never be advanced through the central venous system with the balloon deflated, as this may provoke ectopy or injure the heart or other vascular structures. Conversely, the PAC should always be withdrawn with the balloon deflated.**

Pay close attention to the distance markings on the PAC and to the pressure waveform on the monitor when advancing the PAC. Typical pressure waveforms are illustrated in **Figure 53-4**. The average distances from the different catheter insertion sites

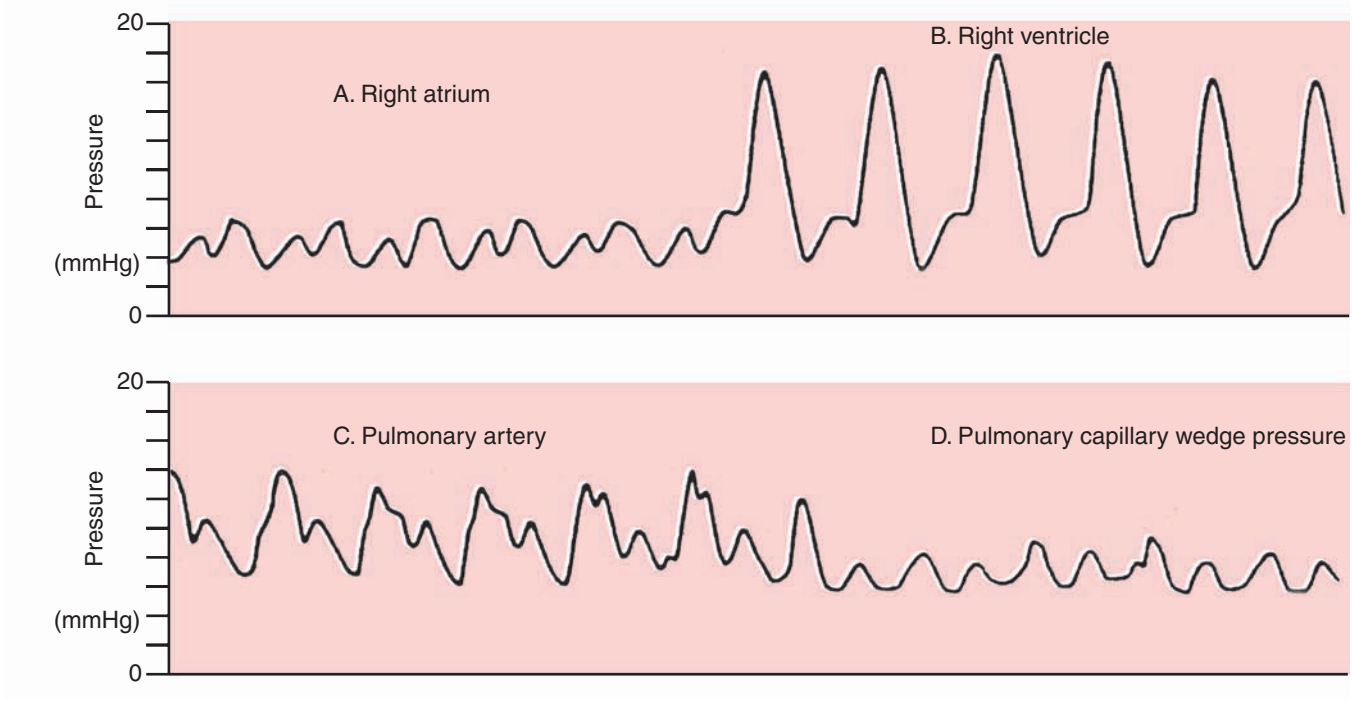


FIGURE 53-4. Typical pressure waveforms recorded by the pulmonary artery catheter during insertion.

into each chamber of the heart are listed in **Table 53-2**. Advance the PAC into the right atrium (**Figure 53-4A**). Continue to advance the PAC into the right ventricle, which will be apparent by an abrupt change in the pressure waveform (**Figure 53-4B**). Continue to advance the PAC into the pulmonary artery outflow tract, again confirmed by a change in the pressure waveform (**Figure 53-4C**). Passing the PAC through the right ventricle may produce some ventricular ectopy, which is generally uncomplicated. Advance the PAC a few centimeters further to produce a wedge tracing (**Figure 53-4D**). Deflate the balloon. This will result in the reappearance of the pulmonary artery waveform. If the wedge tracing persists, withdraw the PAC with the balloon deflated until the pulmonary artery waveform reappears. **Whenever it is unclear where the tip of the PAC is located, deflate the balloon and withdraw the PAC to a spot where the waveform is recognizable.** Take notice of the distance marking. Inflate the balloon and advance the PAC until the desired tracing is obtained.

Difficulties in passing the PAC into the pulmonary artery may occur in patients with pulmonary hypertension, significant tricuspid regurgitation, or markedly dilated right heart chambers. Instruct the patient to inspire slowly and deeply to increase venous return to the right heart. This may allow the PAC to be advanced successfully. Tilting the patient's head upward and repositioning the patient on their left side may also be helpful. Fluoroscopic guidance may be necessary if repeated attempts are unsuccessful.

Pull up the protective sleeve over the catheter and secure it to the introducer sheath. It is important not to advance the PAC itself during this manipulation. Begin any infusions through the PAC. Secure the PAC, dress the access site, and document correct positioning by obtaining an anteroposterior chest radiograph. The assessment and aftercare of the skin puncture site is described in Chapter 49.

DATA INTERPRETATION

As mentioned in the introduction to this chapter, a detailed discussion of PAC data interpretation cannot be undertaken here. However, anyone who places or uses PACs in the management of critically ill patients should be familiar with the standard information provided by the PAC. The data generated by the PAC can be divided into two categories. The first set of information comprises data that are directly measured and include the right-sided heart pressures, thermodilution cardiac output, and blood gas obtained from a mixed venous sample from the distal pulmonary artery port. These data, including normal values, are listed in **Table 53-3**. The second set of data comprises the variables that are mathematically derived from the measured data (**Tables 53-4 & 53-5**). These provide information crucial to understanding cardiac and pulmonary physiology and pathology. Today, this information is routinely available on an instantaneous basis as part of computer software packages that accompany the monitoring equipment. PAC users should become familiar with both sets of information and their application in different clinical situations. The reader is advised to consult a current textbook of cardiology or critical care medicine for a more detailed description of the hemodynamic data provided by the PAC.

COMPLICATIONS

In addition to the complications associated with obtaining central venous access and with prolonged use of indwelling catheters (Chapter 49), complications may occur during or after the insertion of the PAC. The complications directly related to the PAC may be divided into those that are associated with catheter insertion and those associated with long-term maintenance (**Table 53-6**). Both sets of complications can be further divided into those problems where there has been systematic study and the incidence of complications has been published and those that have been observed and published as case reports but the actual incidence of which is unknown.

Problems with tracing quality may occur due to problems involving the catheter itself or other parts of the system. Catheter problems include positioning too distal or not distal enough, balloon rupture, or clot formation at the tip. Problems elsewhere in the system include air in the lines, loose connections, failure of the transducer, failure of the wires, or failure of the monitor. The system should be

TABLE 53-2 Average Distances from the Catheter Insertion Site to the Catheter Tip Position*

Catheter insertion site	Right atrium distance (cm)	Right ventricle distance (cm)	Pulmonary artery distance (cm)	Wedge distance (cm)
Subclavian vein	10	20	30–40	40–45
Right internal jugular vein	15	25	35–45	45–50
Left internal jugular vein	20	30	40–50	50–55
Right antecubital vein	45	60	70–80	80–85
Left antecubital vein	50	65	75–85	85–90

* These distances are considered the common estimates for uncomplicated PAC placement in patients with normal-sized hearts. The distances will vary in patients and may be greater, especially in the patient with a dilated right ventricle. Any time there is a gross discrepancy between these distances and the actual observed placement distance, the physician should consider catheter misplacement, catheter looping, or catheter knotting. An immediate portable anteroposterior chest radiograph should be obtained to evaluate the situation.

TABLE 53-3 Variables Obtained from the Pulmonary Artery Catheter Through Direct Measurement

Variable	Normal values	Main utility	Comments
Cardiac output (CO)	4–6 L/min	Diagnosis of shock (high output vs. low output); titration of vasoactive medications	Measurement is prone to error; should be indexed to patient's size
Pulmonary capillary wedge pressure (PCWP)	5–15 mmHg	Volume status, diuresis, fluid challenges	Often overinterpreted; must be used with other values
Right atrial pressure (RAP)	0–10 mmHg	Status of right ventricle	Less useful than PCWP
Pulmonary artery pressure (PAP)	15–25 mmHg systolic; 8–15 mmHg diastolic	Status of right ventricle and pulmonary circuit	Pulmonary artery diastolic can be substituted for PCWP in most patients
Mixed venous oxygen saturation ($S\bar{v}O_2$)	70%–80%	Evaluation of oxygen delivery; pulmonary shunt fraction	Best obtained by blood gas from distal pulmonary artery

TABLE 53-4 Derived Variables Obtained from the Pulmonary Artery Catheter

Variable	Normal values	Main utility	Comments
Systemic vascular resistance (SVR)	800–1600 dynes/s/cm^{-5}	Shock states, vasodilator versus vasopressor therapy (afterload)	Unclear whether value should be indexed to patient's size
Pulmonary vascular resistance (PVR)	20–200 dynes/s/cm^{-5}	Pulmonary hypertension; acute and chronic lung disease	Unclear whether value should be indexed to patient's size
Left ventricular stroke work index (LVSWI)	56 ± 6 g m/m^2	Left ventricular performance	Clinical utility uncertain
Right ventricular stroke work index (RVSWI)	8.8 ± 0.9 g m/m^2	Right ventricular performance	Clinical utility uncertain
Oxygen DO delivery $\dot{D}O_2$	900–1100 mL/min	Shock states, anemia, low cardiac output	Often amenable to therapy, but controversial
Oxygen consumption $\dot{V}O_2$	200–250 mL/min	Sepsis, burns, trauma, ventilator patients	Affected by many variables; use is controversial
Pulmonary shunt fraction (Q_s/Q_t)	3%–5%	Acute and chronic lung disease	Underused in the evaluation of pulmonary disease

TABLE 53-5 Formulas for the Derivation of Variables

SVR = (mean arterial pressure – mean arterial pressure) × 80 cardiac output
PVR = (mean pulmonary artery pressure – pulmonary capillary wedge pressure) × 80 cardiac output
LVSWI = SV × (mean arterial pressure – pulmonary capillary wedge pressure) 0.0136 body surface area
RVSWI = SV × (mean arterial pressure – right atrial pressure) × 0.0136 body surface area
$(DO_2) = [(\text{cardiac output} \times \text{hemoglobin}) \times (13.4) \times (\%\ O_2\ \text{saturation})] + (PO_2 \times 0.0031)$
$(VO_2) = (\text{cardiac output} \times \text{hemoglobin}) \times (13.4) \times (SaO_2 - SvO_2)$
$Q_s/Q_t = (\text{pulmonary capillary } O_2 \text{ content} - CaO_2)/(\text{pulmonary capillary } O_2 \text{ content} - CvO_2)$

Key: CaO_2, arterial oxygen content; CvO_2, mixed venous oxygen content; PO_2, partial pressure of oxygen; SaO_2, arterial oxygen saturation; SV, stroke volume. Other terms are defined in **Tables 53-3** and **53-4**.

TABLE 53-6 Recognized Complications of Pulmonary Artery Catheterization

Related to catheter insertion (published incidence)
Complete heart block (0%–2.6%)
Ventricular arrhythmias requiring treatment (0%–3%)
Hematoma (0%–3%)
Air embolism (0.1%)
Pneumothorax (0.1%–1.5%)
Inability to place catheter with multiple attempts (1.7%)
Injury to great vessels (0.1%–13%)
Ventricular arrhythmias (20%–50%)
Related to catheter insertion (reported, but incidence unpublished)
Hemothorax
Hemomediastinum
Lymphatic duct perforation
Injury to trachea
Injury to phrenic or vagus nerve
Guidewire embolism
Catheter knotting (requiring surgical removal)
Cardiac perforation
Related to long-term maintenance (published incidence)
Pulmonary artery rupture (0%–0.5%)
Pulmonary infarction (0%–0.5%)
Catheter infection (1%–5%)
Related to long-term maintenance (reported, but incidence unpublished)
Catheter shearing with embolization
Misreading or misunderstanding of data provided by catheter

zeroed and calibrated again to confirm the accuracy of the pressure values if abnormally high or low values are obtained. Sometimes it is just not possible to obtain a good wedge tracing despite repeated attempts. In such cases, the pulmonary diastolic pressure may be used as a surrogate for the wedge.

A right bundle branch block may occur due to impact of the PAC with the right side of the septum during insertion. This is usually transient. Even if it persists for hours, it is well tolerated in most patients. However, superimposition of a right bundle branch block in the presence of a preexisting left bundle branch block leaves the patient with complete heart block. This complication can result in severe bradycardia and hemodynamic embarrassment. **It is important to be prepared to institute temporary transcutaneous or transvenous pacing when placing a PAC in patients with a left bundle branch block.**

Arrhythmias during insertion, most commonly premature ventricular beats, are usually due to irritation of the right ventricle. This is especially true of the outflow tract. Premature ventricular contractions are usually well tolerated unless sustained ventricular tachycardia or ventricular fibrillation occurs. Slight withdrawal and redirection of the PAC is usually adequate. Arrhythmias after insertion may be due to catheter loops in the right heart, which will be apparent on the chest radiograph and can be corrected by careful withdrawal of the PAC until the loop is removed. Arrhythmias may also occur if the PAC tip slips back into the right ventricle. In this case, the pressure tracing will show a typical right ventricular waveform. Readvancement of the PAC into the pulmonary artery should eliminate the arrhythmias.

Other potentially serious but rare complications during placement include injuries to the great vessels, trachea, lymphatic duct, vagus nerve, or phrenic nerve as well as a pneumothorax, hemothorax, hemomediastinum, and cardiac perforation. On occasion, the PAC can become knotted intravascularly or within the heart during placement. This requires an Interventional Radiologist to unknot it or surgical removal if this fails.

The most serious complications related to long-term maintenance of the PAC are pulmonary artery rupture, pulmonary artery infarction, and catheter infection. Pulmonary artery rupture is usually the result of the catheter becoming overwedged and/or the balloon over-inflated. Pulmonary infarction has been seen primarily in patients with mitral regurgitation or pulmonary hypertension and may be avoided if the duration of balloon inflation is kept to a minimum. Catheter infection occurs in 1% to 5% of PAC placements and can be minimized by strict sterile maintenance of the PAC as well as continually reevaluating the need for the PAC and keeping the placement time as short as possible. The majority of PACs should be used for 72 hours or less.

SUMMARY

Since its introduction four decades ago, the PAC was initially embraced by Emergency Physicians and Critical Care Physicians for its ability to provide real time information regarding variables such as cardiac output and pulmonary capillary wedge pressure at the bedside. PAC use had become common practice. However, over the last 15 years this has come into significant question. At this point, the utility of the PAC is unclear. The PAC has not led to improved outcomes, decreased mortality, or decreased ICU length of stay. Thus, its use as common practice cannot be supported. However, there are still many clinical situations for which the use of the PAC may benefit the Emergency Physician to make crucial decisions. The PAC is a tool in the armamentarium of any clinician taking care of critically ill patients. Therefore, it is important to be well versed in the information that it provides and its application in the clinical context of the disease state that they are managing.

54 Peripheral Venous Cutdown

Flavia Nobay

INTRODUCTION

Venous access in the critically ill patient is of the utmost importance. The literature regarding peripheral venous cutdowns extends back to 1940 when Keeley introduced this technique as an alternative to venipuncture in patients with shock.[1] Interestingly, there has been a noticeable lack of recent investigations regarding venous cutdowns, most likely due to the focus on central venous access via the Seldinger technique with ultrasound guidance and intraosseous access. Recent editions of the ATLS text refer to the saphenous venous cutdown as an optional skill to be taught at the discretion of the instructor.[2] However, despite the apparent lack of popularity of the peripheral venous cutdown, the importance of obtaining venous access in critically ill patients supports the need to know a wide variety of techniques in order to be successful in every situation. The steps outlined in 1940 by Keeley to expose and cannulate the saphenous vein remain mostly unchanged.[1]

Peripheral venous access can be extremely difficult due to vascular collapse from shock, vascular injury, obesity, or scars. Direct visualization of the vein to be cannulated can be more fruitful than indirect visualization with central venous lines without ultrasound guidance in the patient with shock. However, in a study in 1994 comparing venous cutdowns versus percutaneous femoral venous access, all times to completion of the procedure and infusion times were faster in the percutaneous femoral access group versus the cutdown

group.[3] Despite these statistics, it is not uncommon to be managing a critically ill patient who cannot be cannulated peripherally or centrally and the venous cutdown becomes a procedure of necessity for resuscitation. An additional advantage of the venous cutdown is that it does not interfere with concurrent resuscitative efforts at the head, neck, thorax, and abdomen.

Familiarity with this procedure allows for large-bore access and the rapid infusions required in the critically ill trauma or medical patient with difficult access. All Emergency Physicians should be familiar with the peripheral venous cutdown in order to effectively manage resuscitations in the trauma or medical setting. This technique can only be successfully performed if one understands the anatomy and details of venous cannulation. Practicing the cutdown technique before its critical need will help one to perform optimally in the emergent setting.

ANATOMY AND PATHOPHYSIOLOGY

There are three critical areas for venous cutdowns (**Figure 54-1**). All Emergency Physicians should be knowledgeable of the anatomy of the saphenous vein at the ankle, the saphenous vein at the groin, and the basilic vein at the elbow. **The potential injury to the patient can be significant if one approaches this procedure without regard to the clinical anatomy.**

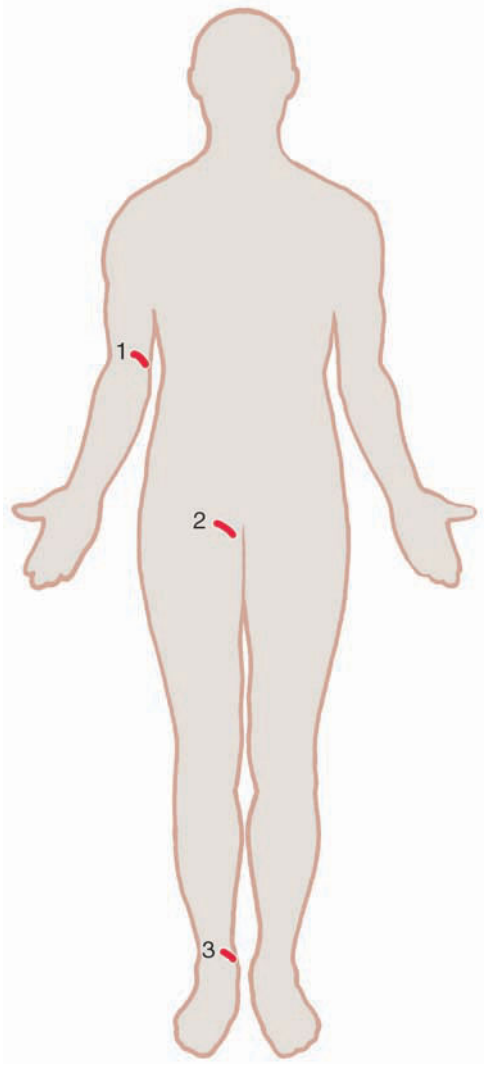


FIGURE 54-1. Common sites for peripheral venous cutdowns include the inner arm above the elbow (1), the inner thigh (2), and the inner ankle (3).

GREATER SAPHENOUS VEIN

The greater saphenous vein is the longest vein in the body. It is the ideal vein for a peripheral venous cutdown due to its anatomical regularity and superficiality (**Figure 54-2**). **The superficial and consistent position of the saphenous vein, in both adults and children, makes this the ideal vessel for a peripheral venous cutdown.** The saphenous vein begins at the medial dorsal venous arch of the foot. It passes upward and 1.5 to 2.5 cm directly anterior to the medial malleolus (**Figure 54-2A**). At the level of the medial malleolus, the saphenous vein lies just above the periosteum of the tibia.[4] It continues to ascend in the leg, along with the saphenous nerve, in the superficial fascia over the medial aspect of the leg. The vein passes posteromedially to the knee. Above the knee, it curves forward onto the anteromedial thigh. It passes over the falciform margin of the deep investing fascia to join the femoral vein approximately 4 cm below and 3 cm lateral to the pubic tubercle (**Figure 54-2B**).

The greater saphenous vein is easily identified at the ankle. It will be found, approximately, 2.5 cm anterior and 2.5 cm superior to the medial malleolus. It may be palpable if the patient is not hypovolemic or obese. The saphenous nerve, a branch of the femoral nerve, travels with the greater saphenous vein. It supplies sensory innervation to the skin of the medial leg and foot as far as the first metatarsal. This nerve is often transected when isolating the greater saphenous vein at the ankle. Fortunately, this nerve is of minimal clinical significance.

The saphenous vein in the thigh travels on the anteromedial surface and enters the fossa ovalis to join the femoral vein (**Figure 54-2B**). The femoral vein is at its largest diameter 3 to 4 cm distal to the inguinal ligament. This is approximately 2 cm distal to the approach for the placement of a femoral central venous line, at the same level where the scrotal or labial fold meets the thigh. The greater saphenous vein is also at its largest diameter in this location. At the level of the scrotal or labial fold meeting the thigh, the greater saphenous vein is easily isolated from the surrounding subcutaneous tissue. If the deep investing fascia of the thigh muscles is visible, the dissection has progressed deeper than the position of the greater saphenous vein.

BASILIC VEIN

The basilic vein is the site of choice for a peripheral venous cutdown in the upper extremity (**Figure 54-3**). It can be traced starting from the dorsal venous arch of the hand. It ascends on the posteromedial forearm to become anteromedial on the mid-to-upper forearm. It continues to ascend to the midportion of the arm where it pierces the deep fascia. The basilic vein runs in the groove between the biceps and triceps muscles in the distal one-third of the arm. The vein can always be found in the groove between the biceps and triceps muscles. A peripheral venous cutdown should be performed in this location. The basilic vein is more consistently found 2 cm cephalad and 1 to 2 cm lateral to the medial epicondyle of the humerus on the volar (anterior) surface of the arm. **The brachial artery and median nerve lie deep to the basilic vein in this location and are unlikely to be injured if the dissection remains superficial.**

Simon et al. recommend the approach to the basilic vein through the groove between the biceps and triceps muscles in the distal one-third of the arm.[5,6] These authors feel that locating the vein above and lateral to the medial epicondyle of the humerus will result in difficult cannulation secondary to the surrounding dense venous plexus. There is a significant risk of injury to the medial antebrachial cutaneous nerve and the deep brachial artery if one tries to find and isolate the basilic vein in the middle third

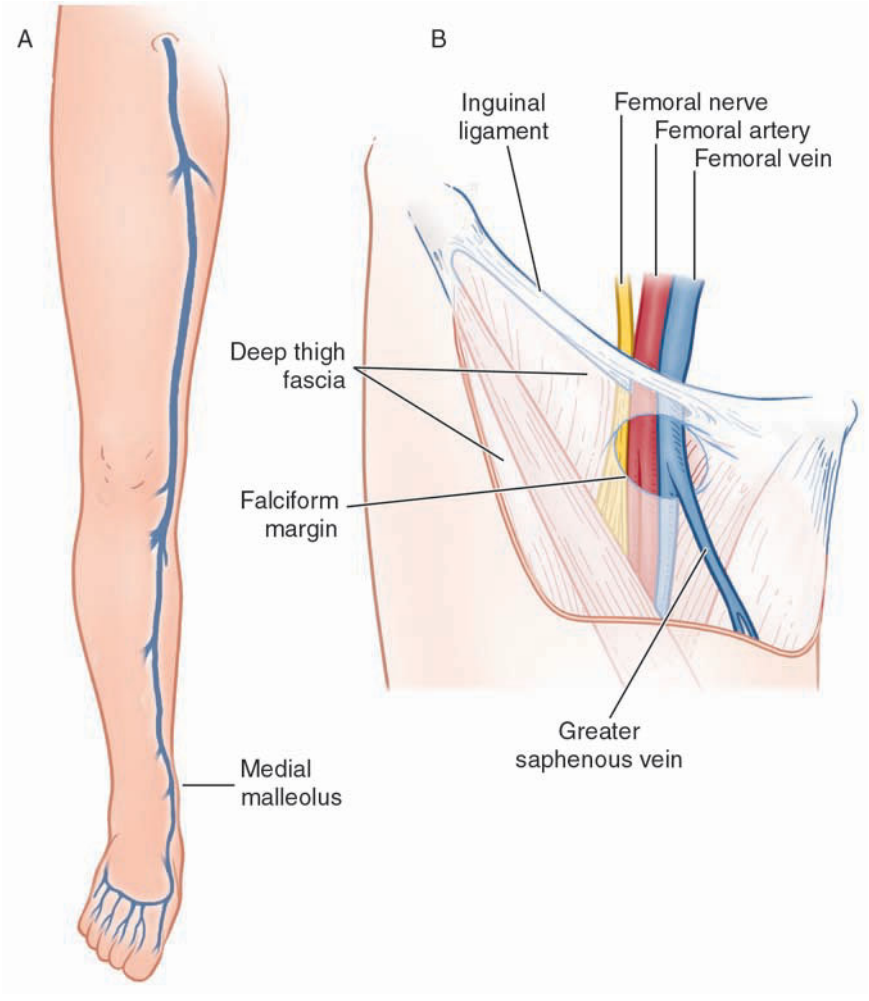


FIGURE 54-2. Anatomy of the greater saphenous vein. **A.** The subcutaneous course of the vein in the lower extremity. **B.** Detail of the greater saphenous vein at the groin.

or proximal third of the arm. Injury to the median antebrachial cutaneous nerve will result in sensory loss to the ulnar aspect of the forearm.

BRACHIAL VEIN

Brachial vein cutdowns should not be performed in the Emergency Department. The brachial vein is small in diameter. It is located relatively deep and would require significant and time-consuming steps to locate it. The anatomical structures surrounding the brachial vein include major arteries and nerves that can easily become injured while isolating the vein. Patients in hypovolemic shock will often not have a brachial artery pulse. This can lead to confusion as to which vessel is the artery and which is the vein.[4] Inadvertent cannulation of the brachial artery can result in a brachial artery thrombosis and upper extremity ischemia.

AXILLARY VEIN

The axillary vein is rarely used as a site for a venous cutdown. The axillary vein, in the axilla, is contained within the axillary sheath. Also contained within the axillary sheath are the axillary artery and brachial plexus. A venous cutdown for the axillary vein can injure these structures and is associated with a high rate of complications. It is not recommended to perform a cutdown for the axillary vein unless the Emergency Physician has specific experience with this particular technique.

INDICATIONS

The primary indication for a peripheral venous cutdown is the need for venous access in a patient with no peripheral access and in whom central access is not obtainable or contraindicated. This is the ideal procedure for the intravenous drug user with no peripheral veins and scarred central access sites, the burn patient with peripheral venous collapse and scarring, the patient in cardiorespiratory arrest, or the hypovolemic trauma patient that requires definitive and lifesaving volume resuscitation.[7] Hypovolemic shock is well treated with peripheral venous cutdowns because a unit of blood can be infused in less than 3 minutes with intravenous extension tubing inserted directly into the vein.[4]

This is also an excellent technique for emergent pediatric vascular access. Direct visualization of the vein will aid in cannulation of a vessel that may be collapsed secondary to hemorrhage, hypovolemia, and/or shock. This technique should only be used after other access attempts (i.e., interosseous access, ultrasound-guided central venous access, peripheral venous access—including scalp veins) have failed.[8]

CONTRAINDICATIONS

The absolute contraindications to a peripheral venous cutdown are vascular injury, saphenous vein removal, or long bone fractures proximal to the cutdown site. Relative contraindications include infection overlying the cutdown site, bleeding disorders, or severely

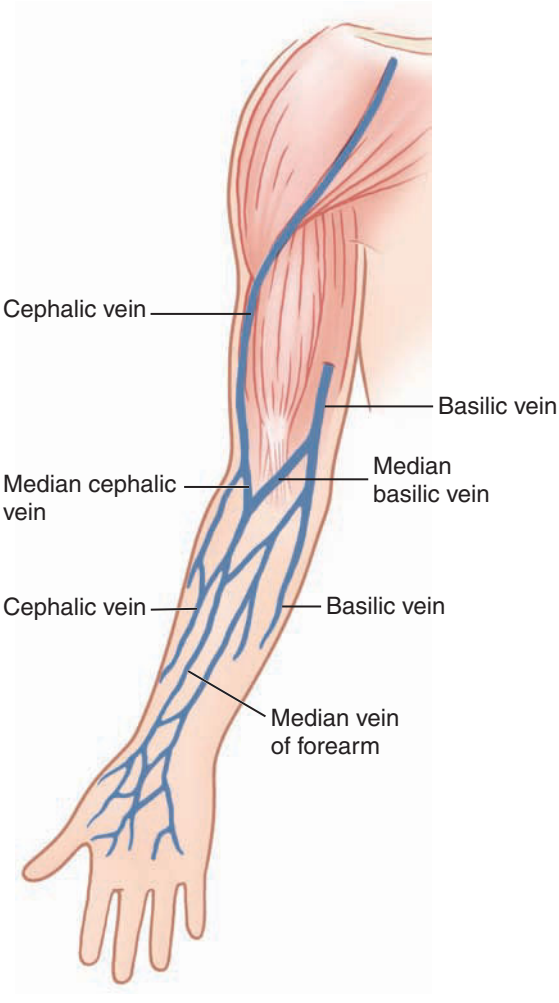


FIGURE 54-3. The superficial veins of the upper extremity.

distorted anatomy from congenital malformations, blunt trauma, or penetrating trauma in the area of the cutdown or the limb. A cutdown should not be performed unless peripheral intravenous access has failed and intraosseous access equipment is not available or has failed.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Local anesthetic solution
- 10 mL syringe
- 22 gauge needle
- #10 scalpel blade
- #11 scalpel blade
- #3 scalpel handle
- Curved Kelley hemostat
- Small mosquito hemostat
- Vein pick
- Fine tooth forceps
- Iris scissors
- Sharp tissue-cutting scissors
- Sterile drapes
- Towel clips
- Sterile polyethylene intravenous tubing
- Sterile intravenous extension tubing
- Central line kit (for Seldinger method)
- Catheter-over-the-needle, 16 or 18 gauge
- Sterile 4 × 4 sponges
- 5 mL syringe
- 18 gauge needles
- Self-retaining skin retractors
- Small rake, two
- Needle driver
- Silk suture, 3-0 and 4-0
- Injectable sterile saline
- Intravenous tubing and solution
- Wound dressing supplies
- Antibiotic ointment

PATIENT PREPARATION

The patient is usually in extremis and positioned supine if a peripheral venous cutdown is to be performed. They may also be in the Trendelenburg position, although this is not ideal for the procedure. The limb selected for the peripheral venous cutdown should be secured to the bed with a restraint, tape, or by an assistant. **Although this is an emergent procedure, time should be taken to perform it in as sterile a manner as possible.**

Identify the landmarks for the procedure. Clean the skin of any dirt and debris. If the patient is awake and aware of the surroundings, the area of the cutdown should be anesthetized. Infiltrate local anesthetic solution into the subcutaneous tissue where the incision will be made. Prepare the skin with povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to isolate a surgical field. Collect and set up all the required equipment on a bedside table covered with a sterile drape.

TECHNIQUES TO ISOLATE THE VEINS

The technique of cannulation is the same regardless of the vein chosen. The methods to isolate the saphenous vein and the basilic vein will be discussed in this section. A discussion of three different techniques to cannulate the isolated vein will be presented in the following section.

GREATER SAPHENOUS VEIN ISOLATION AT THE ANKLE

The saphenous vein is easily found and isolated at the ankle (**Figure 54-4**). Extend and externally rotate the lower extremity. Identify the medial malleolus of the tibia. Find the location 2.5 cm anterior and 2.5 cm superior to the medial malleolus. The greater saphenous vein will be found at this site. Alternatively, place your index and middle fingers at the level of the malleolus (**Figure 54-4A**). The vein will be found two finger breadths cephalad and two finger breadths in anterior of the medial malleolus. The vein may be palpable if the patient is not hypovolemic or obese. Alternatively, the vein may be visualized in patients with thin skin, superficial veins, minimal subcutaneous tissue, or dark vessels.

Stretch the skin taught over the distal tibia with the nondominant hand (**Figure 54-4B**). Note the position of the hands in the illustration. **The nondominant hand is placed with the fingertips pointing toward the Emergency Physician.** This will prevent inadvertent injury while making the skin incision. Transversely

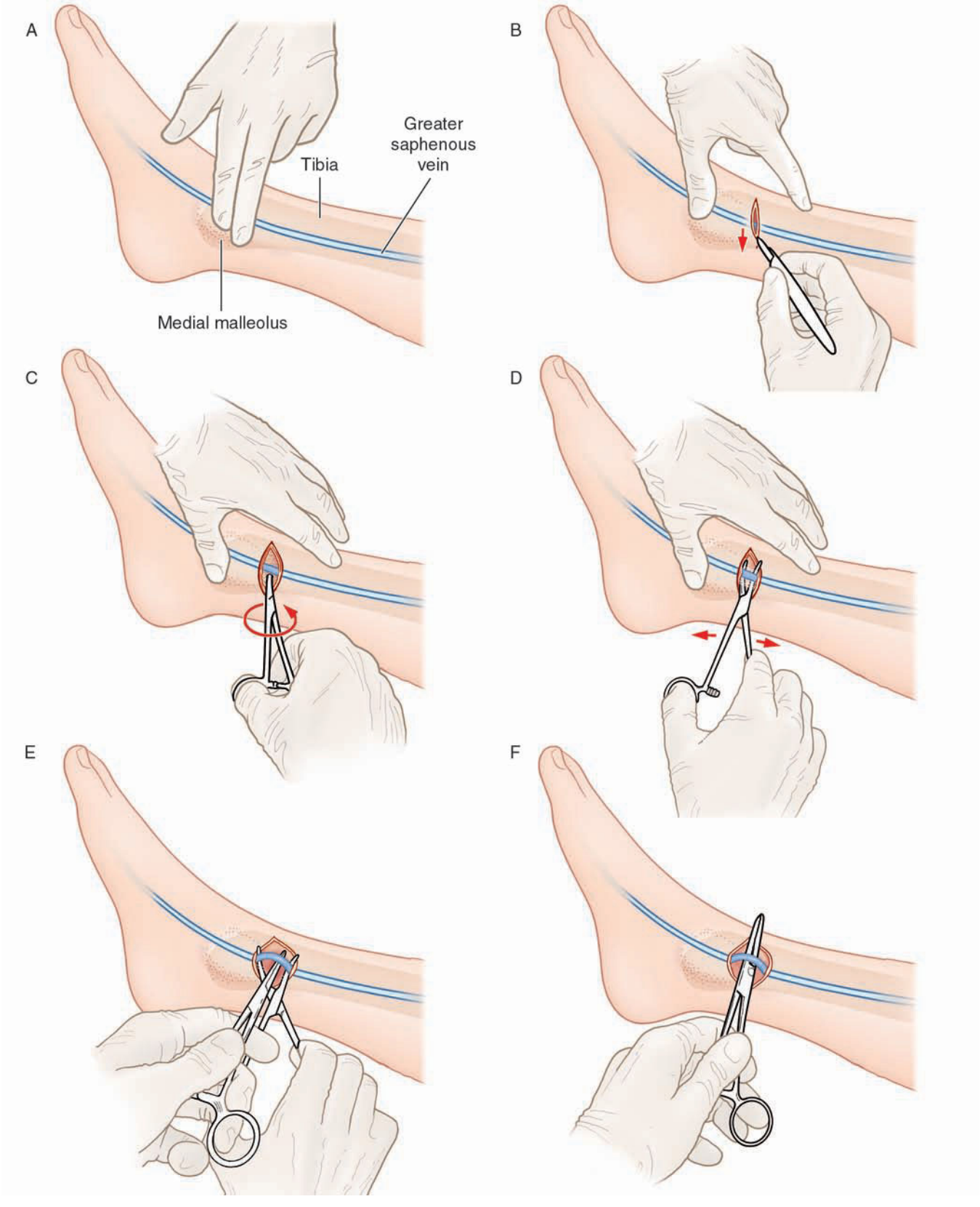


FIGURE 54-4. Isolation of the greater saphenous vein at the ankle. **A.** Identifying the vein. **B.** A transverse skin incision is made from the anterior to the posterior border of the medial tibia. **C.** The tip of a curved hemostat is scraped along the tibia then rotated 180° (*curved arrow*). **D.** The hemostat is spread to separate the tissues. **E.** A straight hemostat is inserted between the jaws of the curved hemostat to elevate the vein. **F.** The curved hemostat has been removed.

incise the skin overlying the great saphenous vein using a #10 scalpel blade, from the anterior tibial border to the posterior tibial border after appropriate anesthesia (**Figure 54-4B**). **This incision should be superficial so that the subcutaneous tissue is barely exposed.** A deep incision may transect the vein causing significant bleeding, difficulty visualizing the surgical field, and difficulty finding the ends of the vein that retract proximally and distally. Apply tension to the skin on either side of the incision to expose the underlying structures. This can be accomplished with the nondominant hand, a self-retaining retractor, or skin rakes held by an assistant.

Isolate the greater saphenous vein.[5] This may be difficult in some patients in shock or patients in the Trendelenburg position as the vein may be poorly perfused. Grasp and hold a curved hemostat (Kelly clamp) with the tip facing downward. Insert the hemostat along the posterior border of the tibia and scrape the tip anteriorly along the tibia (**Figure 54-4C**). If done properly, all of the tissue between the skin and the tibia will be above the hemostat. Rotate the hemostat 180° (**Figure 54-4C**). The tip of the hemostat will be facing upward (**Figure 54-4D**). Widely open the arms of the hemostat (**Figure 54-4D**). This will open the jaws of the hemostat and separate the saphenous vein from the saphenous nerve and fibrous strands of connective tissue. The saphenous vein should be visible between the jaws of the hemostat. If there is difficulty identifying the vein, squeeze the foot to backfill the vein with blood. Insert a straight hemostat (Kelly clamp) between the jaws of the curved hemostat and below the greater saphenous vein (**Figure 54-4E**). Remove the curved hemostat to leave the straight hemostat elevating the greater saphenous vein (**Figure 54-4F**). This straight hemostat will be useful as a "cutting board" to later transect the vein by allowing more manual control of the vein.

An alternative technique to isolate the vein is used by some Physicians. **This technique is not recommended by the editor but is briefly described for the sake of completeness.** Make the transverse skin incision. Place the jaws of a curved hemostat parallel to the greater saphenous vein. Open the arms of the hemostat to allow the jaws to dissect through the subcutaneous tissue. Continue placing the hemostat and opening the jaws until the vein is isolated. This technique is harder to perform because the vein is less likely to be identified given the white background of the periosteum.[1,8,9] Additionally, this technique takes significantly longer to find and isolate the vein.

GREATER SAPHENOUS VEIN ISOLATION AT THE GROIN

The groin vasculature offers the potential for massive infusion of blood or fluids in a matter of minutes. These vessels are closer to the central circulation and large enough to easily accommodate intravenous tubing, cut off at a 45° angle, as a catheter. The greater saphenous vein is superficial at the groin and lies in a meshwork of subcutaneous tissue. It is superficial to the femoral artery and vein. The saphenous vein travels on the anteromedial surface of the thigh and enters the fossa ovalis to join the femoral vein (**Figure 54-2B**). The greater saphenous vein is at its largest diameter 3 to 4 cm distal to the inguinal ligament. This is approximately 2 cm below the site for placement of a femoral central venous line and level with where the scrotal or labial fold meets the thigh.

Identify the location where the scrotal or labial fold meets the thigh (**Figure 54-5**). Identify the lateral edge of the mons pubis. Identify the point where a vertical line from the lateral edge of the mons pubis meets a horizontal line from the scrotal/labial fold. Make a transverse, medial to lateral, incision with a #10 scalpel blade on the patient's thigh starting where the scrotal or labial fold meets the thigh after appropriate anesthesia. Extend the incision laterally until it meets the vertical line from the lateral edge of the mons pubis.

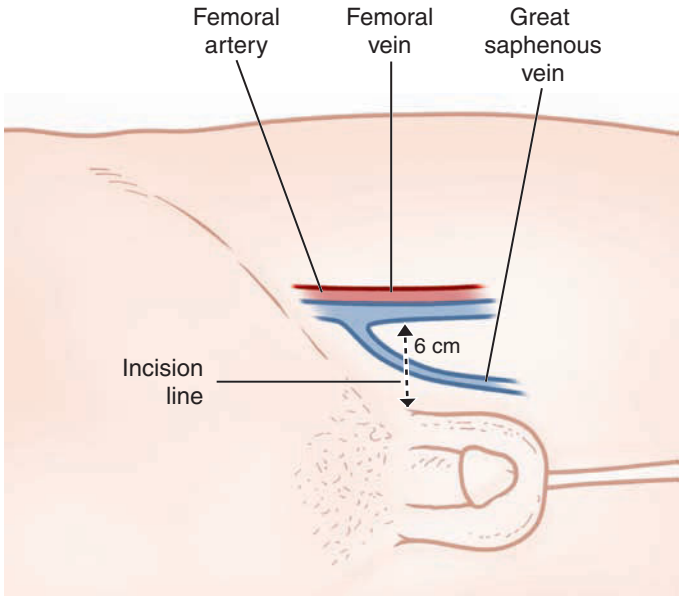


FIGURE 54-5. Isolation of the greater saphenous vein at the groin. The skin incision should begin where the scrotal or labial fold meets the thigh. Extend the incision laterally until it meets a vertical line from the lateral edge of the mons pubis.

Dissect the subcutaneous tissue to locate the greater saphenous vein. Place the jaws of a curved hemostat parallel to the greater saphenous vein. Open the arms of the hemostat to allow the jaws to dissect through the subcutaneous tissue. Continue placing the hemostat and opening the jaws until the vein is isolated. **The dissection is too deep if the deep investing fascia or the muscle bellies of the thigh muscles are encountered.** Stop, reidentify the landmarks, and adjust the skin incision and dissection as necessary.

Alternatively, the subcutaneous tissues can be bluntly dissected using 4 × 4 gauze squares. Grasp two or three gauze squares in each hand. Put the fingertips of both hands, covered with gauze, in the center of the incision. Move the hands in opposite directions, cephalad and caudad, while scraping the subcutaneous tissue with the gauze. Reapply the hands in the incision and repeat the motion until the greater saphenous vein is exposed. This technique applies pressure parallel to the greater saphenous vein and will not injure the vein.

BASILIC VEIN ISOLATION AT THE ELBOW

The basilic vein may be used for a peripheral venous cutdown. This is often performed when the greater saphenous vein cannot be accessed due to lower extremity amputation, deformity, injury, or trauma. This site is not ideal as it may interfere with resuscitative efforts while the basilic vein is being exposed. The basilic vein is consistently found 2 cm cephalad and 1 to 2 cm lateral to the medial epicondyle of the humerus on the volar surface of the arm. It may also be found in the groove between the biceps and triceps muscles. There is controversy in the literature as to where the incision for the basilic vein cutdown should be performed. The simple answer is that if one fails in isolating the vein in one location, make an incision in the second location to isolate the vein.

Position the patient to allow exposure of the basilic vein. Abduct the patient's arm 90° with the elbow flexed 90° and the palm facing upward (**Figure 54-6**). This positioning is required to access the basilic vein at either location.

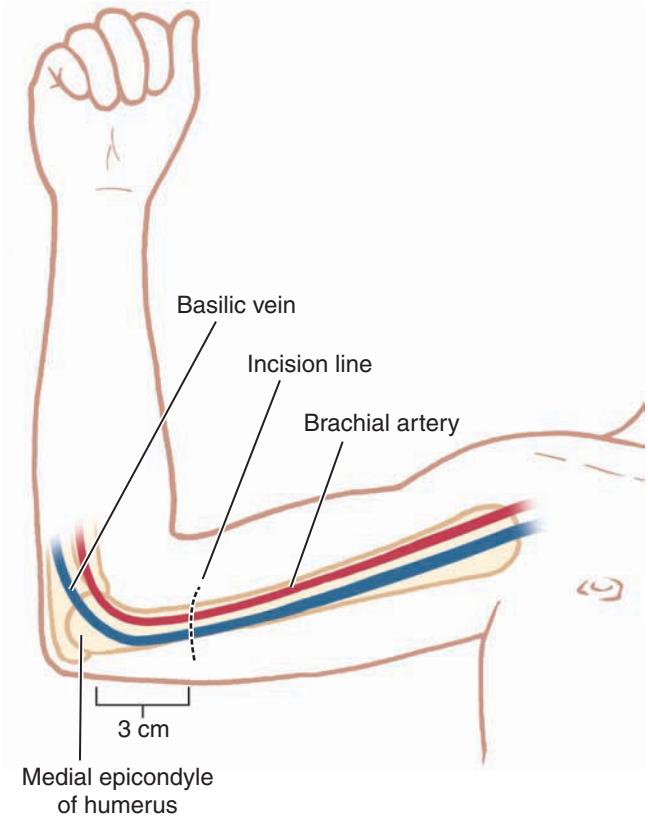


FIGURE 54-6. Isolation of the basilic vein.

Identify the point 2 cm cephalad and 2 cm lateral from the medial epicondyle of the humerus. This is the location of the basilic vein. Make a 4 to 6 cm transverse incision with a #10 scalpel blade centered on the reference point after appropriate anesthesia. The incision should only cut through the epidermis. Bluntly dissect the subcutaneous tissue with a curved hemostat or 4 × 4 gauze squares, as described previously, to locate the basilic vein. **The dissection is too deep if the brachial artery, median nerve, or muscle fibers are encountered.** Stop, reidentify the landmarks, and adjust the skin incision as necessary.

Alternatively, the basilic vein can be isolated in the middle of the distal third of the arm. Palpate the groove between the biceps and triceps muscles. This is the location of the basilic vein. Make a 4 to 6 cm horizontal incision centered about the groove after appropriate anesthesia. Bluntly dissect with a curved hemostat until the vein is located. The basilic vein is superficial to the muscle fascia and the brachial artery.

TECHNIQUES FOR CANNULATION OF THE VEIN

There are a number of techniques to cannulate a vein after it has been isolated. Either of the following techniques can be used to cannulate the greater saphenous vein or the basilic vein. It is important to realize that this may be a lifesaving procedure in an emergent setting, and the rapid and definitive cannulation of the vessel is the primary goal and not the technique chosen.

SURGICAL TECHNIQUE USING INTRAVENOUS TUBING

Isolate the chosen vein as described previously. Place a straight hemostat (Kelly clamp) under the midportion of the vein (**Figure 54-7A**). Slightly elevate the hemostat. Pass a silk suture under the vein at its proximal end and a second silk suture at its distal end (**Figure 54-7B**). Grasp the silk sutures with a hemostat to maintain the position of the tie and to allow for manipulation of the vein. Tie the distal suture to occlude inflow of blood from distal veins (**Figure 54-7C**). Do not cut either of these two sutures. The proximal suture will be left untied at this time to allow for control and manipulation of the vein.

Have an assistant prepare the catheter. Attach sterile intravenous polyethylene tubing to a bag of sterile saline. Cut the angiocatheter attachment hub off the end of the tubing at a 45° angle. Some authors suggest using a feeding tube instead of intravenous tubing.[8] This is not recommended. Intravenous tubing is ubiquitously available. With a feeding tube, the rounded tip may be more difficult to advance into the vein. The only advantage to using a feeding tube is that the rounded tip has less chance of puncturing the posterior wall of the vein.

Incise the vein. With the nondominant hand, grasp the hemostat holding the proximal suture. Raise the hemostat to flatten the vein and prevent back bleeding. Make an incision through half of the vein with the tip of a #11 scalpel blade (**Figure 54-7D**). **Do not cut the entire vein as this will cause significant bleeding and loss of the proximal end. If the incision is too large, greater than one-half the vein's diameter, the vessel may be torn completely and retract from the surgical field.**[8] The straight hemostat below the vein will act as a "cutting board" and prevent injury to underlying structures from the scalpel blade. As an alternative, the jaws of the straight hemostat can be opened and the vein cut with an iris scissors (**Figure 54-7E**).

Insert the intravenous tubing into the vein. Gently relax the tension on the proximal suture to allow the vein to open. Advance the intravenous tubing 2 to 3 cm into the vein (**Figure 54-7F**). Often times, there is considerable difficulty advancing the catheter. **Do not force the catheter through the vein as it is very delicate.** Troubleshoot by removing the catheter and make sure that the lumen of the vein has been cannulated. This is sometimes difficult to accomplish. If so, have an assistant control the proximal suture. Using a mosquito hemostat, grasp the cut edge of the vein and lift upward to expose the vein's lumen and insert the intravenous tubing (**Figure 54-7G**). For small veins, a mosquito hemostat may be too large to grasp the cut edge of the vein. Insert a vein pick or an 18 gauge needle with the tip bent into a 90° angle into the lumen of the vein (**Figure 54-7H**). Lift upward to expose the vein's lumen and insert the intravenous tubing.

After inserting the intravenous tubing, palpate the posterior aspect of the vein for penetration of the catheter. **The catheter must be removed if it penetrates through the posterior wall of the vein.** Release the proximal suture and allow the intravenous fluid to flow into the vein if the tubing has not penetrated the posterior wall of the vein. Tie the proximal suture to secure the intravenous tubing within the vein if the fluid flow is unobstructed and the fluid is not extravasating into the surrounding tissues (**Figure 54-7I**). **Do not tie the suture too tight to occlude the tubing.** Tying the suture too tightly may also result in a thrombosis.[10] If the tubing is within the lumen of the vein and the fluid is not flowing, the tubing may be against a venous valve. Gently advance the catheter 2 to 3 mm or withdraw it 2 to 3 mm and observe the fluid for flow. It is not necessary to close the skin incision at this time. Place saline moistened gauze over the incision site. Wrap a sterile dressing (e.g., Kerlix) around the extremity and the skin incision site.

If the patient survives the episode for which a venous cutdown was performed, the skin incision must be closed. If the intravenous tubing was inserted as above, the skin incision will be sutured

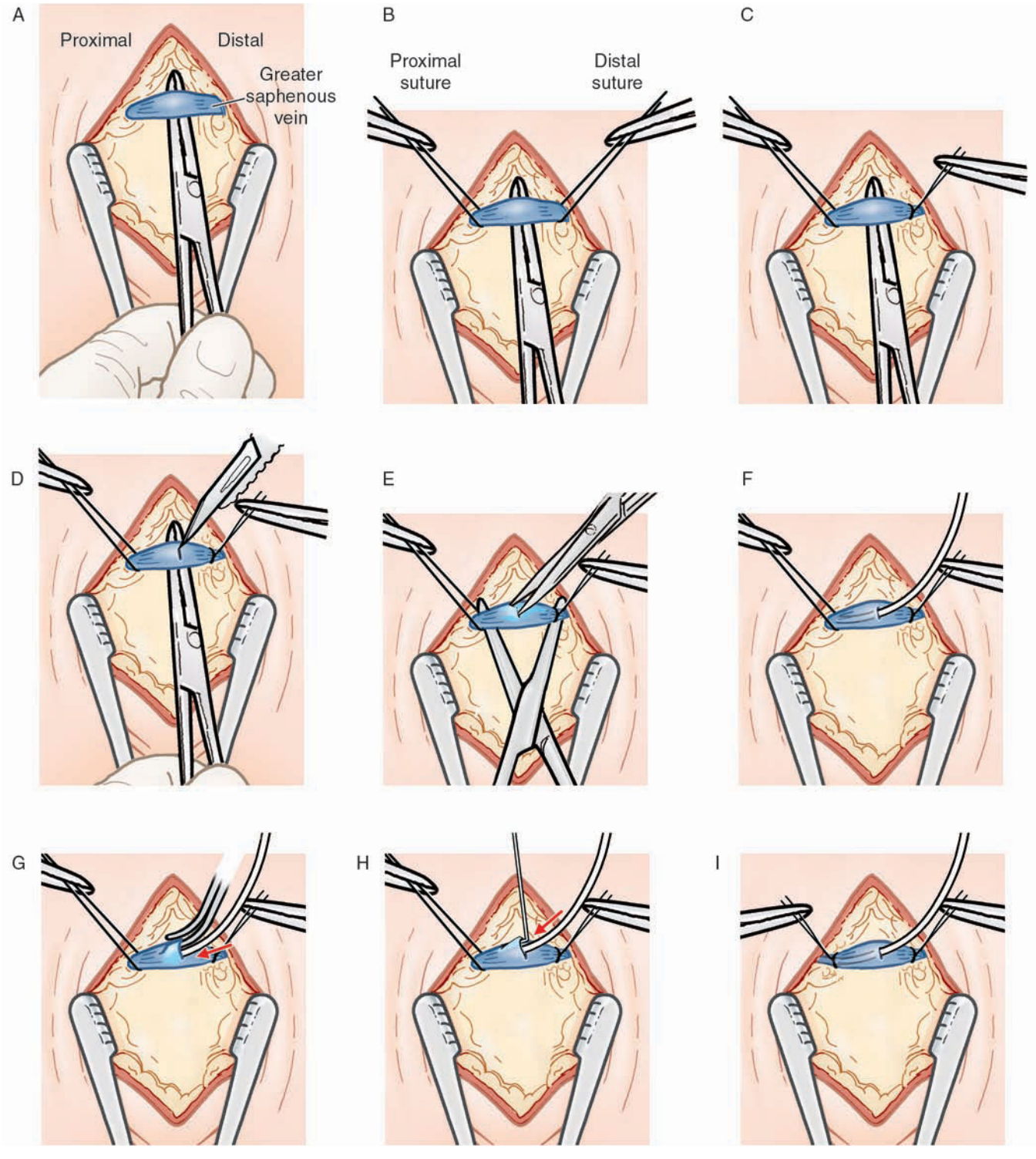


FIGURE 54-7. Venous cannulation using intravenous tubing. **A.** The vein has been isolated. **B.** A silk suture has been placed proximally and distally around the vein. **C.** The distal suture is tied. **D.** An incision is made through half of the vein with a #11 scalpel blade. **E.** Alternatively, the hemostat is opened and an iris scissors is used to cut half of the vein. **F.** The catheter is inserted into the vein and advanced. **G.** A mosquito hemostat can be used to grasp the vein and hold it open while the tubing is inserted. **H.** For small veins, a vein pick or 18 gauge needle with the tip bent can be used to hold open the vein. **I.** The proximal suture is tied to secure the tubing.

closed and the tubing will exit the incision. This is not optimal, according to some physicians, as it may allow access of bacteria through the wound and into the underlying vein. An alternative method is available (**Figure 54-8**). After exposing the vein, grasp and elevate the distal skin edge with a hemostat. Make a stab incision with a #11 scalpel blade approximately 1 cm distal to the previously made skin incision (**Figure 54-8A**). Use caution not to cut the underlying vein. Insert the intravenous tubing through the stab incision and pull it through the skin incision. Incise the vein and insert the tubing as described previously. This allows the tubing to be tunneled through the subcutaneous tissue before cannulating the vein (**Figure 54-8B**).

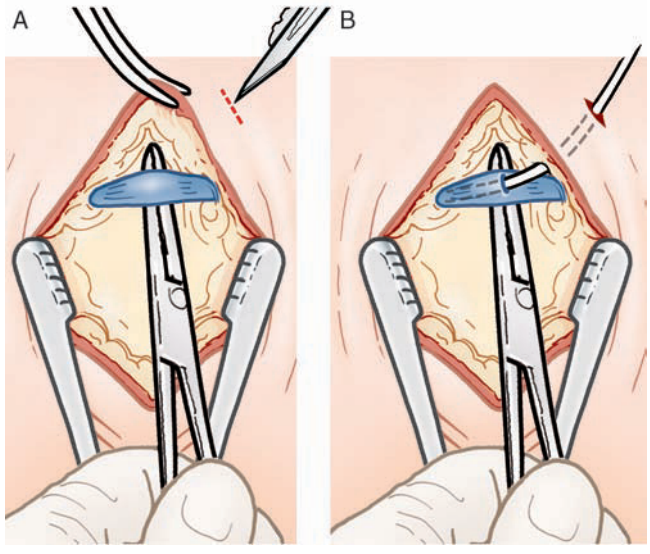


FIGURE 54-8. Alternative technique of venous cannulation with intravenous tubing. **A.** The distal skin edge is elevated. A #11 scalpel blade is used to make a stab incision in the skin and subcutaneous tissues. **B.** The tubing is fed through the stab incision and into the vein.

SELDINGER TECHNIQUE

Another technique of venous cannulation uses the Seldinger method.[9,11] This technique will insert the catheter as if cannulating a central vein. Refer to Chapter 49 for complete details. All of the required equipment can be found in a prepackaged central venous line access kit. This includes the guidewire, introducer sheath, dilator, and the venous catheter. This technique can accommodate a large caliber line, such as an 8 or 9 French introducer sheath. This technique may save 1 to 2 minutes on cannulation time by eliminating the ligature and tie off steps.

Isolate the chosen vein as described previously. Place a straight hemostat (Kelly clamp) under the midportion of the vein and open the jaws (**Figure 54-9A**). Insert the catheter-over-the-needle into the vein (**Figure 54-9A**). Stop advancing the catheter-over-the-needle when a flash of blood is seen in the needle hub. Be cautious not to puncture the posterior wall. Remove the straight clamp. Advance the catheter into the vein while securely holding the needle. Remove the needle. Insert the guidewire through the catheter. Remove the catheter by backing it out over the guidewire which will remain in the vein. Place the dilator through the introducer sheath. Feed the dilator–introducer sheath unit over the guidewire (**Figure 54-9B**). Advance the unit into the vein with a twisting motion while securely holding the guidewire (**Figure 54-9C**). Continue to advance the unit until the hub of the introducer sheath is just above the vein (**Figure 54-9D**). Remove the guidewire and dilator as a unit (**Figure 54-9D**). Attach intravenous tubing to the hub of the introducer sheath and begin instilling fluids. It is not necessary to close the skin incision at this time. Place saline-moistened gauze over the incision site. Wrap a sterile dressing (e.g., Kerlix) around the extremity and the skin incision site.

MODIFIED SELDINGER TECHNIQUE

An alternative and quicker method can be used to insert the introducer sheath into the vein (**Figure 54-10**). Isolate the chosen vein as described previously. Place a straight hemostat (Kelly clamp) under the midportion of the vein and open the jaws (**Figure 54-10A**). Assemble the unit by placing the dilator through the sheath and insert the guidewire through the dilator (**Figure 54-10B**). The guidewire should protrude 3 to 4 mm beyond the tip of the dilator. Make an incision in the lateral half of the vein (**Figure 54-10C**). While holding the proximal guidewire and sheath, insert the distal guidewire into the vein. Continue to insert the entire unit with a twisting motion into the vein (**Figure 54-10D**). Continue to advance the unit until the hub of the introducer sheath is just above the vein. Remove the guidewire

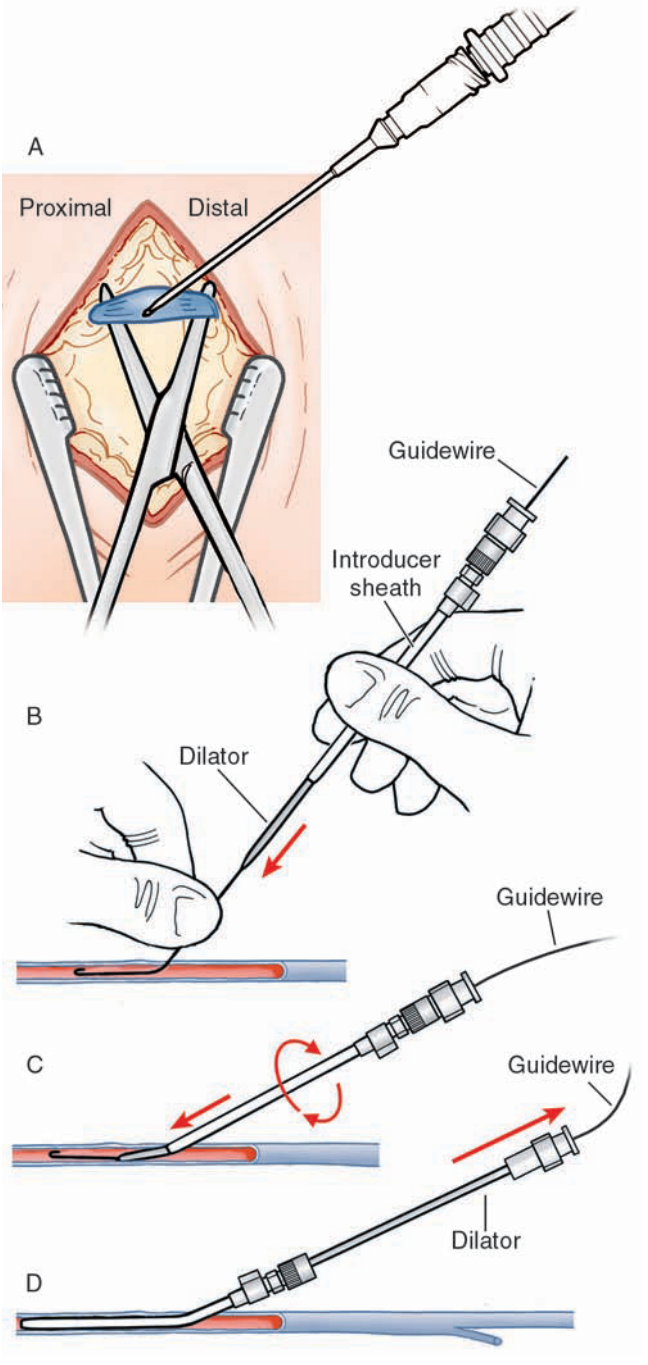


FIGURE 54-9. The Seldinger technique of venous cannulation. **A.** The vein has been isolated. The catheter-over-the-needle is inserted into the vein. **B.** A guidewire has been placed into the vein. The dilator and sheath are fed over the guidewire. **C.** The dilator and sheath are advanced into the vein with a twisting motion. **D.** The guidewire and dilator are removed as a unit.

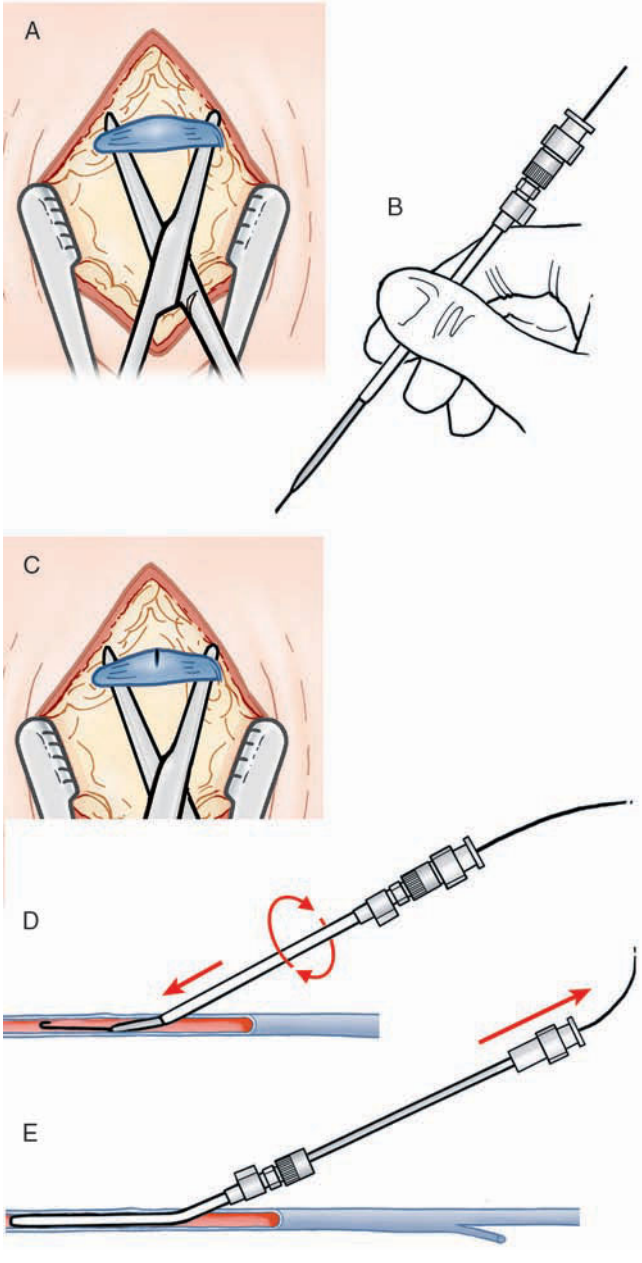


FIGURE 54-10. The modified Seldinger technique of venous cannulation. **A.** The vein has been isolated. **B.** The dilator, guidewire, and sheath are assembled as a unit. **C.** An incision has been made in the vein. **D.** The unit is inserted into the vein, guidewire first. A twisting motion will aid in its insertion. **E.** The guidewire and dilator are removed as a unit.

and dilator as a unit (**Figure 54-10E**). Attach intravenous tubing to the hub of the introducer sheath and begin instilling fluids.

INTRAVENOUS CATHETER TECHNIQUE

This final technique involves the insertion of a standard, 16 to 18 gauge, intravenous catheter-over-the-needle into the vein (**Figure 54-11**). This technique is sometimes referred to as the mini-cutdown. The vein is cannulated under direct visualization through a skin incision. This technique will insert the catheter as if cannulating a peripheral vein. Refer to Chapters 47 and 48 for complete details. This method is very quick, provides a more secure cannulation, and potentially decreases the chance of infection.

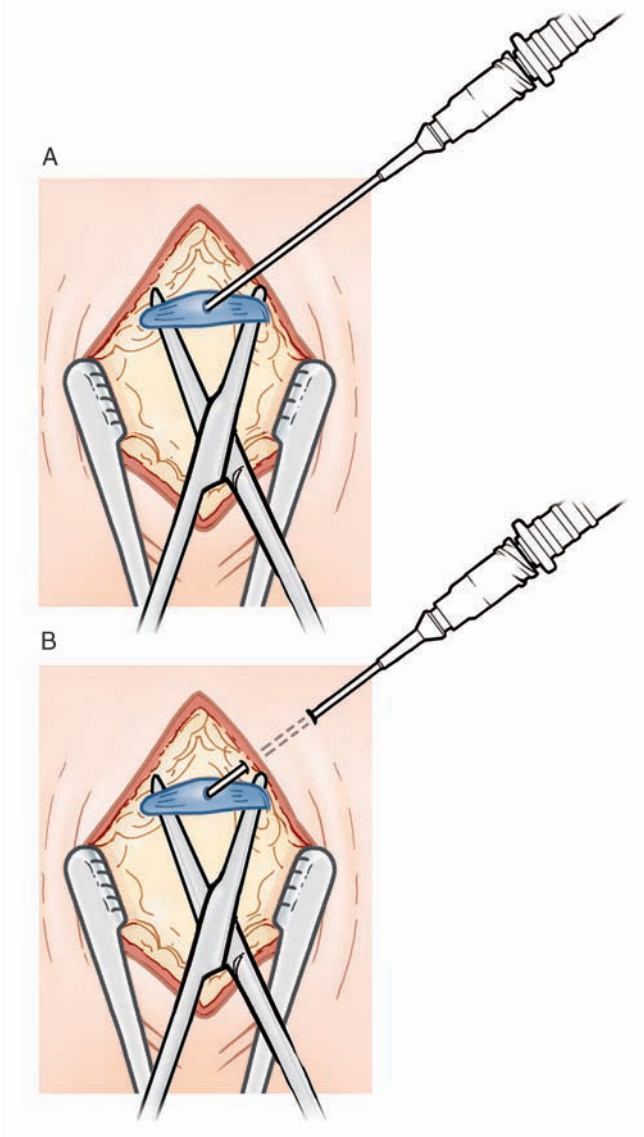


FIGURE 54-11. Intravenous catheter technique of venous cannulation. **A.** A catheter-over-the-needle is inserted into the vein. **B.** A catheter-over-the-needle is inserted through the skin and into the vein.

Isolate the chosen vein as described previously. Place a straight hemostat (Kelly clamp) under the midportion of the vein and open the jaws (**Figure 54-11A**). Insert the catheter-over-the-needle into the vein under direct visualization (**Figure 54-11A**). Stop advancing the unit when a flash of blood is seen in the needle hub. Advance the catheter into the vein while removing the straight clamp. Advance the catheter until the hub is just above the vein. Remove the needle. Attach intravenous tubing to the catheter hub and begin instilling fluids. Gently tie the proximal suture to secure the catheter within the vein. It is not necessary to close the skin incision at this time. Place saline-moistened gauze over the incision site. Wrap a sterile dressing (e.g., Kerlix) around the extremity and the skin incision site.

Alternatively, insert the catheter-over-the-needle through the skin, 1 cm distal to the distal skin edge, until the tip is visualized in the incision (**Figure 54-11B**). Insert the catheter-over-the-needle into the vein under direct visualization. Stop advancing the unit when a flash of blood is seen in the needle hub. Advance the catheter into the vein while removing the straight clamp. Advance

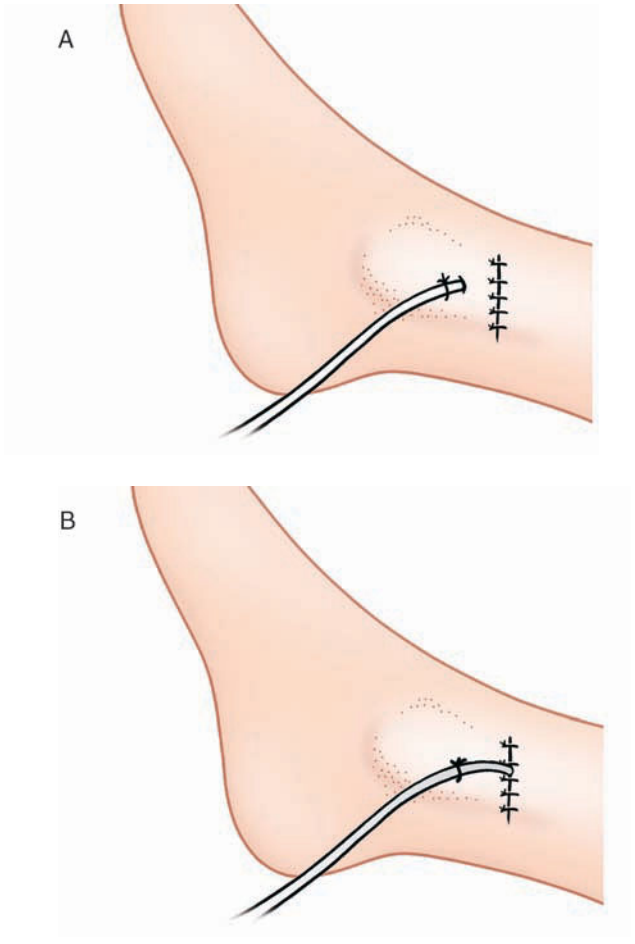


FIGURE 54-12. The skin incision is closed with interrupted 4-0 nylon sutures. The catheter exits a separate skin incision (**A**) or the original skin incision (**B**) and is secured with a suture.

the catheter until the hub is against the skin. Remove the needle. Attach intravenous tubing to the catheter hub and begin instilling fluids. The advantage of this method is that the catheter goes through the skin, which will stabilize the catheter and prevent it from becoming dislodged.

AFTERCARE

Suture the wound closed with simple interrupted 4-0 nylon sutures (**Figure 54-12**). Place a suture through the skin, wrap it around the catheter and tie it to secure the catheter to the skin. Apply antibacterial ointment to the incision, the sutures, and the site where the catheter exits the skin. Secure the intravenous tubing (**Figure 54-13**). The catheter can be looped around the toe, for a cutdown at the ankle, and secured with gauze wrap or an elastic wrap (**Figure 54-13A**). The catheter can be secured by taping it to the skin (**Figure 54-13B**). The limb can be immobilized on a board, after the catheter is secured at the ankle or elbow, for added security from inadvertent dislodgement of the catheter (**Figure 54-13C**).

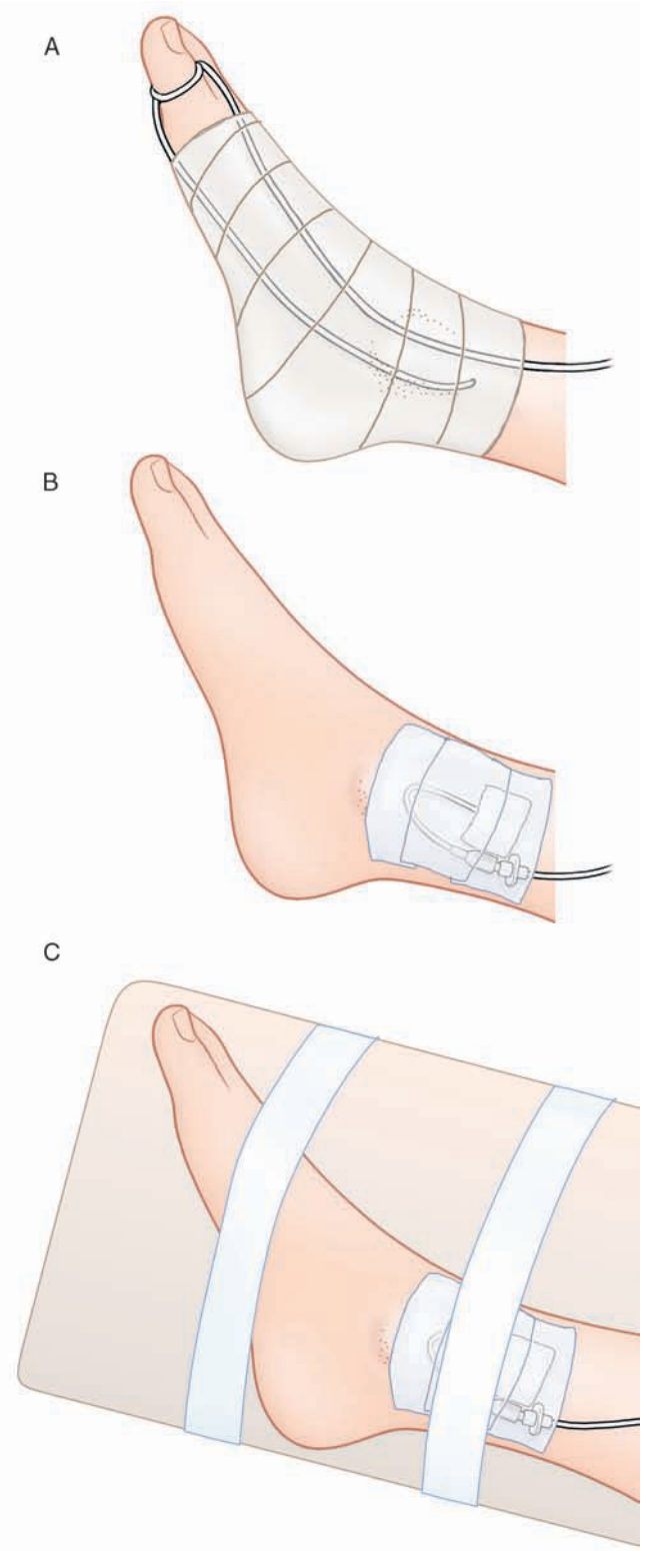


FIGURE 54-13. Securing the intravenous catheter. **A.** The catheter is looped around the great toe, for an ankle cutdown, and secured with gauze or elastic wrap. **B.** The catheter is secured with tape. **C.** The ankle or elbow can be secured to a board for additional security.

COMPLICATIONS

The complications of a peripheral venous cutdown include arterial injury, nerve injury, phlebitis, thromboembolism, wound dehiscence, and wound infection. The incidence of complications ranges from 2% to 15%.[12,16] The difficulty in reporting complications is that there is a high mortality rate in patients undergoing this procedure due to the primary problem (e.g., hypovolemia, sepsis, shock, trauma, etc.). The knowledge of the local anatomy and the technical aspects of the various cutdown techniques may avoid arterial, venous, and nerve injury. The other complications may be reduced by removal of the catheter within 12 hours after placement.[16]

PHLEBITIS

It is generally agreed that phlebitis occurs more commonly in the lower extremity than the upper extremity. However, there are little data to support this. Phlebitis usually results from prolonged catheterization. It may be seen within hours of catheter placement and as long as 18 days after the removal of the catheter.[16] In 1960, Bogen looked at 234 ankle cutdowns and found a 4% phlebitis rate.[14] He felt this was secondary to infection. The strength of the correlation was attributed to a previous nonrelated study that found *Staphylococcus aureus* on almost all catheter tips in patients with phlebitis as opposed to catheter tips in patients without phlebitis. Interestingly, these cases of phlebitis all resolved without the use of antibiotics. Moran et al. cultured 89 cutdown sites and observed that the pathogenic species causing infection were *S. aureus, Enterococcus*, and *Proteus*. These organisms were cultured more frequently in patients that had cutdowns that were left in place for longer periods of time. Moran et al. did not find a correlation between infection and phlebitis and postulated that phlebitis was due to irritation of the vein wall by the catheter.[13] Regardless of the rates and species, it is clear from all of these studies that **early removal of the intravenous catheter within 12 hours of placement will significantly decrease the incidence of phlebitis.**

INFECTION

Moran et al. did not find that prophylactic antibiotics reduced infection rates.[13] They found that daily topical antibiotic ointment, in particular Neosporin™, reduced positive local wound cultures from a rate of 78% to 18%. In 1968, Collins et al. studied polyethylene catheters and found a 2% bacteremia rate and a 1% death rate from *Pseudomonas* species in debilitated patients.[15] Rhee et al. in 1988 found only one case of cellulitis in their study of 78 patients.[11] Regardless of the rates and species, it is clear from all of these studies that **early removal of the intravenous catheter within 12 hours of placement will significantly decrease the incidence of infection and subsequent complications.** Obviously, sterile technique is also encouraged with this procedure in order to minimize complications related to infection.

ASSOCIATED INJURIES

Injury to adjacent arteries, nerves, and veins can be avoided by a detailed understanding of the local anatomy and careful procedural technique. Aggressive and forceful dissection without an understanding of the anatomy or the procedure will increase the incidence of complications. Injury to adjacent cutaneous nerves is unavoidable and inconsequential. Venous spasm, which causes nonuniform acceptance of the intravenous extension tubing, may also occur.[16]

SUMMARY

The peripheral venous cutdown is an excellent technique for rapid fluid or blood product infusion in the emergent setting. This is usually performed when other methods of venous access are unavailable or have failed. It is a relatively simple procedure. If learned properly, it can be lifesaving in the critically ill or injured patient. It is imperative to understand the relevant local anatomy and identify the clinical landmarks before this procedure is performed. Strict adherence to sterile technique and the early removal of the catheter will decrease the rate of infection and complications.

55 Intraosseous Infusion

Amanda Munk and O. John Ma

INTRODUCTION

Obtaining peripheral vascular access in the critically ill patient may be difficult and time-consuming. The vascular collapse that may accompany severe dehydration or a cardiac arrest can be profound and delay administration of essential therapies. Pediatric patients, in particular, may present a challenge due to the small size of their peripheral veins and the increased subcutaneous tissue. Administration of endotracheal medications may not provide rapid and reliable drug absorption during a cardiorespiratory arrest.[1,2]

Intraosseous (IO) access was first described in 1922 by Dr. Drinker. He referred to the medullary cavity as a "non-collapsible vein" that can be used for obtaining rapid vascular access. IO access for pediatric use was introduced in 1941. The first IO blood transfusion was documented in1942. The IO route of venous access did not become popular for many reasons. The equipment at the time was crude and did not improve until the 1970s. The technique of a saphenous venous cutdown was soon developed as an alternative method for obtaining vascular access. The development of plastic, disposable, and single use intravenous (IV) catheters revolutionized the technique of IV access.

IO access is an alternative route for blood, drug, and fluid administration. This previously abandoned technique was reintroduced in the mid-1980s in response to the need for more immediate vascular access during cardiopulmonary resuscitation.[3,4] This procedure has focused on pediatric patients due to the increased difficulty and necessity of access in critically ill children. Studies have demonstrated that peripheral venous access during pediatric cardiac arrest constituted the most expeditious manner of obtaining vascular access (mean time of 3.0 minutes). However, it was only successful in 17% of patients. This was in stark contrast to the 83% success rate for IO lines, 81% for peripheral venous cutdowns, and 77% for central venous lines.[5,6] The time required to place an IO line was 4.7 minutes compared to 8.4 minutes for a central venous line and 12.7 minutes for a peripheral venous cutdown. The insertion of an IO line was recently studied in the prehospital arena, where it was shown to be safe and effective.[7,8] IO infusion is also quick, safe, and effective in compromised neonates.[9]

IO access has been increasingly used in the resuscitation of adult patients when vascular access is unobtainable.[10,11] For prehospital providers, IO access has proved to be an invaluable procedure. One national prehospital study noted success rates for IO placement at 91%, with the majority of patients being adults.[12] In adults over the age of 80 years, success rates neared 97%. The newer powered devices make penetrating the adult cortical bone much less difficult.[12]

ANATOMY AND PATHOPHYSIOLOGY

Long bones are composed of a dense outer cortex and inner soft, spongy (cancellous) bone (**Figure 55-1**). The nutrient artery supplies the bone with a rich vascular network. It pierces the cortex and divides into ascending and descending branches that further divide into arterioles and then capillaries. Venous drainage from the capillaries into the medullary venous sinusoids, located at the proximal and distal portions of the long bone, flows into the central venous channel located in the shaft of the long bone.[13]

The IO needle is inserted through the cortex and into the bone marrow (medullary) cavity of a long bone. Numerous anatomic sites can be used to access the medullary cavity. The most traditional

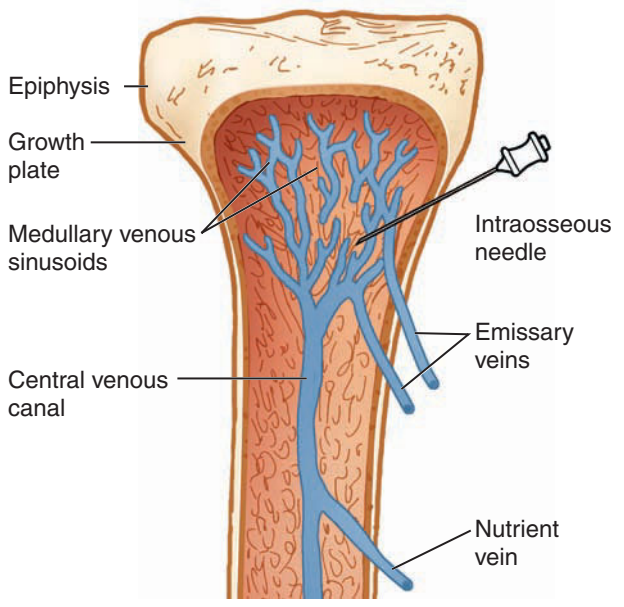


FIGURE 55-1. Venous anatomy of a long bone.

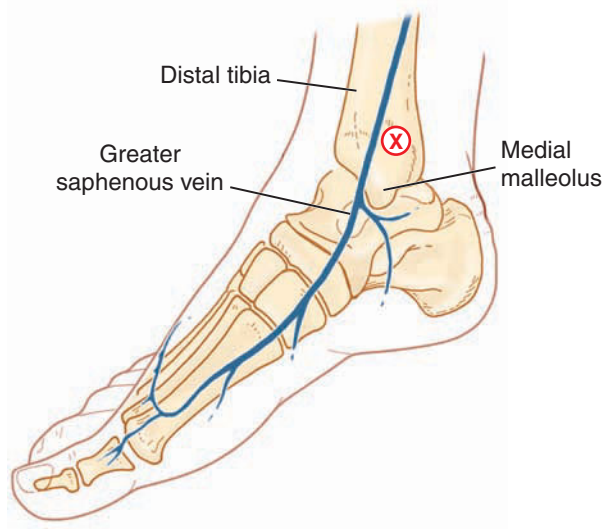


FIGURE 55-3. The distal tibia is one of the preferred sites for IO access in adult patients. The ⊗ represents the site of IO needle insertion.

site, which is favored in pediatric patients, is the flat anteromedial surface of the proximal tibia (**Figure 55-2**). The distal tibia just above the medial malleolus is the preferred site in adult patients (**Figure 55-3**). In the adult, it is easier to penetrate the cortex of the medial malleolus than the thicker cortex of the proximal tibia. Other sites for IO access include the flat anterior surface of the distal femur (**Figure 55-4**) and the anterolateral surface of the proximal humerus (**Figure 55-5**).[14]

Crystalloid infusion studies through an IO line in animals have demonstrated an infusion rate of approximately 10 to 20 mL/min with gravity and up to 40 mL/min under pressure.[15,16] Fluids and medications administered through an IO line are immediately absorbed into the systemic circulation. Sodium bicarbonate infusion, even during a cardiac arrest, was shown to have superior buffering capacity when administered via an IO line than by a peripheral IV line.[17] Medications and fluids that may be administered by the IO route are listed in **Table 55-1**.[18,19] **The medication concentrations, dosages, and infusion rates through an IO line are the same as those through a peripheral IV line.** Succinylcholine has been effectively infused by the IO route for muscle paralysis prior to endotracheal intubation.[20]

INDICATIONS

The placement of an IO line is indicated when vascular access is rapidly required for the resuscitation of a patient and standard vascular access is unobtainable or delayed. It may be operationally useful to define a specific time frame or a specified number of peripheral IV attempts before proceeding to IO access. Situations that may require the placement of an IO line are cardiac arrest, shock, sepsis, trauma, severe dehydration, extensive burns, status epilepticus, or any condition that requires urgent administration of fluids, medications, or blood products.[18] Current American Heart Association Advanced Cardiac Life Support guidelines recommend IO access if IV access is unobtainable within 90 seconds or two attempts and for the administration of medications over endotracheal medication administration.

In addition to resuscitation, IO access can provide blood samples for typing, crossmatching, and laboratory analysis. Electrolytes, creatinine, blood urea nitrogen (BUN), glucose, calcium, and arterial blood gas values from blood samples obtained through an IO needle

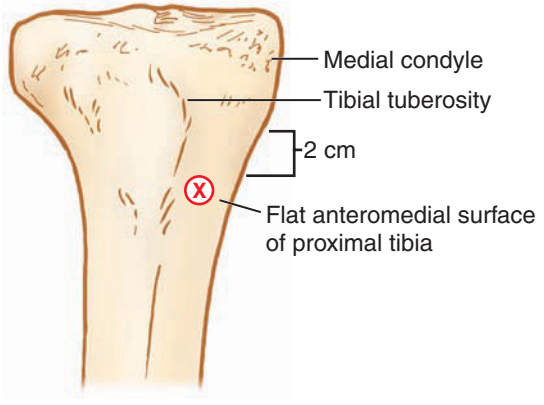


FIGURE 55-2. The proximal tibia is the traditional site used in pediatrics for IO access. The ⊗ represents the site of IO needle insertion.

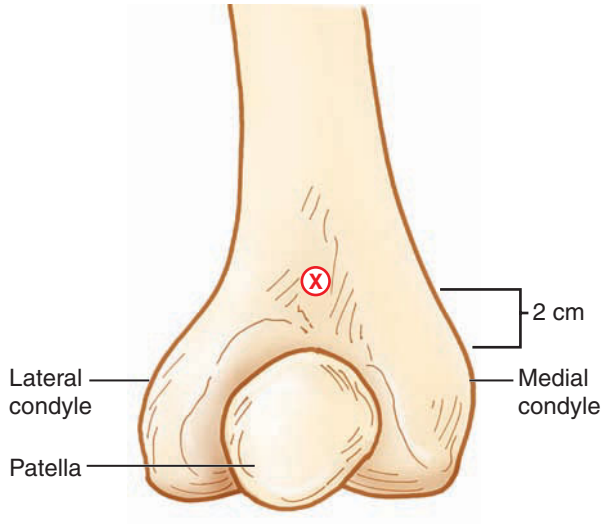


FIGURE 55-4. The distal femur is an alternative site for IO access. The ⊗ represents the site of IO needle insertion.

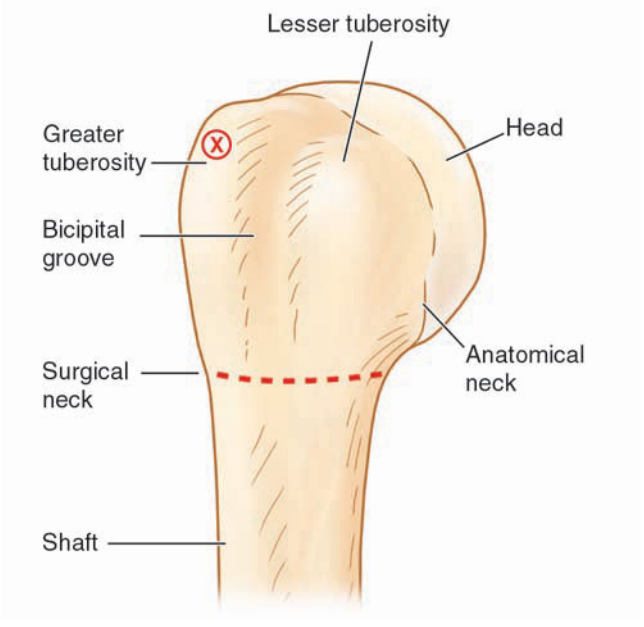


FIGURE 55-5. The proximal humerus is an alternative site for IO access in the adult. The ⊗ represents the site of IO needle insertion.

TABLE 55-1 Medications and Fluids that may be Administered Through an IO Line[16–19,43,44]

Medications

Adenosine	Diazoxide	Lorazepam
Amiodarone	Digoxin	Mannitol
Antibiotics	Dobutamine	Morphine
Antitoxins	Dopamine	Naloxone
Anesthetics	Ephedrine	Norepinephrine
Atracurium besylate	Epinephrine	Pancuronium
Atropine	Heparin	Phenobarbital
Calcium gluconate	Insulin	Phenytoin
Calcium chloride	Isoproterenol	Propranolol
Contrast media	Ketamine	Sodium bicarbonate
Dexamethasone	Levarterenol	Succinylcholine
Diazepam	Lidocaine	Tenecteplase
		Thiopental
		Vecuronium

Fluids

Blood products
Dextrose solutions
Iodinated contrast agents
Lactated Ringer's solution
Packed red blood cells
Plasma
Sodium chloride solutions

are similar to those from samples taken via traditional routes.[21,22] Laboratory values may be less accurate after five or more minutes of active resuscitation, or if drugs or fluid have been infused through the IO site.[22]

CONTRAINDICATIONS

Placement of an IO line is contraindicated in diseased or osteoporotic bone. The placement of an IO line through areas of cellulitis, abscesses, or burns should be avoided.[23] Fractures in the ipsilateral bone increase the risk of an extravasation-induced compartment syndrome and nonunion of the fractures.[24] Failed placement of an IO line in the same bone is a relative contraindication. Do not use a bone that has had a previous orthopedic procedure, contains hardware, or may contain hardware (i.e., pins, plates, screws, and artificial joints). An IO line should not be inserted if the patient is morbidly obese as the needle is too short to enter the medullary cavity or if the patient is so obese that the bony landmarks cannot be palpated.

There are contraindications specific to sternal IO access. Do not attempt sternal IO access in patients who weigh less than 50 kg, are small in stature, have a small sternum, have congenital sternal malformations, or have chest wall malformations. The blunt trauma patient with a suspected sternal fracture or soft tissue injury over the sternum should not be considered for sternal IO access. A history of a sternotomy or osteoporosis is also a contraindication.

EQUIPMENT

- Sandbag or towels
- Povidone iodine or chlorhexidine solution
- Local anesthetic solution, 1% or 2% lidocaine
- Syringe, 5 to 60 mL
- Primed intravenous tubing with normal saline
- Tape
- Plastic protective cup
- Leg board for immobilization
- IO access device

IO needles are available in a number of sizes and styles (**Figure 55-6**). **Only specifically designed IO needles should be used for this procedure.** Spinal needles often bend and do not penetrate the cortex of the bone. Their long length causes increased resistance to fluid flow. Standard hypodermic needles also often bend and do not penetrate the cortex of the bone. Both these types of needles may break while being inserted and injure the healthcare provider.

Available models of manually inserted IO devices include the hand-driven threaded-needle SurFast and Cook Intraosseous needle (Cook Critical Care, Bloomington, IN), the Jamshidi bone marrow needle (Baxter Healthcare, Valencia, CA), and the MedSurg Industries Illinois sternal/iliac aspiration needle (MedSurg Industries, Rockville, MD). The typical unit consists of a detachable



FIGURE 55-6. IO infusion needles. *From left to right*: the Cook Intraosseous infusion needle, two models of the Illinois sternal/iliac aspiration needle, and the Jamshidi bone marrow needle.



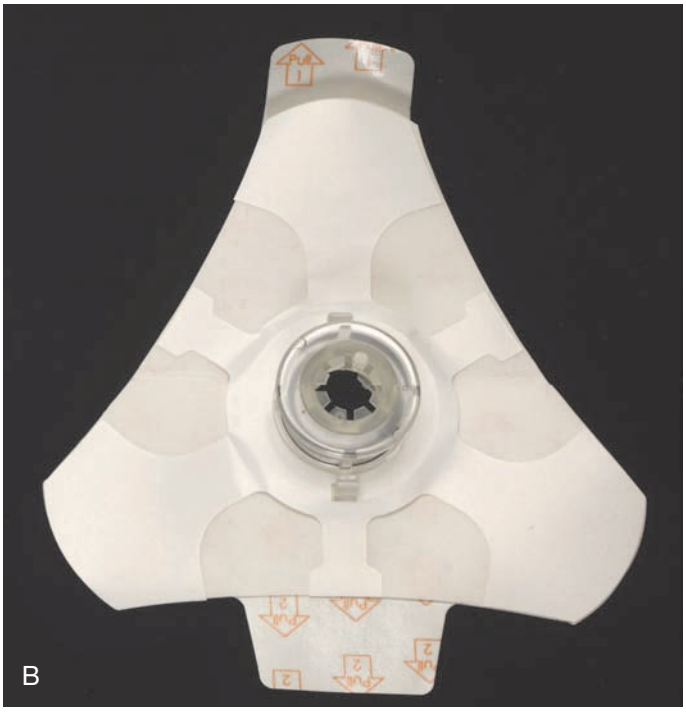


FIGURE 55-7. The EZ-IO. **A.** The driver and three lengths of IO needles. **B.** The EZ-Stabilizer (Photos courtesy of Vidacare, San Antonio, TX).

handle, an IO needle, an obturator, and a sleeve to prevent the needle from penetrating too deeply. The IO needle ranges in size from 12 to 20 gauge. The IO needles available today are variations of the basic unit and include adjustable-length shafts to decrease the risk of penetrating too deeply, a variety of tips on the obturator (e.g., lancet, pencil point, and trocar), threaded versus nonthreaded shafts, needle side ports to increase flow rates, numerous lengths, and numerous handle types.

New powered and spring loaded injection devices have evolved. Two currently available devices are the EZ-IO Intraosseous Driver (Vidacare, San Antonio, TX) and the Bone Injection Gun (BIG, Wais Medical, Kress USA Corporation). The EZ-IO uses a battery-powered driver to insert the needle to a preset depth (**Figure 55-7**).[14] The BIG incorporates a loaded spring to inject the IO needle, and the desired depth of injection may be adjusted (**Figure 55-8**).[25] Both devices are available in adult and pediatric needle sizes. The EZ-IO and the BIG have numerous advantages when compared to



FIGURE 55-8. The BIG in adult and pediatric sizes (Photo courtesy of Wais Medical, Houston, TX).

the manual devices. They are easier to use, quicker to establish IO access, require less or no force to insert the IO needle, and do not bend during insertion.

Sternal access devices include the MONOJECT™ I-Type Sternal-Iliac Aspiration Needle (Covidien, Mansfield, MA), the First Access for Shock and Trauma (FAST1™ and FASTX™, Pyng Medical, Richmond BC), and Life/form® Adult Sternal Intraosseous Infusion System (Nasco, Modesta, CA). The F.A.S.T.1™ is a multiple-component kit to be used for sternal IO access in the adult patient. A special introducer limits the depth to which the needle can be inserted. This prevents injury to the underlying great vessels, heart, lung, and mediastinum. This system was evaluated in Special Forces military settings, and found to be equally useful and safe in terms of IO access.[27] Sternal IO access devices are used less often than the previously described powered devices due to the possible interference with resuscitation attempts and their incomplete removal on occasion requiring surgical removal.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative if time permits. This procedure is often performed in emergencies; therefore, informed consent can often be waived. Currently, the primary site of choice for IO line placement is the proximal tibia. Alternate sites include the distal tibia, distal femur, proximal humerus, and the sternum. Even with sternal access, it is possible to perform a cricothyroidotomy and cardiopulmonary resuscitation (CPR).[25] The proximal humerus allows more central access, while the proximal tibia is often accessible without disrupting airway management and CPR.[14]

Place the patient supine with the lower extremity supported behind the knee with a towel or sandbag. Identify by palpation the landmarks required to perform the procedure. Palpate the bony landmarks with the nondominant hand. The bony landmarks for the proximal tibia approach are the tibial tuberosity and the flat anteromedial surface of the proximal tibia. The site of IO needle placement is approximately 2 cm below the tuberosity on the flat anteromedial surface of the proximal tibia (**Figure 55-2**). The bony landmark for the distal tibia approach is the junction of the medial malleolus and the flat anteromedial surface of the distal tibia just posterior to the greater saphenous vein[18] (**Figure 55-3**). This is the preferred site in the adult patient. The bony landmarks for the distal femur approach are the medial and lateral condyles of the femur

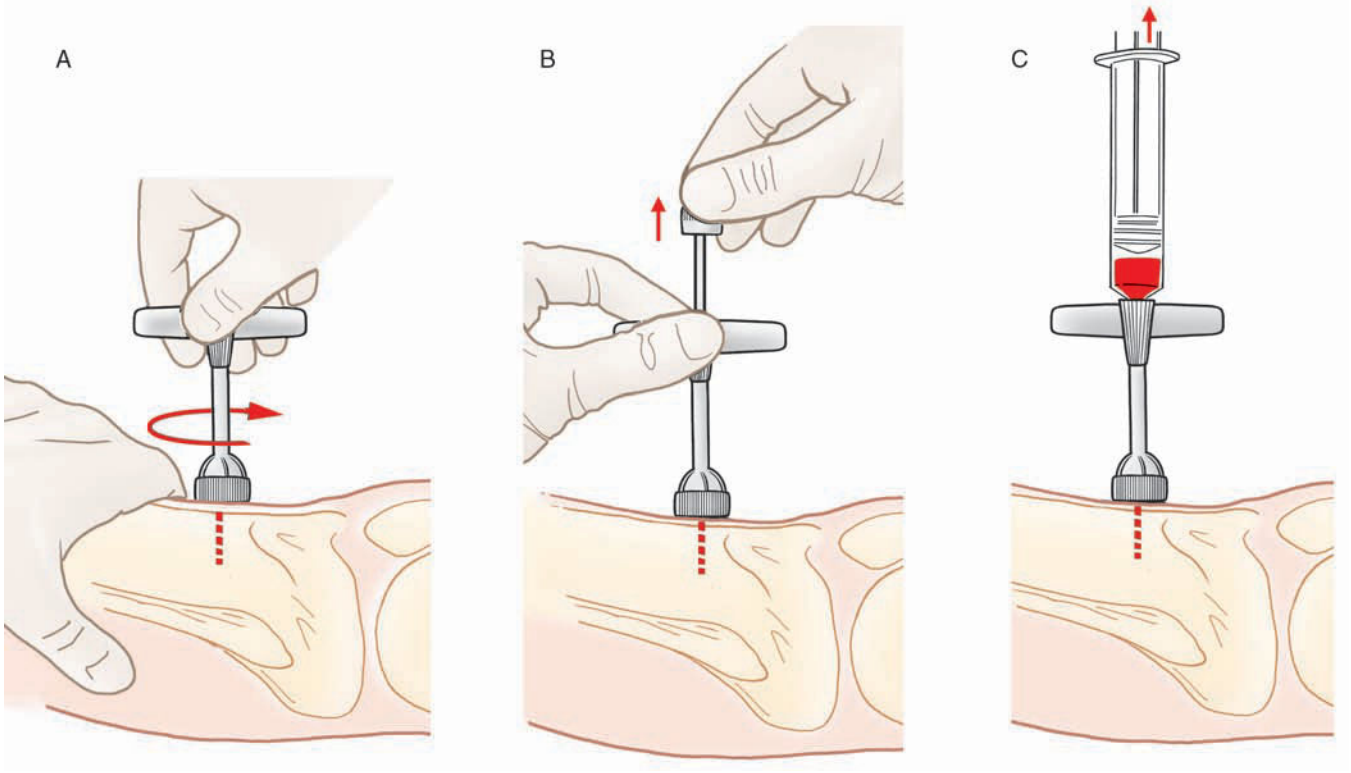


FIGURE 55-9. Placement of an IO line. **A.** The nondominant hand is used to support the extremity. The IO needle is inserted with a twisting motion to cut through the cortex of the bone. **B.** The handle and obturator are removed. **C.** A syringe is attached to the hub of the IO needle and bone marrow is aspirated.

and the patella. The IO needle should be positioned approximately 2 cm above these structures (**Figure 55-4**). This site is utilized less often due to the abundance of muscle and soft tissue structures. The bony landmarks for the humeral approach are slightly anterior to the lateral midline of the arm, with care to avoid the bicipital groove (**Figure 55-5**). The arm should be adducted and internally rotated for optimal positioning.[14]

Prepare the patient. Clean any dirt and debris from the skin. Apply povidone iodine or chlorhexidine solution to the skin and allow it to dry if time permits. This procedure is extremely painful. If time permits, the use of a local anesthetic solution in the conscious or semiconscious patient will be greatly appreciated. Infiltrate local anesthetic solution into the skin, subcutaneous tissues, and periosteum overlying the bone puncture site. Additionally, in the alert patient, consider infusing 3 to 5 mL of 2% lidocaine intravenously both initially and at regular intervals to minimize patient discomfort.[11]

TECHNIQUE

MANUALLY INSERTED IO DEVICES

Examine the IO needle to ensure that it appears to have been manufactured properly. Reidentify the landmarks with the nondominant hand. Stabilize the extremity with the nondominant hand (**Figure 55-9A**). Grasp the IO needle firmly with the dominant hand. The handle of the IO needle should be firmly planted in the palm of the dominant hand. Insert the needle perpendicularly or slightly angulated (at a 10° to 15° angle) to the long axis of the bone (**Figure 55-9**). **The IO needle should always be directed away from the growth plate to avoid injuring it.** Direct the needle caudad in the proximal tibial approach and cephalad in the distal tibial and distal femoral approaches.

Advance the IO needle through the skin and subcutaneous tissue until the bone is contacted. Advance the IO needle through the bone. A twisting or rotary motion with the simultaneous application of downward pressure should be used to cut through the cortex of the bone (**Figure 55-9A**). A significant reduction in the resistance to forward motion will be encountered when the cortex is penetrated and the needle enters the medullary canal. This distance is rarely greater than 1 cm in most patients. An index finger may be placed 1 cm from the bevel of the IO needle prior to advancement. This will help prevent overpenetration into and through the cortex on the opposite side of the bone.[28] Alternatively, adjust the sleeve so that only 1 cm of the IO needle is exposed. **Stop advancing the IO needle when it enters the medullary canal.**

Remove the stylet when the medullary canal is entered (**Figure 55-9B**). Attach a 5 or 10 mL syringe onto the hub of the IO needle (**Figure 55-9C**). Aspirate blood from the medullary canal to confirm proper placement of the IO needle. Any samples obtained may be sent to the laboratory for subsequent analysis. The aspiration of more than 2 to 3 mL of blood may not be possible in cardiac arrest situations. Attach IV tubing to the hub of the IO needle and begin the infusion of fluids. Medications can be administered through the injection port of the IV tubing. Place a sterile dressing around the skin puncture site and apply pressure for 5 minutes.[29]

IO ACCESS USING THE EZ-IO

The EZ-IO is a reusable, nonsterile, battery powered driver that uses sterile, disposable, single patient use IO needles. The IO needles are available in three lengths (15, 25, and 45 mm). Choose the proper IO needle for the patient, their body habitus, and the insertion site. Assess the tissue depth by palpation. Choose an IO needle so that at least one black line on the IO needle shaft will be



FIGURE 55-10. Using the EZ-IO. **A.** An IO needle has been applied onto the driver. **B.** Insert the IO needle at a 90° angle to the skin. **C.** The driver has been removed. **D.** The stylet is removed. **E.** The EZ-Stabilizer and tubing have been applied.

above the patient's skin when the tip is against the bone. The IO needle tip is designed to cut the bone and create a hole the same size as the needle.

Identify the IO insertion site and prepare for the procedure. Clean and prep the skin at the site and surrounding area. The procedure requires aseptic technique. Select the appropriate size IO needle. Open the cover of the case that holds the sterile IO needle. Insert the bit on the EZ-IO driver into the base of the IO needle (**Figure 55-10A**). **Leave the cap on the IO needle until it is ready to be inserted.** Open the EZ-Connect tubing and flush it with a syringe containing 10 mL of sterile normal saline. Leave the syringe attached to the tubing after it is flushed.

Reidentify the landmark for the insertion site. Inject local anesthetic solution subcutaneously and down to the periosteum. Remove the cap from the IO needle. Insert the IO needle perpendicular or at a 90° angle to the skin (**Figure 55-10B**). Advance the IO needle through the skin and subcutaneous tissues until the tip is against bone. At least one black line on the needle shaft should be visible above the patient's skin. If a black line is not visible on the needle shaft, withdraw the needle and replace it with a longer

IO needle. Press the trigger to start the driver shaft and IO needle rotating. **Apply gentle and minimal downward pressure to advance the IO needle into the medullary canal. Stop advancing the driver when a loss of resistance is felt.**

Grasp and firmly hold the hub of the IO needle. Remove the driver (**Figure 55-10C**). **Do not allow the IO needle to move while removing the driver.** Twist the stylet counterclockwise and remove it while securely holding the IO needle hub (**Figure 55-10D**). Attach the EZ-IO stabilizer (**Figures 55-7B & 55-10E**), if using it, followed by the primed EZ-Connect tubing. Aspirate bone marrow to confirm proper needle placement. **Do not attach a syringe directly to the IO needle hub.** A syringe attached to the hub can result in a fracture of the hub. **Always attach the EZ-Connect tubing then aspirate and inject through it and not directly through the IO needle hub.** Begin using the IO access.

IO ACCESS USING THE BIG

The BIG is an automatic, spring loaded device that does not require a power source. It is available in two sizes, adult and pediatric. The insertion site is different for adults and children. Always start at the tibial tuberosity as the initial landmark. For adults, move 2 cm medially toward the inner leg and then 1 cm proximally toward the patient's head. For children, move 1 to 2 cm medially toward the inner leg and then 1 to 2 cm distally toward the patient's foot. Mark this final location as the insertion site. It may also be inserted in the proximal humerus in the adult patient.

Prepare for the procedure. This procedure requires aseptic technique. Clean and prep the skin at the insertion site and surrounding area. Open the package and remove the sterile BIG. Rotate the base of the unit to adjust the IO needle penetration depth according to the pediatric patient's age: 0 to 3 years at 0.5 to 1.0 cm, 3 to 6 years at 1.0 to 1.5 cm, and 6 to 12 years at 1.5 cm (**Figure 55-11A**). Use the adult BIG for patients over the age of 12 years. Reidentify the landmark for the insertion site. Inject local anesthetic solution subcutaneously and down to the periosteum.

Position the BIG at the insertion site with the base perpendicular or at 90° to the skin (**Figure 55-11B**). Firmly grasp the BIG with the nondominant hand. Squeeze and pull out the red safety latch while firmly holding the BIG against the insertion



FIGURE 55-11. Using the BIG. **A.** Adjust the penetration depth. **B.** Apply the BIG at a 90° angle to the skin. **C.** Remove the safety latch. **D.** Grasping the BIG in preparation of triggering the unit.



FIGURE 55-11. (*continued*) **E.** Remove the BIG. **F.** Attach and secure the safety latch. **G.** Pull the stylet-trocar from the IO cannula. **H.** Attach IV tubing onto the hub and aspirate bone marrow (Photos courtesy of Wais Medical, Houston, TX).

site (**Figure 55-11C**). **Do not discard the safety latch as it will be used later to secure the IO needle.** Grasp the upper part of the BIG with the dominant hand (**Figure 55-11D**). Place two fingers under the wings and the palm on the top of the BIG (**Figure 55-11D**). Continue to firmly hold the base against the patient's skin with the nondominant hand.

Insert the IO needle. Trigger the BIG by gently pressing down with the palm. The device will eject the spring loaded IO needle into the bone. The IO needle should be standing upright, firmly in the bone, and stable. If not, it has been placed into muscle or soft tissue. Gently lift and remove the BIG device without catching on the IO needle hub (**Figure 55-11E**). Attach the safety latch onto the cannula between the patient's skin and the IO cannula hub (**Figure 55-11F**). Secure the safety latch to the skin with tape (**Figure 55-11F**). Gently remove the stylet-trocar, leaving the cannula in place (**Figure 55-11G**). **If the stylet-trocar is "stuck" and not easily removable, do not pull or try to forcefully remove it.** The IO needle did not penetrate all the way into the medullary cavity and is embedded in the cortex. Insert the square end of the safety latch into the hub of the IO needle and gently twist to remove the IO needle. Repeat the procedure at another site. Attach the IV tubing onto the hub of the cannula (**Figure 55-11H**). Aspirate bone marrow to confirm proper placement (**Figure 55-11H**). Flush the IV tubing and cannula with 5 to 10 mL of sterile saline. Begin using the IO access.

ASSESSMENT

Assess whether the IO needle is correctly positioned within the medullary cavity. First aspirate blood from the marrow cavity. This may not be possible because of poor circulation in patients with a cardiac arrest. A second sign of correct placement is to assess whether the IO needle will stand erect without support. Finally, flush the IO line. The ability of the fluid to flow without inducing soft tissue swelling can also be used to confirm proper placement. Ultrasonic visualization of flow within the medullary cavity using color flow Doppler can also confirm proper placement.[45] A reassessment must be performed again at regular intervals to ensure that extravasation does not occur.[30] Circumferential pressures of the involved extremity may be used for serial examination.[30]

A C-arm fluoroscopic imaging device may be used at the bedside to confirm accurate placement of the IO needle.[31]

AFTERCARE

Secure the IO needle. Secure the manually inserted IO needle by taping it in place. It may be easier to apply 4 × 4 gauze squares on two sides of the IO needle to support it and then tape the needle and gauze in place. Secure the EZ-IO needle in the same manner. Tape the safety latch of the BIG to the skin to secure it. Tape the IV tubing securely at several points. This will prevent traction on the tubing from pulling the IO needle out of the bone. Tape a plastic cup over the IO needle to avoid inadvertent disruption during patient resuscitation or positioning. Immobilize the extremity, if necessary, to help secure the IO line.

Remove the IO line once the resuscitation is complete and another form of secure vascular access has been obtained. Manually inserted IO devices can be removed by gently twisting it and pull it straight out. **Do not rock the device.** To remove the EZ-IO, attach a 5 or 10 mL Luer lock syringe onto the IO needle hub. Rotate the syringe clockwise and pull it straight out. It may take several rotations of the syringe before the IO needle can be removed. **Do not rock the IO needle or syringe.** To remove the BIG cannula, insert the square end of the safety latch into the hub of the cannula and gently twist and pull to remove it. Bleeding at the insertion site can be controlled with a sterile pressure dressing followed by cleansing the skin and a simple bandage.

COMPLICATIONS

The most common complication of IO infusions are subcutaneous and subperiosteal extravasation of fluid due to technical difficulty.[4] Under ideal circumstances, the type of IO needle used should not affect extravasation rates.[30,32] Extravasation is usually due to under- or overpenetration of the cortex. There have been cases of tibial fracture due to overpenetration of the cortex.[33,34] A compartment syndrome may occur when there is extravasation or when IO lines are placed in fractured bones.[26] Necrosis and sloughing of the skin at the insertion site of the IO needle are due to extravasation of fluid or medication.[35]

Localized infections may occur after IO needle placement. Cellulitis or the formation of subcutaneous abscesses occur in 0.7% of patients.[24] Osteomyelitis has been reported in less than 1% of patients with IO needles.[25] Risk of osteomyelitis increases with prolonged IO use, administration of hypertonic fluids, and bacteremia.[25,36]

Injury to the growth plate is a commonly mentioned complication; however, the literature does not support this.[37,38] Additionally, in recent animal studies, the rate of the IO infusion and the osmolarity of the infused fluid did not adversely affect the bone marrow or bone development.[42] Fat embolism has also been mentioned as a possible complication.[41] Consider a fat embolism if the patient becomes hypoxic or experiences respiratory difficulty shortly after beginning an IO fluid infusion or bolus. The use of an IO line for the infusion of emergency drugs and fluids does not increase the magnitude of fat embolization during CPR.[39,40] Animal studies have shown no significant increase in fat emboli in lung tissue when IO infusion is used.[39]

The flow rate of fluid through an IO line is slower than that through a peripheral intravenous line. This may be due to a small marrow cavity, a fibrous marrow cavity, and/or the replacement of red marrow with yellow marrow. Fluid flow rates can be significantly increased by applying a pressure bag onto the intravenous fluid bag or using a level-one infuser. The placement of a second IO line may be required to further increase the amount of fluid that can be infused.

The complications specific to the EZ-IO include hub fracture after insertion and separation of the needle from the hub upon removal. Too much downward pressure upon IO needle insertion can result in it penetrating the back of the bone. The other general complications are described above.

The complications associated with the BIG are primarily from incorrect use. **Never remove the safety latch until the BIG is against the patient's skin over the insertion site.** Removal of the safety latch activates the device. The IO needle can be forcefully ejected and injure someone if the BIG is squeezed after the safety latch is removed. Never place a finger over the distal end of the BIG. **Always grasp the BIG properly. Grasping it upside down can result in the IO needle penetrating the Emergency Physician's hand.** Incorrectly adjusting the penetration depth can result in the IO needle penetrating the back of the bone. The other general complications are described above.

SUMMARY

The placement of an IO line is a viable option in the resuscitation of a patient when traditional vascular access techniques have failed. The procedure is technically straightforward and has been demonstrated to be successful in the hands of trained healthcare workers, including prehospital personnel. Complications have been related mostly to technical mistakes and can be avoided if care is taken to correctly identify landmarks, avoid the growth plate, regulate the depth of IO needle placement, and ensure the early removal of the IO line.

56 Umbilical Vessel Catheterization

Eric F. Reichman, Amy Noland, and Antonio E. Muñiz

INTRODUCTION

Umbilical vessel catheterization was first described by Diamond in 1947 for an exchange transfusion in a neonate.[1] Umbilical vessel catheterization serves many important functions in the ill neonate. Umbilical vessel catheterization can be used as a reliable method of obtaining rapid vascular access in the neonate. Umbilical vessel catheters may be used for fluid resuscitation, blood transfusion, medication administration, frequent blood sampling, and cardiovascular monitoring.[2–5] **However, the use of these catheters also carries significant risk of permanent morbidity and even death.** Either the umbilical artery or vein may be used for vascular access. The artery can usually be accessed within the first 24 hours of life. It is occasionally possible to use the umbilical artery up to 7 days after birth.[2] The umbilical vein can be accessed for up to 2 weeks of age.[2,6]

Umbilical artery catheterization is more desirable than umbilical vein catheterization because it allows frequent arterial blood gas sampling and continuous blood pressure monitoring, in addition to fluid, blood, and medication administration. Unfortunately, umbilical artery catheterization is more difficult and time consuming to perform, especially in unskilled hands. Therefore, umbilical vein catheterization is the preferred procedure for the infant in shock and in need of rapid resuscitation. Arterial access can be obtained later in a more controlled environment, such as in the neonatal intensive care unit. **Umbilical vessel catheterization can lead to serious complications and**

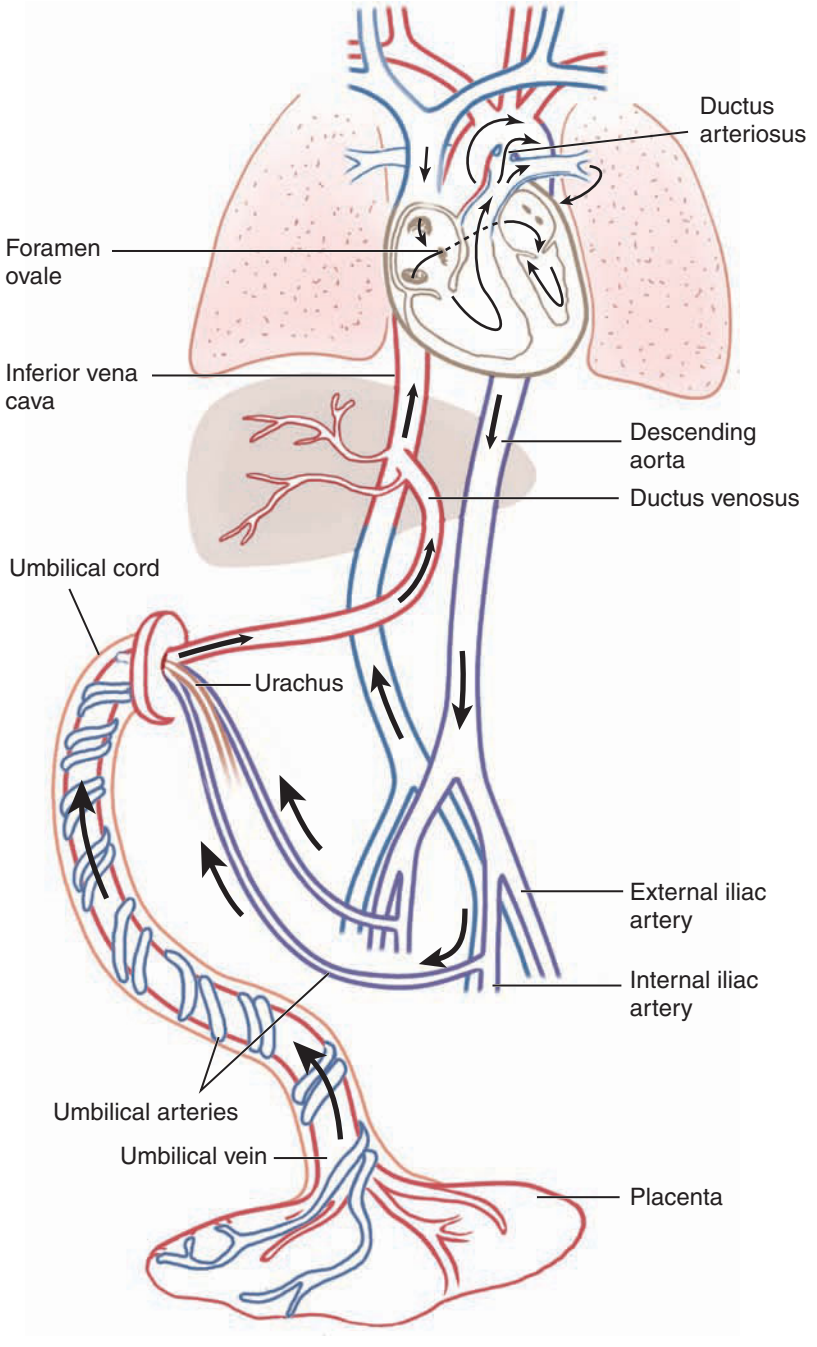


FIGURE 56-1. The fetal circulation.

should be reserved for the patient in whom peripheral venous access attempts have been unsuccessful.[5,7]

ANATOMY AND PATHOPHYSIOLOGY

The fetal circulatory system is quite different from that of the neonate or infant (**Figure 56-1**). Oxygenated blood from the placenta travels via the umbilical vein, through the ductus venosus in the liver, to the inferior vena cava (IVC), and into the right atrium. Oxygenated blood from the IVC preferentially enters the left atrium through the foramen ovale. It then enters the left ventricle, then the aorta. This oxygen-rich blood supplies the brain prior to mixing with the oxygen-poor blood coming through the ductus arteriosus. Deoxygenated blood from the superior vena cava (SVC) enters the right ventricle and is pumped to the pulmonary artery. It then passes through the ductus arteriosus to meet the oxygenated blood in the aorta.

Pulmonary vascular resistance decreases dramatically as the infant takes its first breaths. The systemic vascular resistance increases when the umbilical cord is clamped. The foramen ovale closes with the combination of decreased pulmonary artery pressure and increased systemic resistance. The ductus arteriosus closes within 24 to 48 hours due to the release of prostaglandins and increased blood oxygen tension. The ductus venosus closes when the umbilical cord is clamped.

The umbilical vein and arteries can easily be differentiated by examination of a cross section of the umbilical cord (**Figure 56-2**). The umbilical vein is a single vessel with thin walls and a large

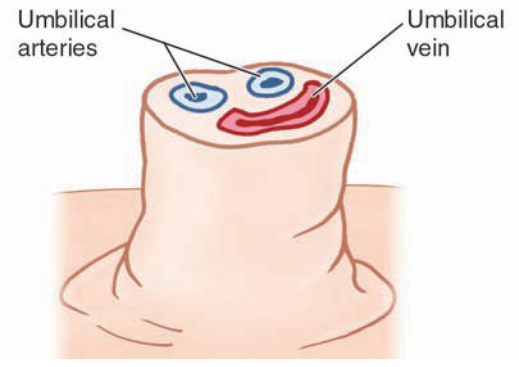


FIGURE 56-2. Anatomy of the umbilical cord.

lumen. It is usually flattened in one direction. There are two thick-walled umbilical arteries that are significantly smaller in diameter than the umbilical vein. Occasionally, only a single umbilical artery is present.

INDICATIONS

Umbilical artery catheterization is indicated when frequent arterial blood gas determinations and continuous monitoring of blood pressure are required in the first few days of life in critically ill neonates.[4] Umbilical artery catheters can be used for delivering blood, fluids, total parenteral nutrition, medications, and for exchange transfusions.[2,3] It reduces the need for multiple venipunctures and heel prick capillary blood sampling in the critically ill neonate.[8] Neonates under 24 hours of age can usually be catheterized without much difficulty. Skilled Emergency Physicians can sometimes perform this in neonates up to 7 days of age.[2]

Umbilical vein catheterization is easier to perform than umbilical artery catheterization. It is the preferred procedure for the neonate in shock needing rapid administration of intravenous fluids, blood, or medications.[1] In critically ill neonates, the umbilical vein can be used to monitor central venous pressure. This procedure is possible in neonates up to 2 weeks of age.[2] Recently, the umbilical vein has been used to perform invasive cardiac procedures.[9]

CONTRAINDICATIONS

Umbilical vessel catheterization in the Emergency Department should be performed only on severely ill neonates in whom peripheral vascular access attempts have failed. The contraindications are similar for the umbilical vein and umbilical artery catheterization. These include gastroschisis, an omphalocele, omphalitis, and peritonitis.[2,10] Never insert an umbilical catheter if there are any signs of infection on or around the remnant of the umbilical cord. Umbilical vessel catheterization is contraindicated if a neonate is older than the previously stated ages. An alternate route of vascular access is required if the possibility of an abdominal abnormality exists, as manifested by a distended abdomen or visible defects.[2] Relative contraindications for placement of an umbilical artery catheter include decrease perfusion to the lower extremities or buttock and suspicion of necrotizing enterocolitis.

EQUIPMENT

- Umbilical vein catheters, 5.0 French and 3.5 French
- Umbilical artery catheters, 5.0 French and 3.5 French
- Umbilical tape
- Povidone iodine or chlorhexidine solution
- Sterile gauze
- Sterile drapes
- Sterile gown and gloves
- Cap and face mask
- Adhesive tape
- Radiant warmer with a light
- Cardiac monitor
- Pulse oximeter
- 3-0 or 4-0 silk suture with a needle
- Needle driver
- Smooth-curved iris forceps
- Iris scissors
- Two small, smooth-curved hemostats
- Straight Crile forceps
- #10 or #11 scalpel blade on a handle
- Three-way stopcock
- 10 mL syringe filled with normal saline
- Heparinized sterile saline solution, 1 unit of heparin/1 mL of saline

Umbilical artery and vein catheters are available in a variety of sizes. Umbilical vein catheters are available as a single-lumen or double-lumen catheter. They should not have side holes unless it is to be used specifically for an exchange transfusion. Use a 5.0 French umbilical venous catheter in neonates weighing >1200 g and a 3.5 French catheter in neonates weighing <1200 g. Use a 5.0 French umbilical artery catheter in neonates weighing >3500 g and a 3.5 French catheter in neonates weighing <3500 g.

Umbilical vessel catheterization kits are commercially available from several manufacturers. One example is the Argyle Neo-Sert™ Umbilical Vessel Catheter Insertion Tray (Tyco Healthcare, Mansfield, MA). The kits are sterile, disposable, and intended for single patient use. They contain all the equipment required including the instruments and catheters.

PATIENT PREPARATION

Attempts at peripheral venous access should have failed in a sick neonate prior to attempting umbilical vessel catheterization. All equipment should be readily available on a pre-prepared sterile tray. Place the tray with the instruments on a Mayo stand next to the neonate's bed. Place the neonate under a radiant warmer with a light source. Place the neonate on a cardiac monitor, continuous pulse oximeter, and supplemental oxygenation if needed. Place the neonate supine with the lower extremities in the frog-leg position (**Figure 56-3**). Their arms and legs may need to be restrained to prevent contamination of the sterile field.

This procedure requires strict sterile technique. The Emergency Physician performing the procedure should wear a cap, mask, sterile gloves, and sterile gown. Scrub the umbilical cord, umbilical cord clamp, and the neonate's abdomen with povidone iodine or chlorhexidine solution and allow it to dry. Place sterile drapes to form a sterile field around the umbilical area, ensuring the neonate's head is exposed for observation.

TECHNIQUES

Sterile technique must be maintained throughout the entire procedure. Loosely tie a piece of umbilical tape around the base of the umbilical cord (**Figure 56-4**). Place a 3-0 or 4-0 silk purse-string suture through the base of the umbilical cord and just above the

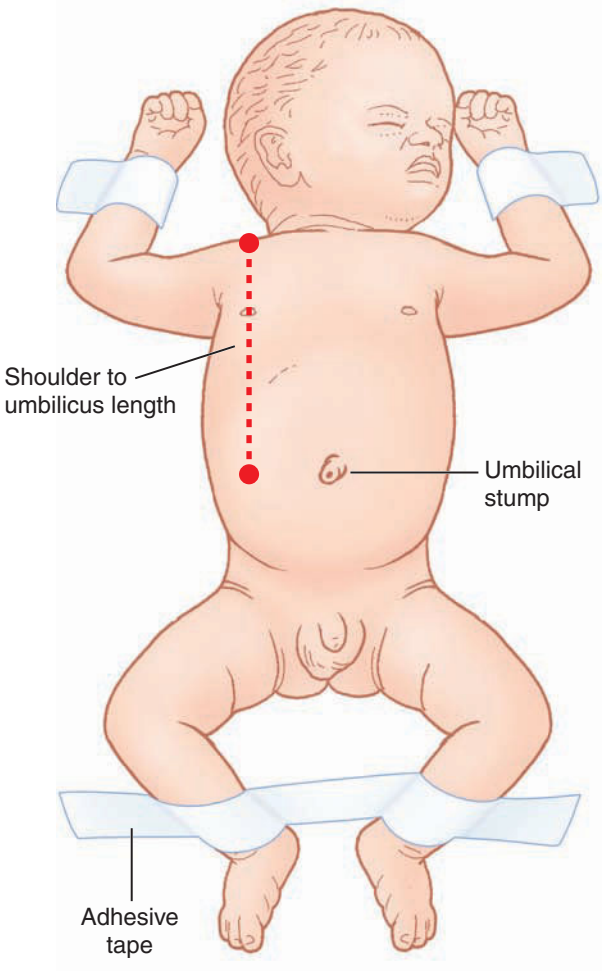


FIGURE 56-3. Positioning of the neonate. The dotted line represents the shoulder-umbilical length.

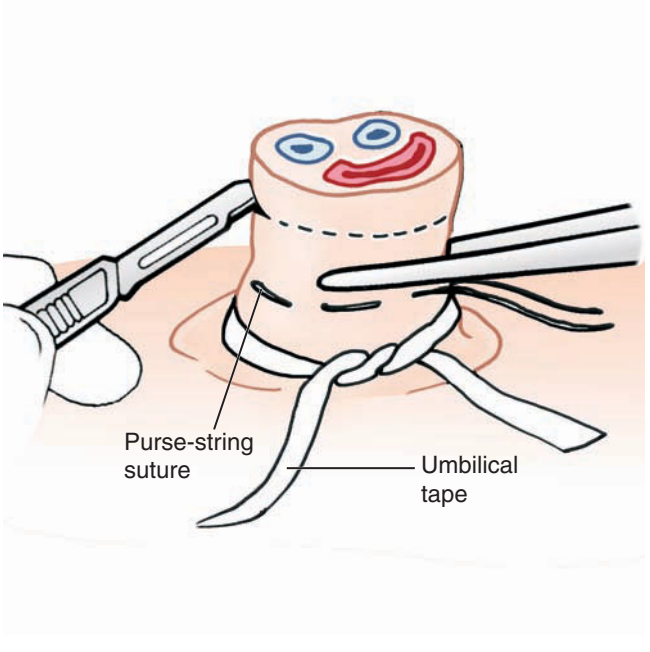


FIGURE 56-4. Preparing the umbilical cord stump. Umbilical tape has been placed at the base and tied loosely. A purse-string suture has been placed through the stump and just above the umbilical tape. The distal end of the umbilical cord is removed along the dotted line.

umbilical tape (**Figure 56-4**). **Avoid piercing the umbilical vessels and the skin of the abdominal wall.** Leave the suture untied and the ends uncut. This will be used later to secure the umbilical vessel catheter. Gently grasp the umbilical cord clamp. Use an #10 or #11 scalpel blade to cut the umbilical cord just beneath the clamp to expose a smooth, clean surface of the umbilical cord (**Figure 56-4**). **Do not cut the cord too close to the base in case it needs to be re-cut for a repeat attempt.** Tighten the umbilical tape if blood is oozing from the cut umbilical cord. **Blot the blood with gauze squares. Do not rub the gauze against the umbilical cord to prevent damaging the fragile umbilical cord.** Grasp the umbilical cord with forceps or fingers and identify the three vessels, two arteries, and one vein. The arteries are smaller, round, and have thick muscular walls. The vein is larger, has thinner walls, and is less round than the arteries. The umbilical artery or vein may now be catheterized as described in the following sections.

UMBILICAL ARTERY CATHETERIZATION

Determine the desired position of the catheter tip (**Figure 56-5**). There are two possible positions for the umbilical artery catheter tip, the high or low position. In the low position, the catheter tip is placed between the third and fifth lumbar vertebrae, a level corresponding to just above the aortic bifurcation.[2,11] In the high position,

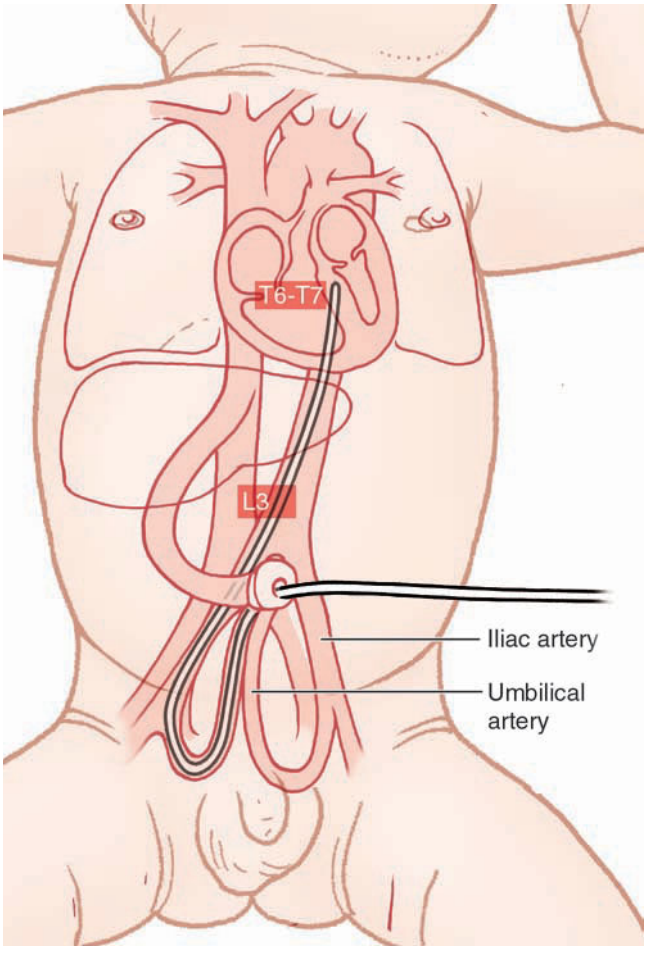


FIGURE 56-5. Positioning of the tip of the umbilical artery catheter. The low position, between L3 and L5, is just above the aortic bifurcation. The high position, between T6 and T9, is above the diaphragm, between the ductus arteriosus and the mesenteric arteries. The shaded boxes represent the vertebral bodies in the midline.

the catheter tip is placed between the sixth and ninth or tenth thoracic vertebrae, a level corresponding to just above the diaphragm, between the ductus arteriosus and the origins of the mesenteric arteries.[2,11–13] Controversy exists over which position is the preferred site for the catheter tip.[14] A recent Cochrane Database review of six controlled trials demonstrated that the high position was associated with a lower occurrence of clinical vascular complications, removal, and adverse sequelae.[4,5,21]

A variety of methods have been used to determine the insertional length of umbilical arterial catheters. Some of these include electrocardiographic changes during placement, echocardiography-guided insertion, and ultrasound-guided insertion.[15–19] However, these are hard to perform in clinical practice. Other methods for determining the appropriate depth of catheter insertion are based on the shoulder-to-umbilicus length and the neonate's birth weight. There are also standardized graphs for determining the appropriate catheter insertion depth.

Most centers use a calculation derived by Dunn on post-mortem infants where the length of insertion to the high position is measured from the external shoulder to the umbilicus (**Figure 56-3**).[20] Measure the shoulder to umbilicus length by measuring the distance between the top of the shoulder to the level perpendicular to the umbilicus (**Figure 56-3**). Using the shoulder-umbilical length and the desired position of the catheter tip, determine the umbilical catheter length to be inserted into the artery (**Figure 56-6**). Add the length of the umbilical stump to the umbilical artery catheter length found on the *y*-axis of the graph to determine the corrected length of catheter to be inserted.

Another popular way to measure the length of insertion is the formula derived by Shulka and Ferrara.[21] The insertion length (cm) at the high position = (3 × body weight [kg]) + 9 + the length (cm) of the umbilical cord stump. To place it in the low position, use this value divided by 2. For neonates <1000 g body weight, another formula seems to be more accurate.[22] The insertion length (cm) at the high position = (4 × body weight [kg]) + 7 + the length (cm) of the umbilical cord stump.

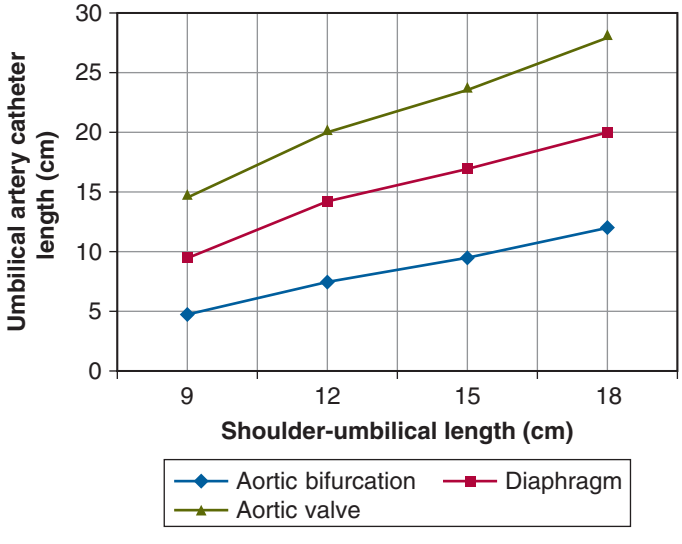


FIGURE 56-6. Graph to determine the correct length of catheter to insert into the umbilical artery. Using the shoulder-umbilical length and the desired position of the catheter tip, determine the length of catheter on the *y*-axis to be inserted into the artery. Add the length of the umbilical stump to the umbilical artery catheter length found on the *y*-axis of the graph to determine the corrected length of catheter to be inserted. (Modified from Shilkofski.[11])

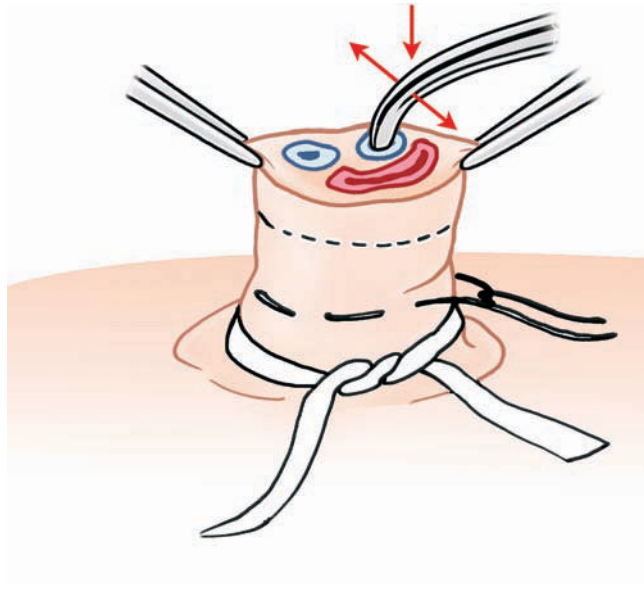


FIGURE 56-7. Preparation for catheter insertion. The upper edges of the umbilical cord stump are stabilized with two smooth-jaw curved hemostats. A smooth-jaw curved iris forceps is placed into one umbilical artery and allowed to open and dilate the artery.

Flush the catheter with the heparinized saline solution, if there are no contraindications to heparin. Attach the three-way stopcock, in the closed position, to the hub of the catheter. Identify the arteries and choose one for catheterization. Grasp the distal portion of the umbilical cord with the two smooth-curved hemostats to stabilize the end of the umbilical cord (**Figure 56-7**). Instruct an assistant to hold the hemostats. **Do not apply traction to the hemostats to prevent injury to the umbilical cord.** Insert the tips of the smooth-curved iris forceps approximately 0.5 cm into the lumen of the artery and gently allow the jaws of the forceps to open (**Figure 56-7**). This will dilate the arterial lumen. Repeatedly insert and open the tips of the curved iris forceps within the arterial lumen to a depth of 0.5 to 1.0 cm.[2]

Grasp the umbilical catheter approximately 1.0 cm from the tip. Gently insert the tip of the catheter into the artery (**Figure 56-8**). Apply gentle pressure for about 30 seconds. The muscles of the artery may spasm and prevent the catheter from advancing. If the spasm persists, remove the catheter. Place 0.1 mL of a 2% lidocaine solution into the catheter tip.[2] Reinsert the catheter and flush the lidocaine into the artery at the level of the spasm. If the catheter still will not advance, a gentle twisting motion may allow it to advance. Catheterize the other umbilical artery if this fails. Advance the catheter to the predetermined length. Increased resistance will be felt as the catheter goes through the base of the umbilical cord and navigates the curve of the umbilical artery entering into the femoral artery. Tighten the umbilical tape to temporarily secure the catheter.

Obtain fluoroscopic, plain radiographic, or ultrasonic confirmation of placement prior to using the catheter. The single lumen catheter may not be properly positioned. The catheter may pass into the aorta but curve distally into the iliac or femoral artery. This can result in cyanosis, blanching, or necrosis of the extremity and/or buttock.[23,24] This occurs more frequently when a 3.5 French catheter is inserted in a large neonate. Using a larger catheter (i.e., 5 French) will usually allow the catheter to go cephalad in the aorta. If the catheter goes distally, it can be partially withdrawn, twisted 90°, and re-inserted only if done during the procedure with real-time fluoroscopy or ultrasound during the procedure. **Never advance a catheter**

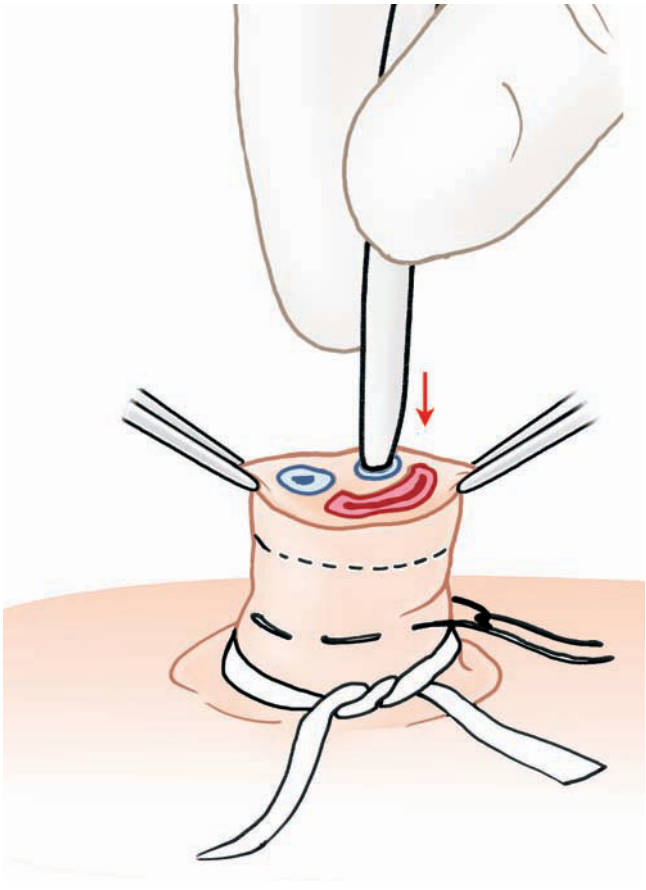


FIGURE 56-8. The catheter is inserted into the umbilical artery and advanced to the desired depth.

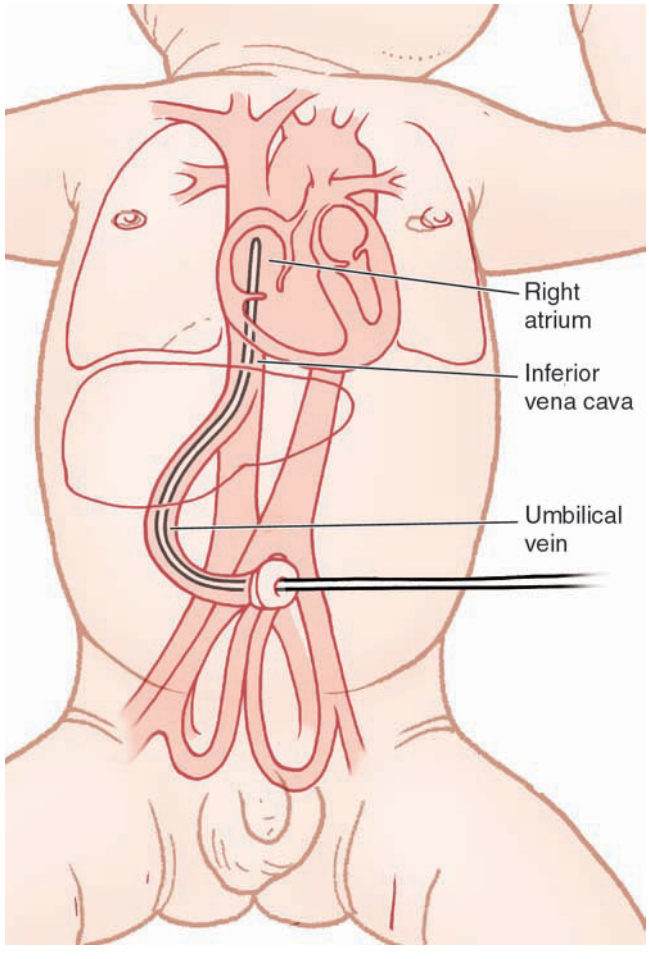


FIGURE 56-9. Positioning of the tip of the umbilical vein catheter. The tip should be above the diaphragm, at the junction of the inferior vena cava and the right atrium.

that has been previously placed as it can introduce an infection. The catheter may also enter the aorta, turn 180° to reverse itself, and enter the iliac or femoral artery. This also occurs more often when a smaller (i.e., 3.5 French) catheter is used in a large neonate. The catheter must be removed if it is placed correctly but there is persistent lower extremity cyanosis, blanching, or decreased distal perfusion.

UMBILICAL VEIN CATHETERIZATION

Catheterizing the umbilical vein is much easier than the umbilical artery. The lumen is larger and easier to negotiate. This quality makes the umbilical vein more desirable for vascular access in emergency situations.[7,25]

First determine the desired position of the catheter tip. Ideally, it should be located at the junction of the IVC and the right atrium (**Figures 56-9 & 56-10**). Measure the shoulder-umbilical length (**Figure 56-3**). Using the shoulder-umbilical length and the desired position of the catheter tip, determine the umbilical catheter length to be inserted into the vein (**Figure 56-10**). Add the length of the umbilical stump to the umbilical vein catheter length found on the *y*-axis of the graph to determine the corrected length of catheter to be inserted. Another method to calculate the depth of insertion is length (cm) = (3 × body weight [kg]) + 9, divided by 2, then add 1 cm.

Umbilical vein catheterization is similar to that of the artery with three exceptions. Any visible clots must be removed from the lumen of the vein prior to inserting the catheter. **The vein requires no dilating. In an emergency, when awaiting radiographic confirmation is not feasible, the umbilical vein catheter should only be inserted 3 to 5 cm until there is free flow of blood. It is imperative that the catheter not be inserted too deeply in order to prevent entry into the hepatic vessels via the ductus venosus, since medications could potentially cause hepatocellular damage.**[2,5–7,26] The catheter can be replaced with a more permanent line once the patient has been stabilized.[25] The nonemergent umbilical venous catheter should be placed with the tip above the diaphragm, at the junction of the IVC and right atrium as determined previously. Tighten the umbilical tape to temporarily secure the catheter. Obtain fluoroscopic, plain radiographic, or ultrasonic confirmation of placement prior to using the catheter.[18]

UMBLICAL MULTIPLE-LUMEN CATHETERS

Reliable vascular access can be problematic in the sick neonate.[27] Insertion of a double-lumen or triple-lumen catheter into the umbilical vein can provide additional venous access for the administration of incompatible drugs such as vasopressor agents, calcium, or sodium bicarbonate solutions.[28] It is also useful for drugs requiring continuous infusions, leaving other ports for blood sampling, central venous pressure measurements, maintenance fluids, or medication administration. Infuse all these solutions into the proximal lumen(s), allowing measurements of central venous pressures from the distal port. Multi-lumen catheters can be placed directly by the same methods as a single-lumen catheter or using the Seldinger

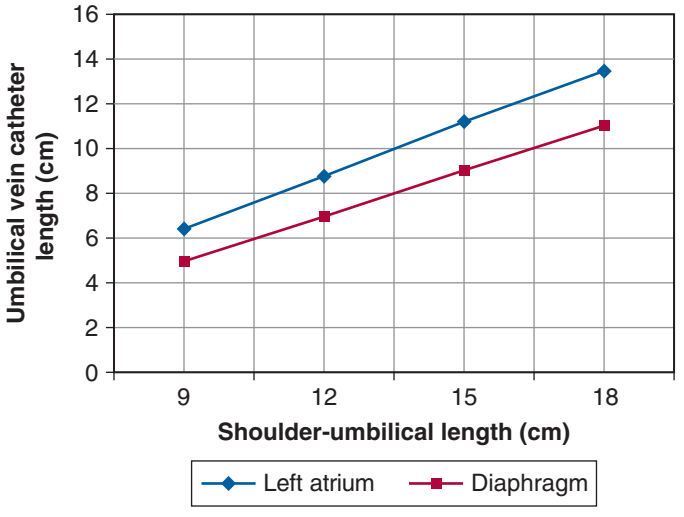


FIGURE 56-10. Graph to determine the correct length of catheter to insert into the umbilical vein. Using the shoulder-umbilical length and the desired position of the catheter tip, determine the length of catheter on the *y*-axis to be inserted into the vein. Add the length of the umbilical stump to the umbilical vein catheter length found on the *y*-axis of the graph to determine the corrected length of catheter to be inserted. (Modified from Shilkofski.[11])

technique similar to inserting a central venous line (Chapter 49). The increased pliability of the multi-lumen catheter makes passage into the hepatic veins more likely.

A wire exchange technique may be used to place a multiple-lumen catheter in neonates with an indwelling single-lumen catheter. This method decreases the probability of loss of vascular access during the exchange. It has the risk of the guidewire entering the heart and causing a cardiac dysrhythmia and/or myocardial perforation. This technique should only be performed by those familiar with the Seldinger technique.

The catheter exchange over a guidewire requires strict sterile technique. Insert a guidewire through the catheter. Firmly hold the guidewire. Withdraw the catheter over the guidewire. The guidewire must always remain within the vein. Advance the multi-lumen catheter over the guidewire and into the vein while securely holding the guidewire. Remove the guidewire while maintaining the catheter in the umbilical vessel. Advance the multi-lumen catheter to the predetermined length. Tighten the umbilical tape to temporarily secure the catheter. Obtain fluoroscopic, plain radiographic, or ultrasonic confirmation of placement prior to using the catheter.

ASSESSMENT

Confirm the proper placement of the catheter tip. The umbilical tape has been tightened to temporarily secure the catheter within the umbilical cord. **Do not infuse anything through the line until proper placement is confirmed.** This can be accomplished with fluoroscopy, plain radiographs, or ultrasonography. If the catheter is in too far, withdraw it and reevaluate the new catheter tip position. **If the catheter is not in far enough, do not advance the catheter. Withdraw the catheter and restart the procedure with a new catheter.**

AFTERCARE

Secure the catheter more permanently after confirming that the catheter tip is in the desired location (**Figure 56-11**). Tighten and tie a knot in the previously placed purse-string suture. Wrap the loose ends of the suture around the catheter as it enters the umbilical vessel, then secure it with several square knots (**Figure 56-11**). **Loosen and remove the umbilical tape to avoid umbilical cord necrosis.**[4] Secure the catheter to the abdominal wall with adhesive tape. Antibiotic ointment may be applied at the junction of the umbilical cord and the catheter.

COMPLICATIONS

Significant morbidity can be associated with umbilical artery and vein catheterization.[29] Prevention of complications requires strict adherence to sterile technique, flushing of the catheter prior to insertion, gentle catheter manipulation during insertion, and accurate positioning of the catheter. It is essential that no air be allowed to enter the catheter. An air bubble can enter the

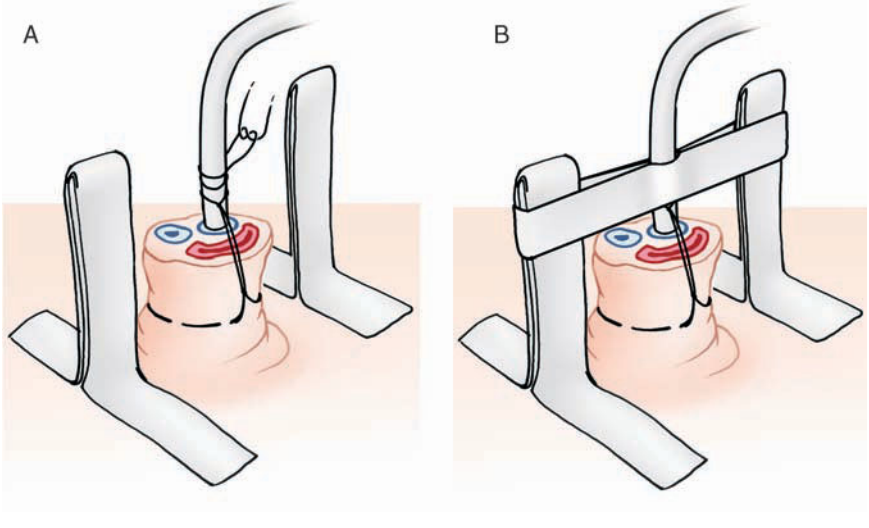


FIGURE 56-11. Securing the umbilical vessel catheter. **A.** The purse-string suture is tied about the umbilical cord and the umbilical tape is removed. The ends of the suture are wrapped around the catheter, as it enters the umbilical vessel, and secured with square knots. **B.** Tape is applied to secure the catheter to the abdominal wall.

central circulation, pass through the foramen ovale, and lodge in an end artery. This air embolism can cause a stroke if it ends up in a central nervous system artery, a myocardial infarction if it ends up in a coronary artery, and it may lead to death.[30,31]

Even if all precautions are observed, complications are still unavoidable.[5] Complication rates as high as 20% for venous catheters and 10% for arterial catheters have been reported.[32] A venous catheter placed in the portal system may lead to hepatic necrosis, hemorrhage, and thrombus formation, which may lead to a pulmonary embolus or portal hypertension.[3–6] Neonates are at higher risk for thromboembolic events because of their underdeveloped clotting mechanisms, small vessel diameters, and critical underlying diseases when compared with older children and adults.[29] Phlebitis or nosocomial sepsis can ensue if strict aseptic technique is not followed.[32] Rarely, the catheter can be transected or form a knot intravascularly.[33,34] Vessel and bowel perforation from forceful manipulation of the catheter, an air embolus from an unflushed catheter prior to insertion, false track formation, cardiac arrhythmias, damage to cardiac valves, and myocardial perforation have all been reported.[3,6,7,32,58] Necrotizing enterocolitis, biliary venous fistula, pericardial effusion, hypoglycemia from high positioning of an umbilical artery catheter, bladder rupture, congestive heart failure, hypertension, transection of an omphalocele, transection of the catheter, intravascular knots in the catheter, and Wharton's jelly embolus have also been reported.[58–65] Occasionally, a persistent urachus in the umbilical cord stump may be mistaken for an umbilical vein. Catheterization of the urachus will result in the flow of urine, and not blood, from the catheter. This is easily identified and corrected.

Malpositioning of the umbilical vein catheter has resulted in rare complications such as pneumopericardium, cardiac tamponade, pleural effusion, pulmonary hemorrhage, pulmonary edema, pulmonary infarction, pulmonary abscess, cardiac thrombosis, endocarditis, myocardial perforation, atrial flutter, hyponatremia, perforation of the peritoneum, perforation of a Meckel's diverticulum, perforated urachal remnant, ascites from intraperitoneal extravasation of total parenteral nutrition (TPN), esophageal varices, hepatic laceration, hepatic necrosis, hepatic abscess, hepatic calcifications or bladder calcifications with infusion of calcium gluconate, biliary fistula, perforation of the IVC, gastric outlet obstruction, or bladder rupture.[8,34–54]

Malpositioning of the umbilical artery catheter has rarely resulted in sciatic nerve damage, refractory hypoglycemia from infusion into the celiac axis, or spinal cord injury with paraplegia from infusion into the artery of Adamkiewicz.[2,23,32,56,57] Umbilical artery catheterization may be complicated by vasospasm, thrombosis or embolism, causing ischemia of the lower extremities or intraabdominal organs.[2,5,6,32,55] Vasospasm can occur within moments of catheter insertion or up to several hours following placement. The signs include progressive ischemia resulting in discoloration or mottling of the lower extremities and/or buttocks. Embolization of clots can cause loss of digits, hematuria, kidney failure, hypertension, necrotizing enterocolitis, bowel infarction, cyanosis or blanching of the skin (of the back, buttocks or legs), or skin ulceration.

SUMMARY

Umbilical vessel catheterization is a readily available method of obtaining vascular access in the sick newborn. These vessels can be used for fluid resuscitation, blood transfusion, medication administration, frequent blood sampling, and cardiovascular monitoring. Because serious complications may result from using this route, it should be reserved for infants in whom peripheral vascular access is unsuccessful.

57 Arterial Puncture and Cannulation

Zak Foy and Susan Stroud

INTRODUCTION

Arterial blood gas (ABG) sampling is an essential component of the care of many Emergency Department patients. It provides key information regarding a patient's oxygenation and acid-base status. Arterial cannulation allows for continuous and accurate blood pressure monitoring and frequent blood gas sampling in the care of the critically ill patient.

ANATOMY AND PATHOPHYSIOLOGY

Knowledge of the arterial anatomy is a key factor in the success of arterial puncture and cannulation. It is important to recognize that nerves and veins are located in close proximity to the desired arteries in order to avoid complications. The anatomy and positioning for radial, brachial, femoral, and dorsalis pedis artery access is described below.

RADIAL ARTERY

The radial artery is the preferred site for arterial puncture and cannulation. One reason is the comparative ease of identifying the anatomical location of this artery. A second reason is the collateral nature of the arterial blood supply to the hand provided by the radial and ulnar arteries. The ulnar artery is not often used due to its smaller size. Terminal branches of these two arteries meet in the palm of the hand to form the deep and superficial palmar arterial arches (**Figure 57-1**).

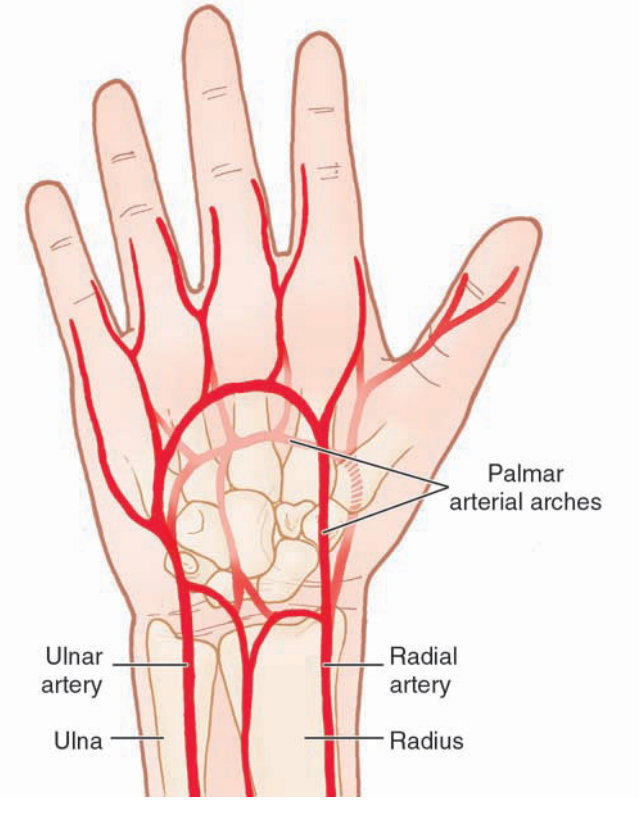


FIGURE 57-1. Anatomical location of the radial and ulnar arteries. Collateral circulation is provided by the superficial and deep palmar arches.

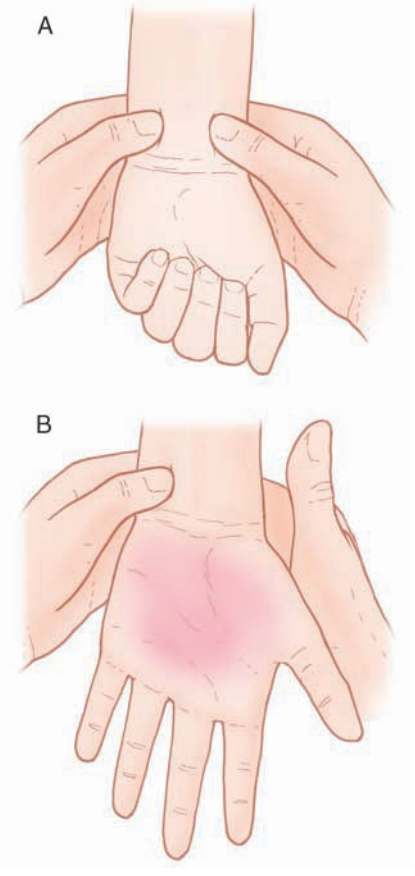


FIGURE 57-2. The modified Allen test. **A.** The distal radial and ulnar arteries are occluded. **B.** The ulnar artery remains occluded while determining if the radial artery can supply adequate blood flow to the hand.

The radial artery can be found just medial and proximal to the radial styloid process on the ventrolateral wrist (**Figure 57-1**). Dorsiflexing the wrist approximately 60° can aid in palpating the arterial pulse. Another notable landmark is the flexor carpi radialis tendon that runs immediately medial to the radial artery. The recommended point of needle or catheter insertion is at the proximal flexor crease of the wrist and directly above the radial artery pulse.

An Allen test should be performed to assess the adequacy of the collateral circulation to the hand prior to radial artery puncture or cannulation (Figure 57-2).[1,2] Ask the patient to repeatedly close their hand tightly into a fist and open it, to force blood out of the fingers, while manually occluding the radial and ulnar arteries (**Figure 57-2A**). Continue this process for 1 minute. Ask the patient to open their hand. The fingers should be blanched and pale due to the occlusion of the arterial inflow. Release the finger occluding the ulnar artery. Measure the time it takes for blushing of the palm to occur. It is considered normal if it is <7 seconds, equivocal at 8 to 14 seconds, and abnormal if >14 seconds.[1] Repeat the test, but this time release the radial artery compression to confirm arterial flow into the hand (**Figure 57-2B**). The purpose is to confirm arterial inflow from both the radial and ulnar arteries.

An alternative method of evaluating the collateral circulation involves the use of a pulse oximeter with a visual pulse waveform display.[3] This is useful in the young, unconscious, or uncooperative patient. Place the pulse oximeter sensor on the patient's thumb. Observe the visual display to confirm a waveform is present. Occlude the radial artery and examine the waveform on the monitor. Either an ulnar dominant system or a radial dominant system with adequate collateral circulation is likely if the waveform remains unchanged during radial artery occlusion.[3]

The performance of an Allen test to confirm adequate collateral circulation to the hand is generally advocated before radial artery puncture or cannulation. There is concern that radial artery occlusion from an intraluminal clot or an external hematoma can result in hand ischemia if the ulnar artery cannot provide adequate collateral blood flow. Some authors have questioned the utility of performing an Allen test.[1,2,4,38] The Allen test is subjective, often improperly performed, and has poor sensitivity and specificity to predict complications.[39] The relative safety of radial artery cannulation without the Allen test has been demonstrated in a large case series of patients without major peripheral vascular disease.[4] Although an abnormal Allen test may not preclude radial artery puncture or cannulation, it may indicate a greater need for caution and alert the Emergency Physician to potential problems after the procedure is performed.[2] This can include arterial thrombosis, hand ischemia, and hand necrosis. **Thus it is recommended, but not required, to cannulate another site if the Allen test is abnormal.**

BRACHIAL ARTERY

The brachial artery courses along the medial side of the antecubital fossa just lateral to the median nerve (**Figure 57-3**). The brachial artery divides at approximately the level of the neck of the radius to become the ulnar and radial arteries. In the antecubital fossa, the brachial artery is located lateral to the medial epicondyle of the humerus and medial to the biceps brachii muscle. The brachial artery is more easily identified when the elbow is fully extended. In order to locate the artery, start by palpating the medial epicondyle of the humerus. Move laterally until the medial edge of the biceps

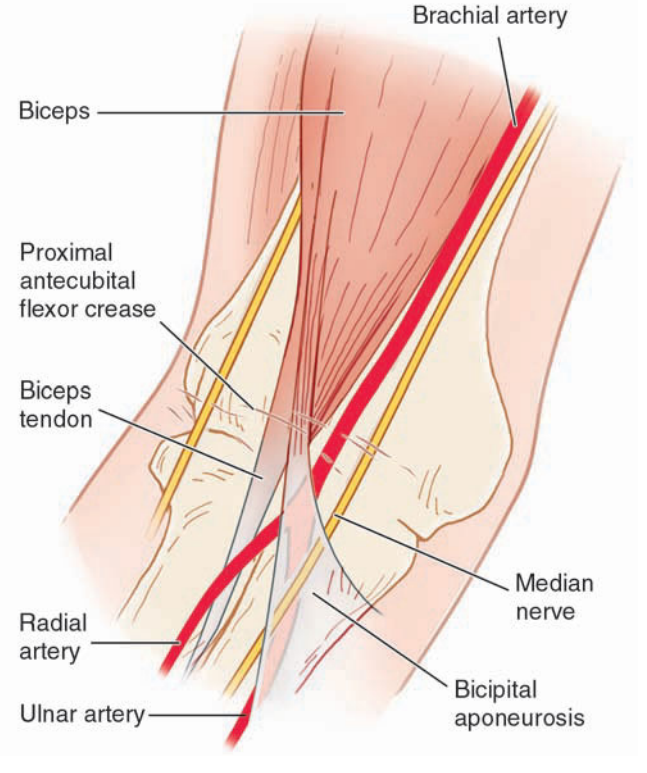


FIGURE 57-3. Anatomical location of the brachial artery. Note the median nerve running just medial to the artery and the biceps brachii muscle just lateral to the artery.

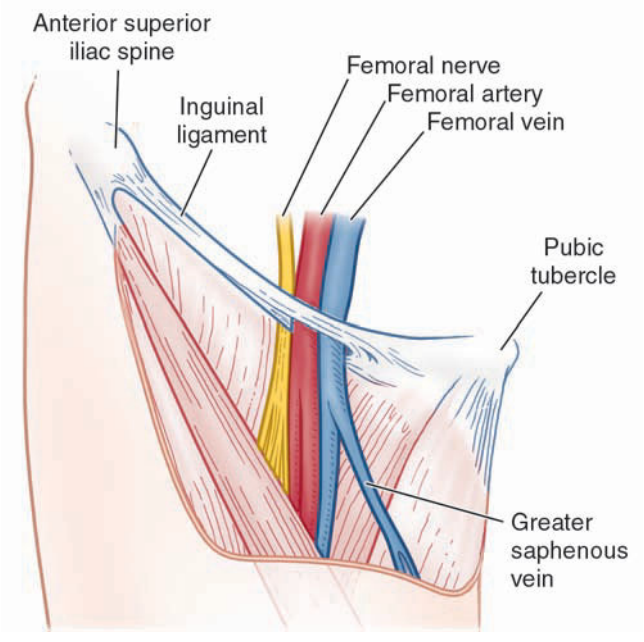


FIGURE 57-4. Anatomical location of the femoral artery. Note the proximity to the femoral nerve and vein.

muscle is palpated. The brachial artery pulse should be palpable just medial to the biceps muscle. The arterial pulsation is most easily identified at the level of the proximal flexor crease of the antecubital fossa. The preferred location for puncture or cannulation of the brachial artery is in, or just proximal to, the antecubital fossa and directly above the brachial artery pulse. If the artery is to be cannulated, the arm should remain in extension while the cannula is in place.

FEMORAL ARTERY

The bony anatomic landmarks used to identify the femoral artery are the anterior superior iliac spine and the tubercle of the pubic symphysis. The artery lies approximately midway between these two points after it courses under the inguinal ligament to enter the thigh (**Figure 57-4**). The femoral nerve and vein are found running in parallel and adjacent to the artery. The vein lies just medial to the artery and the nerve just lateral. The femoral artery is larger than other arteries commonly cannulated and lies significantly deeper than the radial or brachial arteries. This makes it necessary to use a longer cannula and, depending on the patient's body habitus, may require a longer needle for a simple arterial puncture to be successful. Extension and slight abduction of the hip maximizes access to the femoral triangle, improves the ability to palpate the artery, and provides a maximal work area for the procedure.

DORSALIS PEDIS ARTERY

The dorsalis pedis artery is a continuation of the anterior tibial artery on the dorsal surface of the foot. Puncture and cannulation of the dorsalis pedis artery is a good second choice if the radial artery is unsuccessfully cannulated or unavailable. The pulse is often easily palpable between the first and second metatarsal due to its superficial location. Its distal location does not interfere with other resuscitative efforts and is convenient for the patient. The risk of foot ischemia is minimal due to the abundant collateral circulation to the foot and ankle. There are no significant structures to injure adjacent to the dorsalis pedis artery. This artery can be absent in some people or have significant variability in its anatomic location. It may be difficult to identify the pulse in the hypotensive patient.

ALTERNATIVE ARTERIAL SITES

There are several alternative sites that are occasionally used for arterial puncture and cannulation. These include the superficial temporal artery, the axillary artery, and the ulnar artery. The superficial temporal artery is often used in neonates and young infants in the intensive care unit. Cannulation of this artery is rarely performed in the Emergency Department because of its location and the ability to maintain access.

The axillary artery is a continuation of the subclavian artery after the first rib. The axillary artery crosses the teres major tendon to enter the arm as the brachial artery. The axillary artery can be deep to the skin surface. The advantages of this artery include the ease of locating a the palpable pulse, even in the hypotensive patient. An accurate blood pressure, devoid of the effects of vasoconstriction, can be obtained. Unfortunately, the disadvantages of cannulating the axillary artery are significant. The axilla is poorly accessible. The patient's arm must be abducted, externally rotated, and immobilized during and after the procedure. The course of the artery changes with arm position. The artery is contained within the axillary sheath along with the axillary vein and brachial plexus. There is a significant risk of nerve injury if the needle penetrates the brachial plexus. The risk of an arterial embolus is higher in central arteries when compared to peripheral arteries.

The ulnar artery, along with the radial artery, is one of the terminal branches of the brachial artery. It is superficial at the wrist and the pulse is easily palpable. The ulnar artery is significantly smaller in most people when compared to the radial artery, making the procedure more technically difficult. An ulnar artery may be absent or extremely small in some patients. The ulnar artery lies adjacent to the ulnar nerve. This increases the possibility of nerve injury if the needle penetrates the ulnar nerve. It can be difficult to identify the artery in the patient with anasarca, obesity, peripheral edema, or peripheral vascular disease.

INDICATIONS

The principal indications for arterial blood sampling include the determination of the blood carbon dioxide (CO_2) content, oxygen (O_2) content, and acid–base status.[5,6] The need for ABG sampling for determination of oxygenation has decreased substantially with the advent of pulse oximetry. Pulse oximetry may poorly reflect true oxygenation in the setting of severe hypoxia or severe hypotension. Therefore, ABG analysis persists as the true measure of arterial oxygenation.[7] End-tidal CO_2 (E_TCO_2) monitoring has decreased the utilization of ABG samples for CO_2 measurement. In patients who have large dead space ventilation or low cardiac output, E_TCO_2 measurements may grossly underestimate the true CO_2 contents of the blood.[8]

Arterial blood gas samples are useful for accurate pH monitoring of patients with shock, obstructive lung disease, and other pulmonary disorders. Possibly the most important indication for ABG sampling in the critically ill patient is the determination of the patient's acid–base status. Venous sampling may occasionally suffice for monitoring the pH in a few illnesses such as diabetic ketoacidosis.[9] The measurement of venous blood pH is much less reliable as a surrogate for arterial pH in patients with shock and other critical illnesses.[10] Arterial blood samples are still used for the measurement of carboxyhemoglobin and methemoglobin level. One study found that venous and arterial co-oximetry carboxyhemoglobin values are closely correlated and may be used to screen a patient thought to have been exposed to carbon monoxide.[11]

The three principal indications for arterial catheter placement are the need for continuous monitoring of arterial blood pressure, the need for frequent ABG sampling, and the need for frequent blood sampling for laboratory analysis in the critically ill patient. Cycled oscillometric blood pressure measurement may be insufficient to gauge rapid hemodynamic changes in critically ill hypertensive or hypotensive patients. Continuous blood pressure monitoring facilitates titration of rapid-acting vasodilators and vasopressors. The accuracy of auscultated or oscillometric blood pressure readings under conditions of severe shock or malperfusion are suspected.[1,2] Centrally measured aortic pressure is the true gold standard.[1,2] However, given the impracticality of measurement of aortic pressure, peripheral arterial pressure measured with an intraarterial catheter connected to a pressure transducer is the next best gauge.

CONTRAINDICATIONS

Contraindications to arterial puncture and catheter placement relate primarily to abnormalities at the insertion sites. Avoid skin and arteries that are already compromised by trauma, burns, infection, severe dermatitis, severe peripheral vascular disease, or previous surgery in the area.[1,5] Puncture or cannulation of synthetic vascular grafts is also relatively contraindicated. **Do not puncture where the artery "should be" if the arterial pulsation cannot be palpated.** Attempts at cannulation of nonpalpable arteries are generally fruitless and sometimes hazardous. Arterial puncture or catheterization is relatively contraindicated in patients with bleeding diatheses and those who have received, or may receive, thrombolytic therapy.

EQUIPMENT

Arterial Puncture for Single ABG Sample

- Povidone iodine or chlorhexidine solution
- Dorsal wrist extensor splint or small rolled up towel
- 1% lidocaine, 1 mL in a tuberculin syringe
- 5 mL syringe for blood collection with cap retained
- Prepackaged blood gas syringe with lyophilized heparin pellet
- 20 to 22 gauge needle for arterial puncture
- 1 to 2 mL of heparin (1000 U/mL)
- Gauze pads
- Adhesive tape
- Specimen collection bag or cup with 2 to 3 inches (in) of ice

Arterial (Brachial, Radial, Dorsalis Pedis) Cannulation

- Povidone iodine or chlorhexidine solution
- Dorsal wrist extensor splint or small rolled up towel
- 1% lidocaine, 1 mL in a tuberculin syringe
- 4 × 4 gauze squares
- Adhesive tape
- Nylon suture, 3-0 or 4-0 and needle drivers
- 20 or 22 gauge, 1¾ in polyurethane angiocatheter or catheter-over-the-needle
- 0.45 mm diameter, 5¼ in spring wire guide compatible with above catheter

Femoral Artery Cannulation

- Povidone iodine or chlorhexidine solution
- 1% lidocaine, 3 mL in a syringe armed with a 25 gauge needle
- 4 × 4 gauze squares
- #11 scalpel blade
- Nylon suture, 3-0 or 4-0 and needle drivers
- Femoral artery needle, approximately 18 gauge, 2 7/8 in.
- 4 French single lumen catheter, at least 15 cm in length
- 30 cm guidewire compatible with above needle and catheter

Ultrasound Guidance

- Ultrasound machine
- 5 to 10 MHz linear array ultrasound probe
- Sterile ultrasound gel
- Sterile ultrasound probe cover

If a syringe that has not been designed specifically for ABG sampling is used, and it has not been pretreated with heparin or does not contain a lyophilized heparin pellet, it is necessary to prepare the syringe using heparin solution. Draw up 1 to 2 mL of heparin solution into the syringe and then expel the heparin, leaving only the heparin remaining in the dead space of the syringe and the needle. This amount of heparin is sufficient to prevent clotting of the sample.[5] It is important to remove all but the necessary amount of heparin as excess heparin has been found to falsely lower the PCO_2 measurement and may elevate the PO_2 measurement.[37]

Commercially produced, prepackaged kits are available for arterial puncture and arterial cannulation. These kits are complete and contain all the required equipment. Also available are individually packaged heparinized ABG syringes and arterial line catheters in various sizes.

The catheter size used for the procedure will vary by patient age and the artery chosen to cannulate. In neonates and infants, use a 22 or 24 gauge catheter for the radial or dorsalis pedis arteries and an 18 or 20 gauge for the femoral artery. In children up to 8 to 10 years of age, use a 22 gauge catheter for the radial or dorsalis pedis arteries and a 16 to 20 gauge for the femoral artery. In a larger child, adolescent, or adult, use a 20 or 22 gauge catheter for the radial or dorsalis pedis arteries and a 14 to 20 gauge for the femoral artery.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain an informed consent unless the procedure is being performed emergently or the patient is unable to give consent. Identify by palpation the arterial pulse at the intended skin puncture site. Clean the skin of any dirt and debris. Cleanse the skin with chlorhexidine or povidone iodine solution and allow it to dry.

Studies that examined the use of topical anesthetic agents have not shown a benefit that outweighs the delay required to perform the procedure.[12] The use of an injectable local anesthetic agent, however, may greatly aid in the process of arterial puncture or cannulation and significantly reduces patient discomfort.[13] Infiltrate 1 mL of local anesthetic solution subcutaneously over the brachial, dorsalis pedis, or radial arteries. Infiltrate 2 to 5 mL of local anesthetic solution subcutaneously and into the subcutaneous tissues over the femoral artery. **Aspirate before infiltrating the local anesthetic solution to prevent inadvertent intravascular injection.**

Descriptions of the anatomy for arterial puncture or cannulation sites are described in detail earlier in this chapter. The preferred site for the initial attempt at arterial puncture or cannulation is the radial artery.[1] Begin distally where the pulse is most palpable near the proximal wrist flexor crease. If the first attempt at needle or catheter introduction is unsuccessful, and the pulse is still palpable,

reattempt the procedure more proximally along this same artery. The radial artery on the contralateral wrist is also a satisfactory second site for attempted access. Other acceptable second-attempt sites of access include the femoral, dorsalis pedis, and brachial arteries. **An attempt at ipsilateral ulnar artery catheterization is not advisable as both limbs of the hand's circulation may be compromised.** The discussion below focuses on puncture or cannulation of the radial and femoral arteries as over 90% of arterial punctures or cannulations occur at these sites.[1] The use of other sites generally follows the techniques described below for the radial artery with the exception of the regional anatomic differences. Other useable sites include the dorsalis pedis, brachial, posterior tibial, and superficial temporal arteries.

TECHNIQUES

ARTERIAL PUNCTURE FOR A SINGLE SAMPLE

Position the patient to maximize exposure of the skin surface overlying the chosen artery. For the radial artery, this is best accomplished by dorsiflexing the wrist and supporting this position with a small towel rolled up under the dorsal wrist surface (**Figure 57-5**). For brachial and femoral artery puncture, ensure that the elbow or hip is extended fully. These positions provide maximum exposure and working area for the procedure. Locate the chosen artery, prep the overlying skin, and infiltrate local anesthetic solution subcutaneously.

Reidentify the pulse by palpation with the nondominant hand (**Figure 57-6A**). Grasp the heparinized syringe with the dominant hand. Withdraw the plunger of the syringe so that 1 to 3 mL of air space is available in the syringe. This will allow for easier assessment of arterial blood return. Insert the needle at a 30° to 45° angle to the skin and just above the arterial pulse (**Figure 57-5**). Advance the needle through the skin until blood enters the syringe (**Figure 57-6B**). The blood flow will generally fill the syringe without necessitating the withdrawal of the plunger in a patient with a brisk pulse. If no blood return occurs, slowly withdraw the needle and watch for blood flow into the syringe. **If it is necessary to redirect the needle, it is imperative to first withdraw the needle until the tip is just below the skin surface before changing the angle in order to avoid lacerating the artery or adjacent structures.** To minimize the possibility of error due to the presence of heparin, it is necessary to collect at least 1 mL of blood in a prepackaged syringe or 3 mL of blood if preparing your own syringe with heparin.[5]

Withdraw the needle after the arterial sample has been collected. Apply pressure to the puncture site for 3 to 5 minutes followed by a bandage or gauze dressing. Carefully remove the needle from the syringe if not using a safety needle. Evacuate any air from the syringe and apply a cap on the syringe. Place the syringe on ice for immediate transportation to the laboratory. Recheck the skin puncture site in 5 to 10 minutes to assess for the formation of a hematoma and/or vascular compromise to the distal extremity.

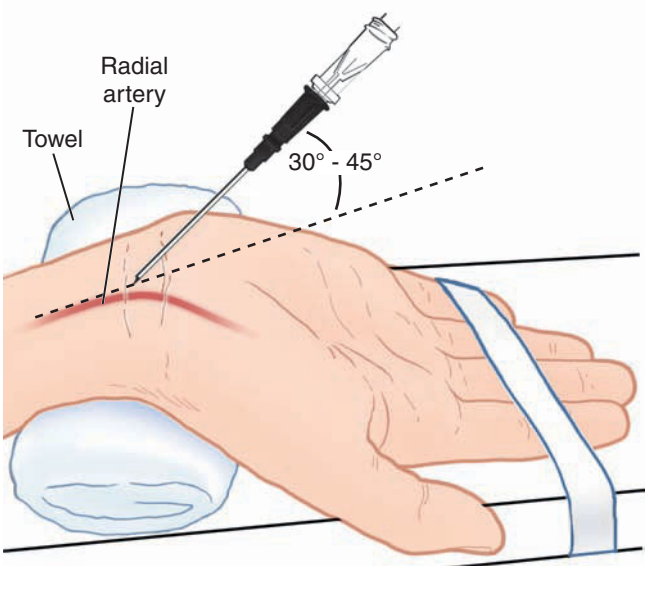


FIGURE 57-5. Correct positioning for radial artery puncture and cannulation. Dorsiflexing the wrist and supporting it with a small towel facilitates palpation of the artery and provides maximum working space. The needle or catheter-over-the-needle is aimed toward the oncoming blood flow at a 30° to 45° angle to the skin.

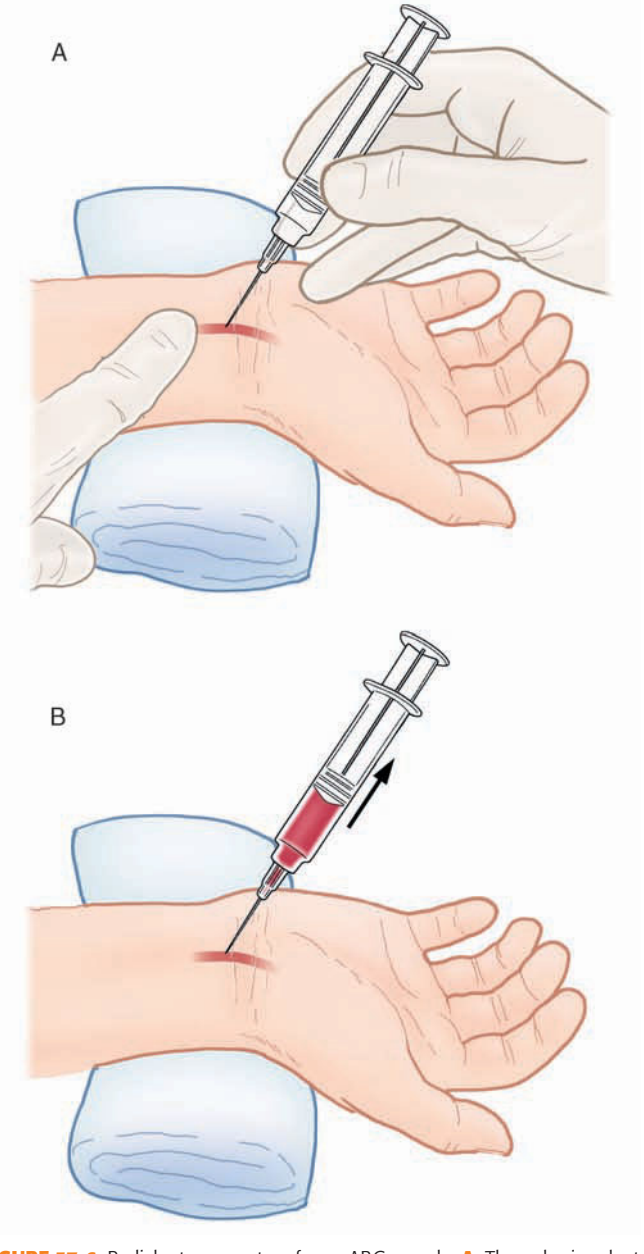


FIGURE 57-6. Radial artery puncture for an ABG sample. **A.** The pulse is palpated with the nondominant hand. The heparinized syringe is inserted at a 30° to 45° angle to the skin surface. **B.** Arterial blood fills the syringe.

RADIAL ARTERY CANNULATION: CATHETER-OVER-THE-NEEDLE-TECHNIQUE

The most basic method is direct introduction of the catheter-over-the-needle in a manner similar to that of inserting an intravenous catheter (**Figures 57-5 & 57-7**). This method is as effective as the more specialized wire-guided-catheter technique, except in situations where the pulse is weak, the pulse is absent, or in the hands of more experienced operators.[14,15] Clean, prep, and identify the radial artery as described previously. Insert the catheter-over-the-needle at a 30° to 45° angle to the skin and directly over the arterial pulse (**Figures 57-5 & 57-7A**). Advance the catheter-over-the-needle into the artery (**Figure 57-7A**). Bright red blood in the hub of the needle indicates that the tip of the needle is within the artery. Advance the catheter-over-the-needle another 1 to 2 mm to ensure that the catheter tip is completely within the arterial lumen. Securely hold the hub of the needle. Advance the catheter over the needle until its hub is against the skin (**Figure 57-7B**). Remove the needle and confirm pulsatile arterial flow from the hub of the catheter. **Free-flowing, pulsatile blood confirms proper catheter placement within the artery.** Apply a stopcock or intravenous extension tubing to the hub of the catheter. Secure the catheter to the skin. Apply a dressing to the skin puncture site.

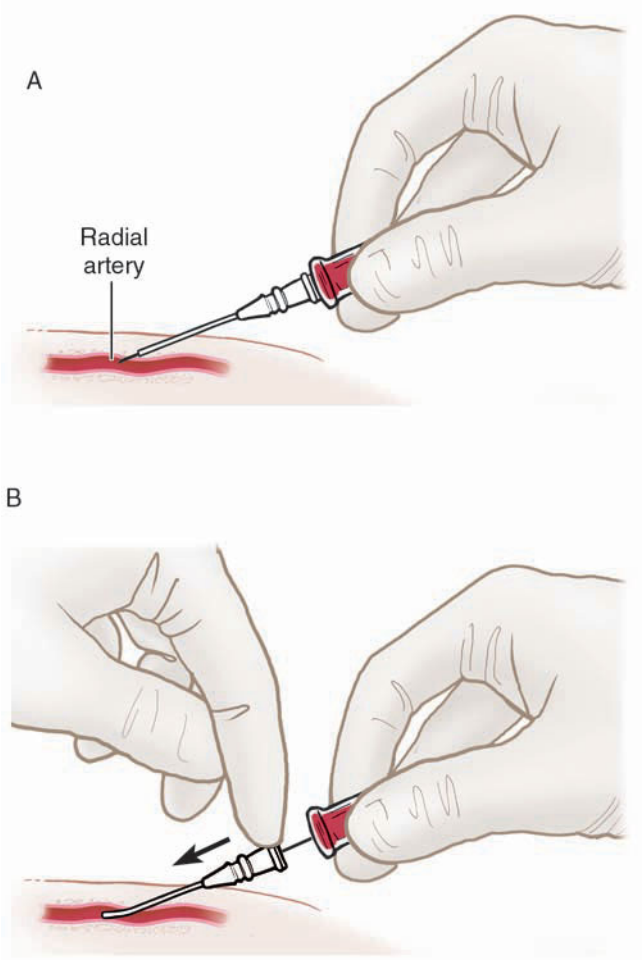


FIGURE 57-7. The catheter-over-the-needle technique for arterial cannulation. **A.** The unit is held at a 30° to 45° angle to the skin and advanced into the artery. **B.** The catheter is advanced over the needle and into the artery.

RADIAL ARTERY CANNULATION: SELDINGER-TYPE, SINGLE ARTERIAL WALL PUNCTURE

The second technique for arterial cannulation is a Seldinger-type technique (catheter-over-the-wire) utilizing one of a number of prepackaged commercially available kits. A commercially available one-piece catheter-over-the-needle kit is very popular (**Figure 57-8**). As noted previously, these wire-guided catheters have not been shown to increase successful cannulation or reduce the number of attempts except in situations where a weak or absent pulse is present, or with more experienced Physicians.[14,15] One study noted that the guidewire can be useful in salvaging an arterial line when a catheter-over-the-needle cannot be effectively advanced.

Open the package, remove the unit, and remove the protective cover over the needle. Advance and retract the guidewire to confirm it moves smoothly and does not get caught on the needle. Retract the guidewire as far back as possible. Identify the arterial pulse with the nondominant hand. Insert the catheter-over-the-needle through the skin and into the artery using a slow and continuous forward motion (**Figure 57-8A**). A flash of blood in the hub of the needle confirms successful entry through the arterial wall and into the vessel lumen. Stabilize the catheter-over-the-needle.

Advance the guidewire through the needle by pushing the actuating lever as far as possible toward the needle (**Figure 57-8B**). **Immediately stop if resistance is encountered while advancing the guidewire. The guidewire may be within the artery wall or through the artery wall and into the perivascular tissue. Do not try to force the guidewire into the vessel. Do not retract the guidewire. Withdraw the entire unit and apply pressure to the puncture site to prevent a hematoma.** Obtain a new kit and repeat the procedure.

Once advanced, the guidewire is successfully within the arterial lumen. Firmly grasp the clear hub of the needle and advance the catheter over the guidewire and into the artery (**Figure 57-8C**). **A rotating motion of the catheter is often helpful to advance it if difficulty is encountered.** Securely hold the catheter at the level of the skin. While firmly holding the catheter hub, remove the guidewire, needle, and feed tube assembly as a unit. Free-flowing, pulsatile blood confirms proper catheter placement within the artery. Apply a stopcock or intravenous extension tubing to the hub of the catheter. Secure the catheter by suturing it to the skin or by using commercially available devices that do not require suturing. Apply a dressing to the skin puncture site.

A commercially available Seldinger-type catheter-over-the-needle kit is an alternative to the one-piece unit (**Figure 57-9**). Open the package and review the equipment it contains. Place the finder needle on the syringe. Withdraw the plunger 1 cm to break the bead of the syringe. Identify the arterial pulse by palpation with the nondominant hand. Insert the needle through the skin and into the artery using a slow and continuous forward motion (**Figure 57-9A**). A flash of blood in the syringe confirms the successful entry through the arterial wall and into the vessel lumen. Firmly hold and stabilize the needle. Remove the syringe. Advance the guidewire through the needle (**Figure 57-9B**). **The guidewire should advance without resistance. Immediately stop if resistance is encountered while advancing the guidewire. The guidewire may be within the artery wall or through the artery wall and into the perivascular tissue. Do not try to force the guidewire into the vessel. Do not retract the guidewire. Withdraw the entire unit and apply pressure to the puncture site to prevent a hematoma.** Obtain a new kit and repeat the procedure.

After the guidewire is inserted, withdraw the needle while leaving the guidewire in place (**Figure 57-9C**). **Do not re-advance the needle as it can shear off the guidewire.** Make a 3 mm puncture wound

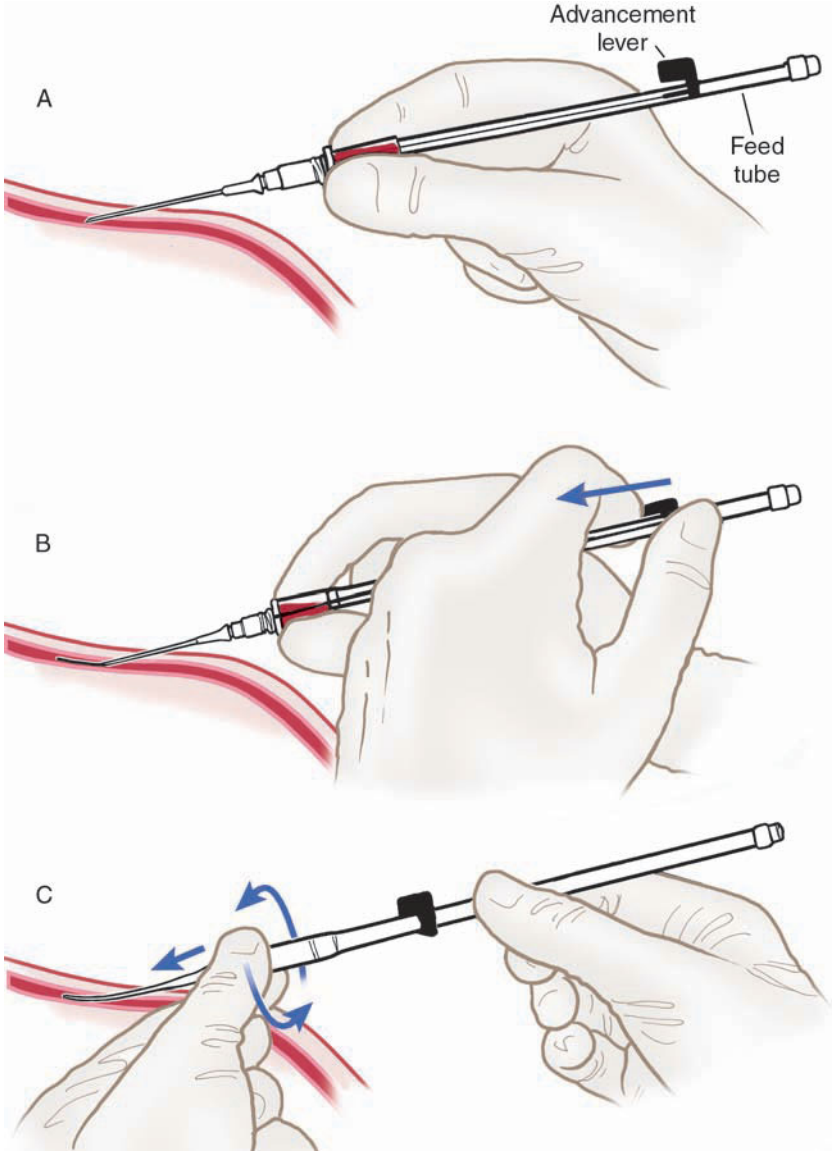


FIGURE 57-8. Catheter-over-the-needle technique using a commercially available one-piece unit. **A.** The catheter-over-the-needle is inserted into the artery. **B.** The guidewire is advanced through the needle and into the artery. **C.** The catheter is advanced over the guidewire into the artery with a twisting motion.

next to the skin puncture site of the guidewire using a #11 scalpel blade to facilitate inserting the catheter (**Figure 57-9D**). Thread the catheter over the guidewire. Advance the catheter over the guidewire until the hub of the catheter is against the skin (**Figure 57-9E**). **A rotating motion of the catheter is often helpful to advance it if difficulty is encountered.** Securely hold the catheter at the level of the skin. Remove the guidewire while firmly holding the catheter hub against the skin. Free-flowing, pulsatile blood confirms proper catheter placement within the artery. Apply a stopcock or intravenous extension tubing to the hub of the catheter. Secure the catheter by suturing it to the skin. Apply a dressing to the site.

RADIAL ARTERY CANNULATION: SELDINGER-TYPE, DOUBLE ARTERIAL WALL PUNCTURE

While localization and needle puncture of the artery are identical in all three techniques, commonly encountered difficulties include threading of the catheter with the first technique and threading of the guidewire into the vessel lumen with the second technique.[16] If the needle orifice is merely at the vessel edge, blood may enter and rise up through the needle. However, when trying to advance the catheter, it may get hung up outside the lumen with the catheter-over-the-needle technique.[17] The guidewire may not easily pass or may dissect into the vessel wall creating a false lumen when using the Seldinger-type single arterial wall puncture technique. Since pulsatile flow is more easily confirmed prior to the passage of the guidewire, this third technique in which both walls of the radial artery are punctured may offer an advantage in passing the guidewire and catheter into the arterial lumen.

It is imperative that the Emergency Physician assumes a position out of the trajectory line of the catheter to avoid being sprayed with blood when using this technique. This method is also a Seldinger-type technique that utilizes a guidewire separate from the catheter-over-the-needle. Locate the arterial pulse and insert the catheter-over-the-needle into the artery. Immediately advance the catheter-over-the-needle through the posterior wall as confirmed by no blood exiting the needle hub. Withdraw the needle while leaving the catheter in place through the artery. Flatten the angle of the catheter to the skin to less than 30°. Hold the tip of the guidewire poised at the hub of the catheter. Slowly

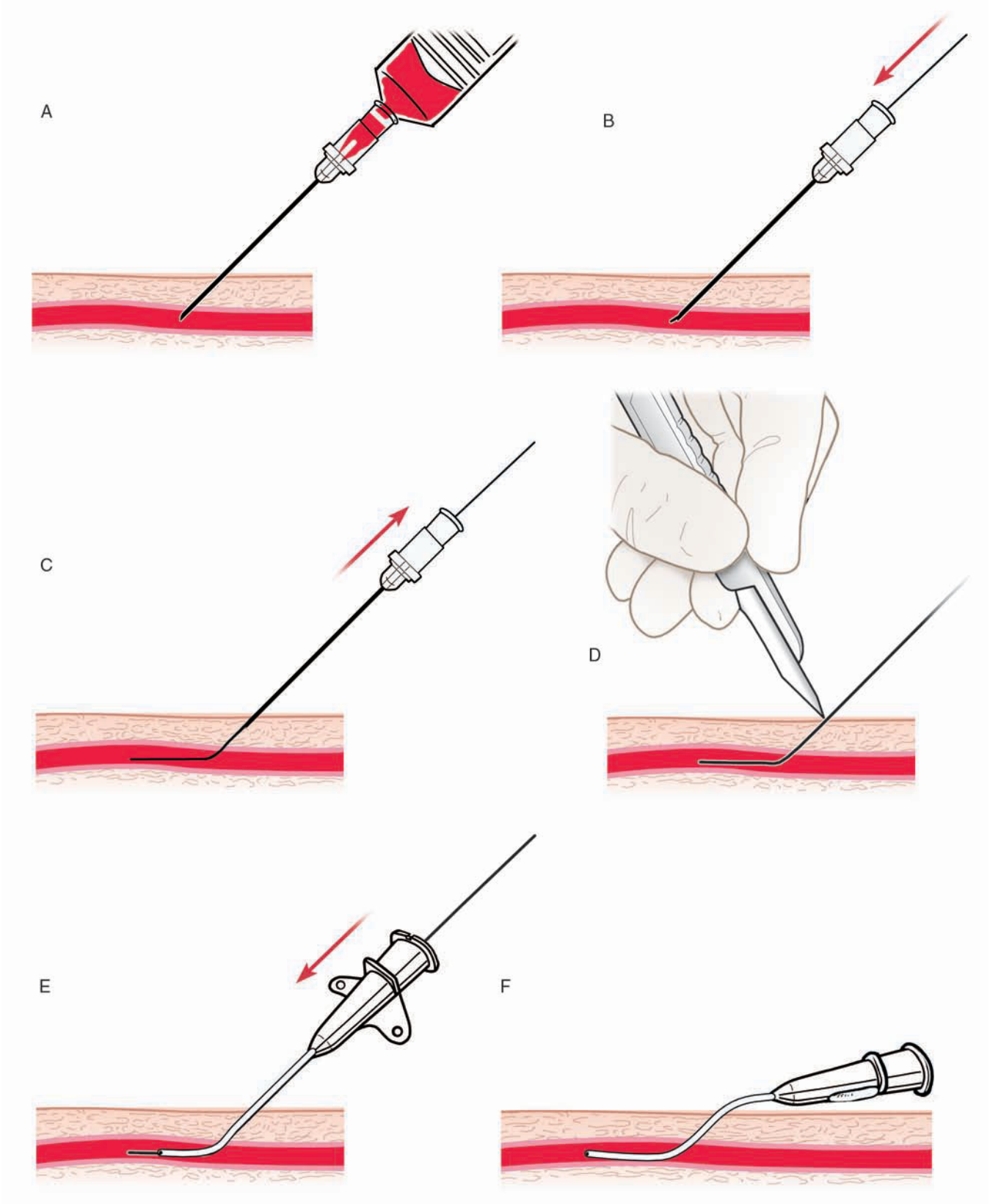


FIGURE 57-9. The Seldinger technique for arterial catheterization. **A.** The needle is inserted into the artery. **B.** The syringe has been removed from the needle. The guidewire is advanced through the needle and into the artery. **C.** The needle is removed while leaving the guidewire in place. **D.** The skin is punctured with a #11 scalpel blade to allow easy insertion of the catheter. **E.** The catheter is advanced over the guidewire and into the artery. **F.** The guidewire has been removed.

withdraw the catheter with the nondominant hand. Promptly insert the guidewire through the catheter and into the artery when pulsatile blood flow is noted from the hub of the catheter. Advance the catheter over the guidewire and into the lumen of the artery. Withdraw the guidewire and apply a stopcock or intravenous extension tubing. Secure the catheter and apply a bandage or dressing.

This double-puncture technique for cannulation theoretically may be associated with greater vascular damage. The technique should be reserved for instances in which the prior two arterial cannulation techniques have been unsuccessful. However, in an analysis of the complications associated with various techniques of peripheral artery cannulation, investigators found no difference in complications when using this technique.[18]

FEMORAL ARTERY CANNULATION

The femoral artery may be cannulated if the radial artery is inaccessible or attempts at cannulation are unsuccessful. A longer catheter, catheter-over-the-needle, and needle is required as the femoral artery is not superficial. Slightly abduct the patient's leg and identify the femoral artery pulse. Prep, drape, and anesthetize the skin and subcutaneous tissues. Maintain the fingers of the nondominant hand on the arterial pulse. Insert the needle or the catheter-over-the-needle at a 45° angle to the skin with the needle bevel pointing superiorly. The remainder of the technique is as described previously.

DORSALIS PEDIS ARTERY CANNULATION

The procedure for cannulation of the dorsalis pedis artery is the same as that described for the radial artery. Clean, prep, and plantar flex the foot. Do not plantar flex the foot more than 45° as this can stretch and occlude the artery. The needle angle of entry should be less than that used for the radial artery due to the superficial location of the artery. Insert it at 20° to 30° to the skin rather than 30° to 45°.

ULTRASOUND-GUIDED ARTERIAL CANNULATION

Ultrasound can be used to guide arterial puncture or cannulation. It can be a rescue method if the palpation technique fails. It can also be used initially to decrease the number of puncture attempts, to decrease the amount of time spent gaining access, and to potentially decrease complications such as hematomas and arterial laceration.[19,20] Most studies have focused on radial artery cannulation, but the technique for alternative sites is the same.

Clean and prep the skin over the artery. Apply a sterile probe cover or a sterile glove over the linear array ultrasound probe. Orient the probe marker on the side of the probe so it matches that on the screen. Identify the artery. It will appear as a round, thick-walled, and pulsatile vessel that is not easily compressible (**Figure 57-10A**). Move the probe proximally and distally over the artery to approximate its course, which is sometimes not perfectly parallel to the long axis of the extremity. Once the vessel has been identified, center it on the screen. The center of the probe is now directly over the vessel and can act as a guide to skin puncture. Hold the probe with the nondominant hand or have an assistant hold the probe. Insert the catheter 1 to 2 cm distal to the probe. When the needle is into the subcutaneous tissue, rock it in and out very slightly to create movement that is apparent on the screen. This will help to identify the location of the needle in relation to the artery. Slowly advance the needle. The needle itself may or may not be apparent, but motion through the tissue can be used to infer the site of the needle tip.

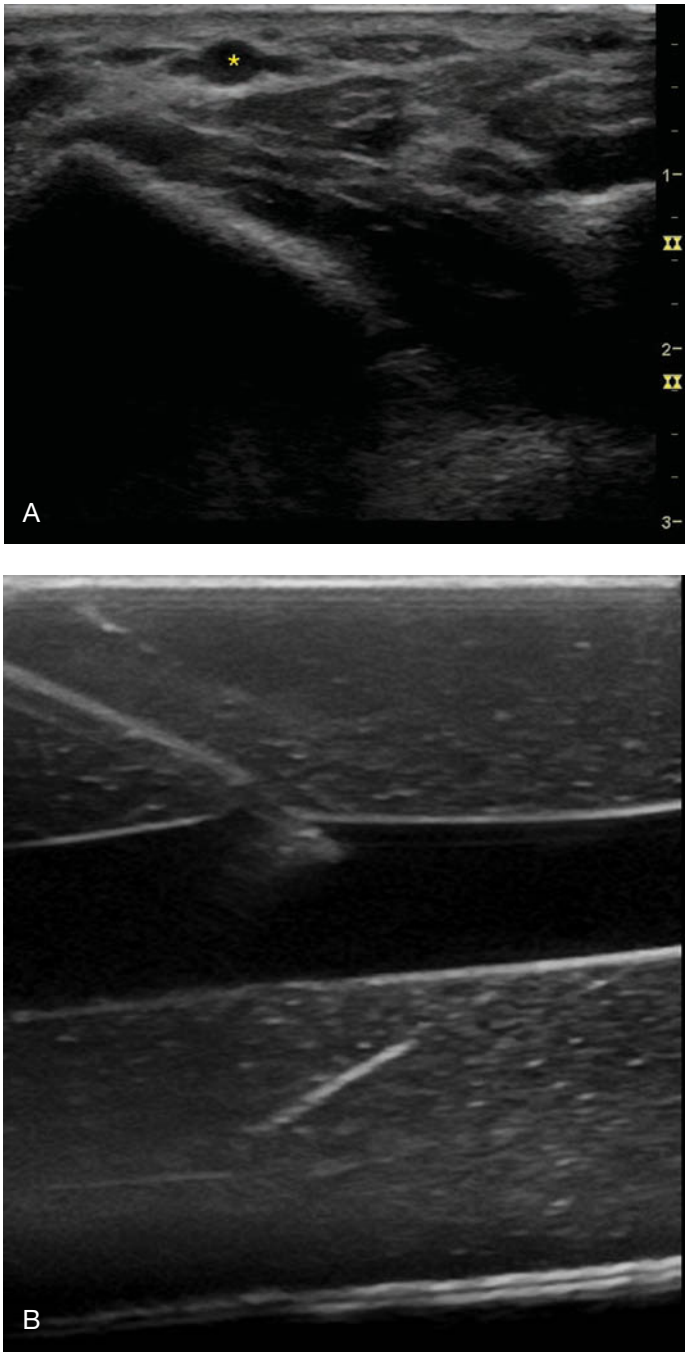


FIGURE 57-10. Ultrasound-guided arterial puncture. **A.** The artery is seen at the top of the image (*asterisk*). **B.** The longitudinal view demonstrating the needle entering the artery.

When the needle reaches the artery, it will dimple the wall of the artery. Advance the needle slowly while watching for the flash of blood in the needle hub. Once the flash is seen, ultrasound can be used to confirm placement of the needle and/or catheter within the artery (**Figure 57-10B**). Proceed from this point with either the catheter-over-the-needle or the Seldinger-type technique to complete the procedure.

ALTERNATIVE TECHNIQUE

A cutdown technique may be performed to cannulate an artery. It is primarily used for the brachial or radial arteries but may be used to access other peripheral arteries. This technique is rarely required

with the availability of ultrasound to locate an artery The technique is briefly described here. Please refer to Chapter 54 for more complete details.

Clean, prep, anesthetize, and drape the skin overlying the chosen artery. Make a 1.5 to 2.0 cm transverse skin incision centered over the artery. **Do not cut into the subcutaneous tissue so that blood vessels, nerves, and tendons are not transected.** Spread the subcutaneous tissues parallel to the artery with a mosquito hemostat. Expose 1.0 cm of the length of the artery. Pass a silk suture under the proximal end of the exposed artery. Insert a catheter-over-the-needle through the skin just distal to the incision and advance it into the incision. Elevate the suture to control the artery and occlude distal blood flow. Advance the catheter-over-the-needle into the artery. Release the suture and advance the catheter into the artery. The remainder of the procedure is as described previously. Apply pressure over the incision site for 5 to 10 minutes to prevent the formation of a hematoma or seroma.

AFTERCARE

Apply direct pressure for 3 to 5 minutes to the skin puncture site after an arterial puncture or removal of an arterial catheter. Apply direct pressure for 10 minutes or more if the patient has a bleeding diathesis or has received thrombolytic therapy. Apply a bandage or gauze dressing to the skin puncture site. Reassess the skin puncture site in 15 minutes for continued bleeding or hematoma formation.

An arterial catheter must be secured to the skin to prevent inadvertent dislodgement, hematoma formation, and exsanguination. Sew the hub of the catheter to the skin using 3-0 or 4-0 nylon sutures. Apply a protective dressing over the site. A splinting device should be used to secure the limb in the desired position for optimal monitoring if the catheter is in the wrist, arm, or foot. Monitor the site regularly to assess for signs of bleeding, infection, hematoma, arterial thrombosis, or catheter dislodgement. It is also important to assess the extremity distal to the catheter for evidence of ischemia. Replace the dressing regularly in accordance with your institutional guidelines.

Flush the arterial catheter with sterile saline solution. In the past, heparinized saline was the standard arterial line flush solution. The use of heparinized saline has not been shown to improve functionality, prevent thrombotic complications, or increase the duration of catheter patency when compared to saline.[40] The use of heparin risks an adverse reaction or heparin-induced thrombocytopenia.

COMPLICATIONS

Arterial puncture and catheterization are generally safe procedures with an incidence of clinically significant complications under 5%.[1] The primary complications of arterial catheterization are infection, bleeding, arterial injury, and thrombosis.[2,21–30] While secondary bacteremia and septic emboli may occur, infection is usually limited to the site of catheterization. The risk of catheter site infection is linearly related to the length of time the catheter is in place.[2] The infection rate is similar for both femoral and radial artery sites.[2,23,31–33] Nerve injury from direct puncture of the nerve has been reported in connection with arterial puncture or cannulation.[34] Multiple cases of neuropathy have occurred as a result of a hematoma formation and subsequent nerve compression.[35] In order to minimize hematoma formation after arterial puncture or arterial catheter removal, apply at least 3 minutes of direct pressure to radial, brachial, and dorsalis pedis puncture sites and 5 to 10 minutes of pressure to the femoral site.[34,36] Although small hematomas are common after arterial puncture, major bleeding is unusual and generally occurs only in the concealed retroperitoneum after femoral artery puncture or cannulation. Angiographically demonstrable thrombosis is common (25% to 40%) after prolonged arterial catheterization.[2] This rarely results in clinically significant morbidity. Secondary limb ischemia and necrosis requiring amputation occur in less than 1:2000 arterial catheterizations.[2] Other rare complications include the formation of a pseudoaneurysm or arteriovenous fistula.

The complications associated with an arterial catheter can be limited. Only insert an arterial catheter if it is truly needed. Always insert it using strict aseptic technique. Remove the catheter as soon as it is determined it is no longer required to assist in the management of the patient. Frequently check the skin puncture site for signs of bleeding, a hematoma, and infection. Frequently assess the distal extremity for signs of perfusion. Remove the catheter at the first sign of a complication. Place the catheter in the patients' nondominant hand, if known, to limit the impact of any complications.

SUMMARY

Arterial puncture and cannulation are quick, safe, and simple to perform. Arterial blood sampling may aid in determining the ventilator and acid–base status of critically ill patients. An arterial catheter is appropriate in patients who need continuous monitoring of arterial blood pressure or frequent ABGs. Arterial puncture and cannulation should be avoided in skin areas with evidence of burn, trauma, infection, severe dermatitis, or severe peripheral vascular disease. Palpation of the arterial pulse and correct anatomical positioning are necessary before these procedures are attempted. It is necessary to monitor the cannulated site for signs of bleeding, hematoma, thrombosis, or infection. After an arterial puncture or removal of an arterial catheter, it is necessary to apply direct pressure to the skin puncture site to prevent the formation of a hematoma.

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SECTION 5

Gastrointestinal Procedures

58 Nasogastric Intubation

Lisa Freeman Grossheim

INTRODUCTION

Nasogastric (NG) intubation is one of the commonly performed procedures in the Emergency Department.[1] Its use as a conduit into the stomach was first popularized in the early twentieth century mainly through the efforts of Dr. Levin. Clinicians have since studied its use, have proposed methods to improve the ease with which the NG tube is inserted, and determined ways to diminish the incidence of potentially lethal complications. A NG tube is often placed in patients who have a bowel obstruction, intractable nausea and vomiting, intoxication, significant trauma, upper gastrointestinal bleeding, or who are endotracheally intubated. The procedure is rapid, simple, and straightforward.

ANATOMY AND PATHOPHYSIOLOGY

The nasal cavity is lined by the very vascular nasal mucosa. The medial wall of the nasal cavity is composed of the septum. The lateral wall of the nasal cavity is covered by the turbinates. The posterior nasal cavities are continuous with the nasopharynx that develops into the posterior oropharynx as you move caudally (**Figure 58-1**). The oropharynx continues inferiorly as the esophagus that enters the stomach below the diaphragm.[2]

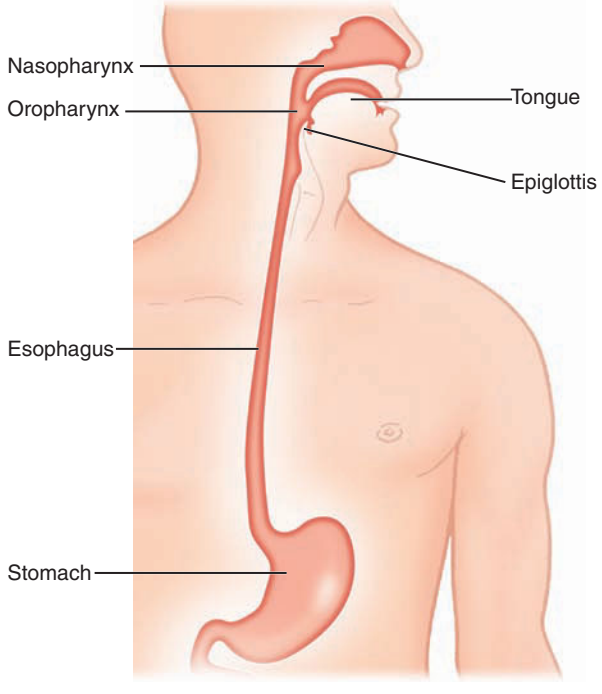


FIGURE 58-1. Basic anatomy of the path of the NG tube.

The placement of a NG tube in children is often difficult. Their large tonsils and adenoids may hinder the passage. These tissues are soft, easily injured, and may bleed as the NG tube is passed. The tongue, large by comparison with adults, may push into the oropharynx and impede passage of the NG tube. Their nostrils and nasal passage are quite small and limit the size of NG tube that may be passed.

INDICATIONS

Nasogastric intubation may be performed for diagnostic or therapeutic indications.[15] The primary indication for NG intubation is to aspirate stomach contents. It is used to evaluate the presence, rapidity, and volume of an upper gastrointestinal hemorrhage. However, unless the aspirate is grossly bloody, detection of blood may be unreliable. The fecal Hemoccult card should not be used to test for occult blood in gastric aspirates, as it may be accurate. The Gastroccult card uses a developer that neutralizes gastric acid, rendering it able to detect hemoglobin.[11] A NG tube may be inserted to instill air into the stomach to assess for an intraperitoneal perforation. Gastric fluid and contents may be aspirated for laboratory analysis. It may also be placed to visualize the stomach on chest radiography to assess for a diaphragmatic hernia. A NG tube is placed in patients for medication administration, relief of a bowel obstruction, treatment of recurrent vomiting, administration of oral contrast for diagnostic imaging, and to perform gastric lavage. They are placed to decompress the stomach preoperatively, postintubation, prior to a diagnostic peritoneal lavage, or prior to a pericardiocentesis.

CONTRAINDICATIONS

Absolute contraindications do not exist for NG tube placement. The relative contraindications are geared toward predicting which patients are more likely to experience complications and which patients are likely to have misplaced tubes. Insertion of a NG tube should be avoided, unless necessary, in the patient with midface trauma. Intubation through the nasal cavity can result in the NG tube being misdirected blindly into the respiratory tract or through the rare perforation of the thin cribriform plate of the ethmoid bone and into the brain. Patients with facial trauma are best served with orogastric intubation.[3] Patients with esophageal varices pose potential problems. Placement of a semi-rigid tube into the esophagus or stomach has the potential to cause rupture of the varices and uncontrollable hemorrhage. However, NG placement is generally considered safe in these patients if done carefully.[12,13] Other relative contraindications include patients with coagulopathies, esophageal strictures, ingestions of alkaline substances, nasal obstruction, or recent nasal surgery.

EQUIPMENT

- Topical anesthetic (benzocaine spray, cocaine, or viscous lidocaine)
- Topical vasoconstrictor (phenylephrine, oxymetazoline, or cocaine)
- 4% lidocaine

- Glass of water with straw
- Emesis basin
- Water-based lubricant
- NG tube, various sizes
- 60 mL syringe
- Wall suction, set to low intermittent suction
- Suction tubing
- Benzoin spray
- 1 in. adhesive tape
- Tongue depressor

NG tubes are usually made of clear polypropylene. They are somewhat rigid and single patient use devices. Typically used are the Levin tube and the Salem Sump tube. They both have multiple distal sideports. The Levin tube is a single-lumen tube that is easy to insert. It is simple to use for the aspiration of gastric contents, the instillation of fluids and/or medications, and the application of low intermittent suction. The tube is nonradiopaque. Unfortunately, the amount of suction is difficult to control with the Levin tube. The distal sideports often become occluded with the gastric mucosa, and damage this tissue, when the tube is attached to suction. The Salem Sump tube is a double-lumen, radiopaque tube. It has a smaller suction lumen than the Levin tube. The second lumen allows a constant inward airflow to prevent the sideports from becoming occluded by the gastric mucosa.

PATIENT PREPARATION

The most beneficial factor in the successful placement of a NG tube is a patient who is informed of the procedure and can cooperate with the instructions. Explain the risks, benefits, and complications associated with the procedure to the patient and/or their representative. Take the patient through each step prior to the start of the procedure to ensure maximal cooperation. Drape the patient to protect them and the bedding from soilage if there is emesis. A glass of water and a straw should be within reach, if not contraindicated, as should an emesis basin.

Place the patient seated upright in the Fowler's or semi-Fowler's position. Examine the patient for nasal septal deviation or other anatomic abnormalities that may hinder the passage of the NG tube. Ask the patient to breathe through one nostril while the other nostril is occluded to determine which nostril is the most patent.[4]

While often underused, consider using some form of anesthesia to make the procedure more tolerable.[20] A recent study suggests that the application of topical lidocaine and phenylephrine to the nose and benzocaine spray to the throat resulted in significantly less pain and discomfort than the use of lubricant alone.[5] The patient should be screened for allergies and contraindications, such as hypertension, if these adjuncts are to be used. A sample protocol would include the instillation of 0.5% phenylephrine nasal spray followed by viscous lidocaine. Cetacaine spray can be used to anesthetize the nose and the throat.[4] Nebulized 4% lidocaine (2.5 mL containing 100 mg of lidocaine) via a face mask can be used in adolescents and adults. It has been shown to be superior to lidocaine spray as an anesthetic to reduce gagging and vomiting and can increase the success of NG tube placement.[14,16] The dose used in children has been 4 mg/kg of lidocaine.[17] Either 2% or 4% lidocaine solutions can be used. **Be cautious when calculating the proper weight-based doses and volume of solution for children.** Lidocaine can also be administered in the nasal cavity, nasopharynx, and oropharynx using a mucosal atomizer device (MAD, Wolfe Tory Medical Inc., Salt Lake City, UT). Allow 3 to 5 minutes for these medications to take full effect before inserting the NG tube.

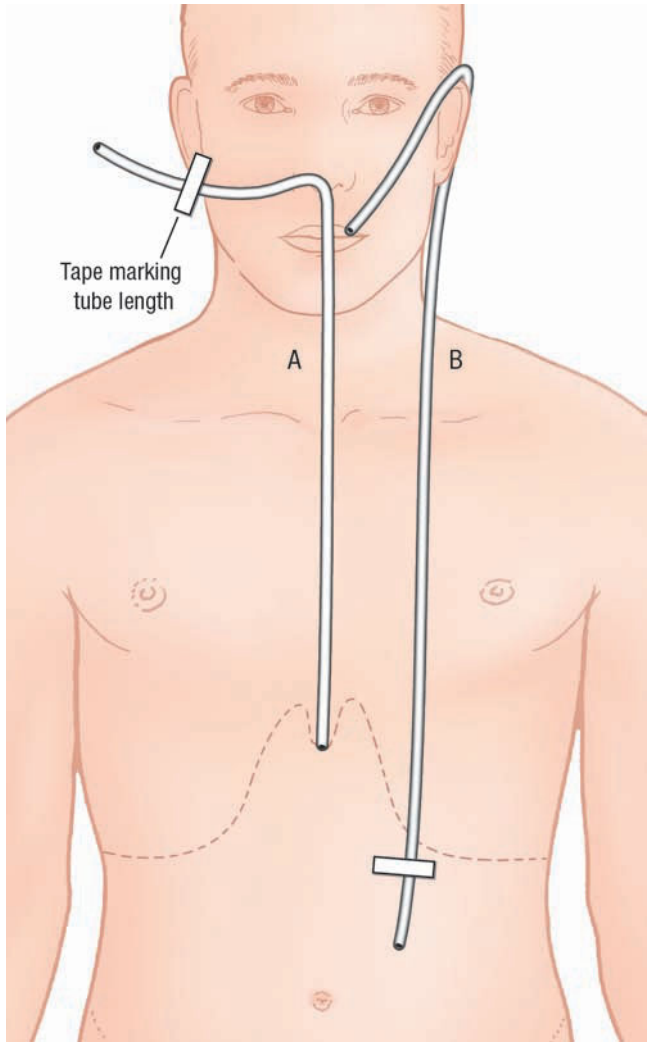


FIGURE 58-2. Determining the proper length of the NG tube to insert. **A.** The length is determined by the distance from the xiphoid process to the tip of the nose to the earlobe. **B.** The length is determined by the distance from the tip of the nose or lip to around the left ear and to just below the left costal margin. A piece of tape should be used to mark the distance on the NG tube.

Choose a size of NG tube that is appropriate for the patient. A size 16 to 18 French is typically used for an adolescent or adult patient. A formula ([age in years + 16] ÷ 2) may be used to choose the proper size NG tube for children. Other less commonly used methods are also available to determine the proper size NG tube in children.[21] Typical sizes include 8 French for infants, 10 to 12 French for small children, and 12 to 14 French for older children.

Estimate the length of the NG tube to be inserted (**Figure 58-2**). Place the tip of the NG tube on the patient's xiphoid process and extend it to the tip of the nose and over the earlobe (**Figure 58-2A**). Mark this distance with a piece of tape.[4] Alternatively, place the tip of the NG tube on the tip of the nose or lip and extend it over the left ear and to just below the left costal margin (**Figure 58-2B**). Mark this distance with a piece of tape.[4]

TECHNIQUE

Lubricate the first 4 in. (10 cm) of the NG tube with a water-soluble lubricant. Position the patient. Place their neck in slight flexion. Gently introduce the NG tube along the floor of the nostril (**Figure 58-3A**). Advance the NG tube parallel to the nasal

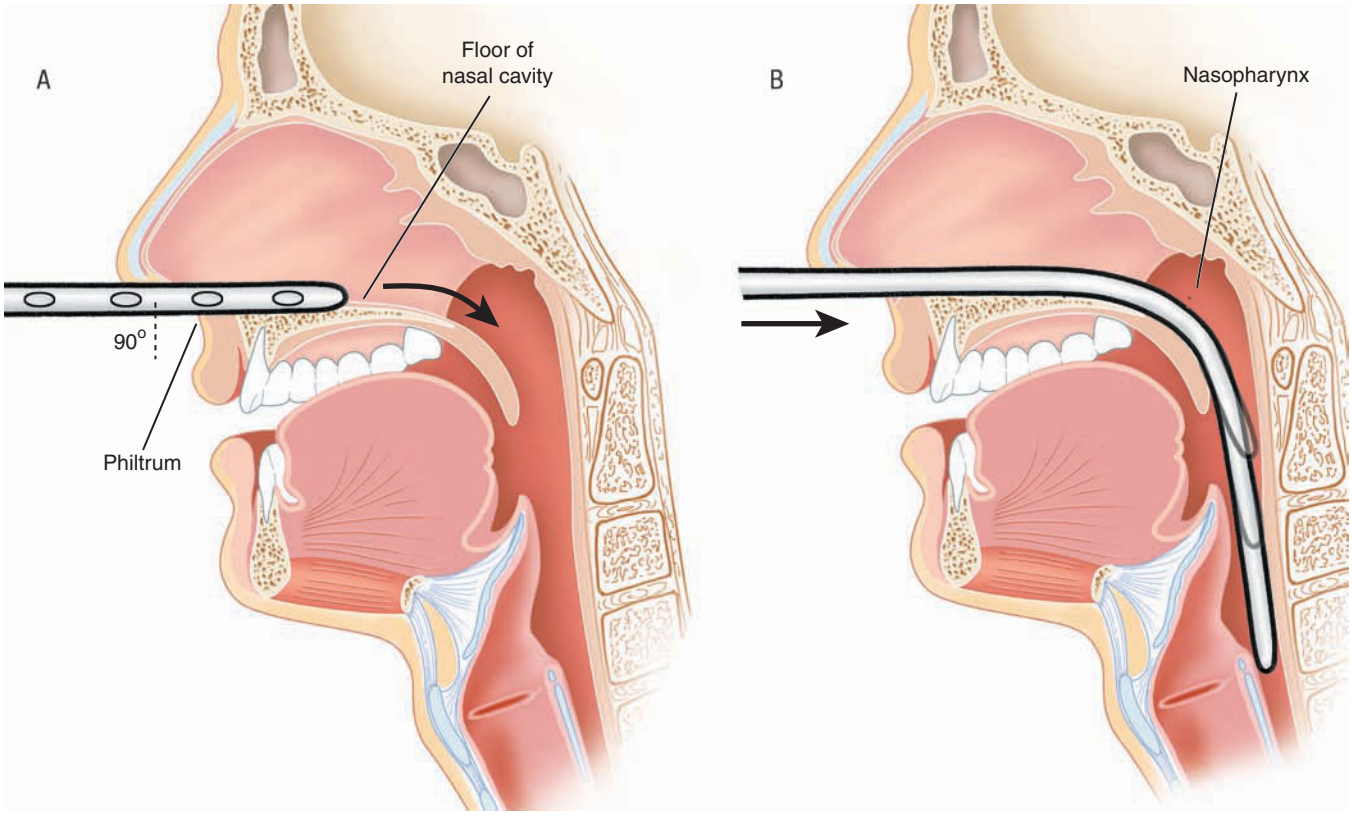


FIGURE 58-3. Insertion of the NG tube. **A.** The NG tube is inserted parallel to the floor of the nasal cavity and at a 90° angle to the philtrum. **B.** The NG tube is advanced along the floor of the nasal cavity, through the nasopharynx and oropharynx, and into the esophagus. It is further advanced until the tape mark is at the philtrum.

floor until it reaches the nasopharynx as indicated by mild resistance (**Figure 58-3A**). Do not insert and advance the NG tube in an upward or lateral direction to prevent impingement and damage to the turbinates. Instruct the patient to swallow. This may be assisted by having the patient sip water through a straw if not contraindicated. Continue to advance the NG tube (**Figure 58-3B**). Advancement may be aided by rotating the NG tube medially. **Withdraw the NG tube if at any time significant resistance to advancement, respiratory distress, the inability to speak, or significant nasal hemorrhage occurs.**[5]

Advance the NG tube until the distance previously measured with the tape is at the nostril (**Figure 58-4**). Verify proper placement by aspirating stomach contents, by auscultating a rush of air over the stomach while 60 mL of air is insufflated through the NG tube, or by radiographically demonstrating the tip of the NG tube in the stomach and below the diaphragm. The latter is the most reliable and should be strongly considered when the NG tube is to be used for medication administration or alimentation.[6] **Infusion of substances through a misplaced NG tube could be disastrous.** Apply benzoin to the patient's nose. Apply tape to the nose and around the NG tube to secure it in place (**Figure 58-5**). Attach the NG tube to wall suction.

ALTERNATIVE TECHNIQUES AND HELPFUL HINTS

One study attempted to improve the success rate of NG tube placement by providing external and medially directed pressure on the ipsilateral neck at the level of the thyrohyoid membrane.[7] This maneuver will collapse the piriform sinus and eliminate it as a potential site for impaction. This maneuver was successful for difficult NG intubation in 85% of patients.

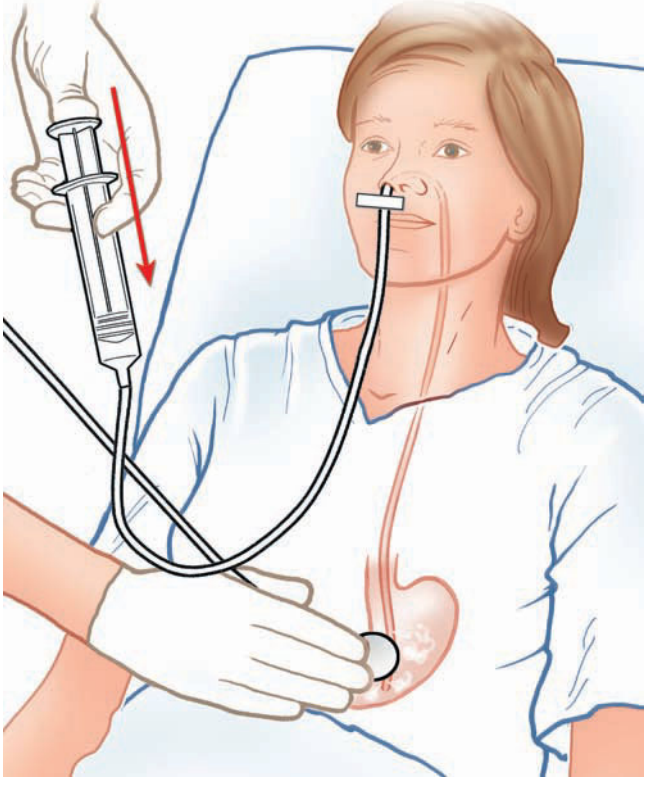


FIGURE 58-4. Proper placement of the NG tube. The tip of the tube resides within the stomach. To confirm proper placement, inject air through the NG tube while simultaneously auscultating over the stomach.

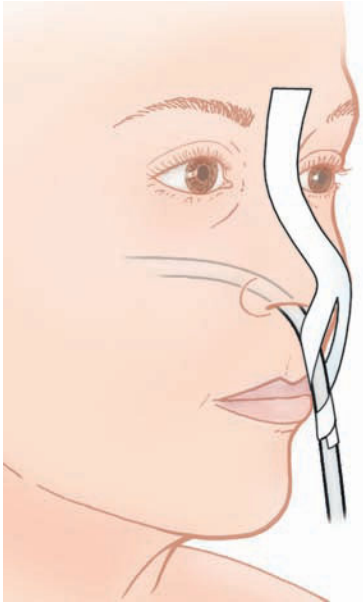


FIGURE 58-5. Securing the NG tube. Apply tincture of benzoin to the bridge of the nose. A piece of tape is attached to the nose with the distal end split into two and intertwined around the NG tube.

The NG tube may coil in the oropharynx, mouth, or hypopharynx. A larger-bore NG tube may be used and may not coil. Cool the NG tube in cold tap water or ice water for 5 minutes to make the tube stiffer and then reinsert it. An alternative is to place the distal end of a NG tube into an oropharyngeal airway then chill it in ice water (**Figure 58-6**). The oropharyngeal airway will place a curve in the chilled NG tube, which may allow it to pass easier. The chilled NG tube will retain this curve for 30 to 60 seconds until it rewarms (**Figure 58-6**).

A final option is to place several fingers through the patient's mouth and into the oropharynx. The fingers can be used to guide the NG tube against the posterior oropharyngeal wall and into the hypopharynx without it coiling. A tongue depressor may be used to move the tongue to the floor of the mouth and make manipulation of the NG tube easier by creating more space in the mouth to maneuver. **This finger technique should be reserved for intubated patients in whom the gag reflex is not a concern. Do not attempt this unless the patient is unconscious or paralyzed to prevent them from biting and injuring the fingers.**



FIGURE 58-6. A NG tube is inserted into an oropharyngeal airway before being chilled in ice water. The chilled NG tube will retain its curve for 30 to 60 seconds.

The NG tube may easily pass the hypopharynx but not be able to be passed completely through the esophagus and into the stomach. The tip of the tube may be caught at the level of the cricopharyngeus muscle, behind the left mainstem bronchus, or at the lower esophageal sphincter. Attempt to pass a NG tube that has been cooled for 3 to 5 minutes in cold tap water or ice water. Grasp the thyroid cartilage and lift it anterior and upward to open the esophagus and allow passage of the NG tube through the upper esophagus.

An orotracheally intubated patient requires a NG tube to decompress the stomach. Unfortunately, one cannot always be passed into the stomach. Remove the respiratory adapter from the proximal end of a second endotracheal tube. Liberally lubricate the endotracheal tube and insert it through the patient's mouth and into the esophagus. Insert a well-lubricated NG tube through the endotracheal tube and into the stomach. Confirm the proper position of the NG tube. Carefully withdraw the endotracheal tube over the NG tube. Reconfirm that the distal end of the NG tube still remains within the stomach.

The risk for tube misplacement is greater in the intubated patient who is unable to assist with NG intubation. Observe that the NG tube does not come out of the patient's mouth and that there are no changes in the patient's oxygen saturation when inserting the NG tube. It is very easy for the NG tube to pass by the cuff of an endotracheal tube without much resistance.[7] **It is paramount that correct placement of the NG tube is verified both clinically and radiographically before it is used to instill any fluid or medication.**

A final technique to help pass a NG tube involves direct visualization using a laryngoscope and Magill forceps. Insert the NG tube through the nose and advance it into the oropharynx or hypopharynx. Insert the laryngoscope blade and visualize the distal tip of the NG tube and the esophageal opening. Grasp the tip of the NG tube with the Magill forceps and advance it into the esophagus. Continue to advance the NG tube until the tip is within the stomach. The technique can be used on the unconscious and intubated patient in which a NG tube will not pass into the esophagus.

ASSESSMENT

The patient should be able to speak without respiratory distress immediately after placement of the NG tube. Observe the patient for complaints of neck pain, substernal chest pain, dysphagia, drooling, trismus, fever, or subcutaneous and mediastinal air. These would be signs of esophageal perforation or errant placement of the NG tube.[6] Although auscultation of air in the stomach has been classically used to determine correct placement, air insufflated into the pleural space or the esophagus after misplacement of the NG tube can be just as easily heard over the upper abdomen.[6] Gastric contents should be able to be aspirated through the NG tube. Testing the pH of the gastric contents can help predict the placement of the NG tube. The pH of the aspirated fluid will be ≥7 in 99% of patients if the NG tube is in the respiratory tree.[8] The pH of the aspirated fluid will be ≤5 in 70% of the patients if the NG tube was correctly placed in the stomach. The use of H_2 blockers makes the assessment of gastric pH difficult. Radiographic demonstration of the tube in the antral or fundal portion of the stomach is the preferred method of confirmation.[9]

NASOGASTIC TUBE REMOVAL

Explain to the patient the procedure and what they will experience as the NG tube is removed. It is recommended for the Emergency Physician to wear gloves, a mask with an eye shield, and a gown to prevent being contaminated during the removal. Place the patient in the Fowler's or semi-Fowler's position. Place towels or pads over the

patient's neck and chest. Have an emesis basin, tissues, and Yankauer suction immediately available. Disconnect the NG tube from suction. Fold over the proximal end of the NG tube and hold it tightly. Ask the patient to slightly flex their neck, breath in, and hold it. Place a drape or towel around the NG tube as it is exiting the patient's nose. Firmly squeeze the drape around the NG tube. Briskly withdraw the NG tube through the drape. The drape will contain all the secretions and bodily fluids and prevent them from splashing on the patient or the Emergency Physician. Discard the NG tube and the drape.

COMPLICATIONS

The most common complication of NG intubation is discomfort in the nasopharynx and oropharynx. Placement in the nares can result in epistaxis if the nasal mucosa is irritated, abraded, or ulcerated. These complications can be reduced or avoided with generous lubrication of the NG tube and the instillation of topical anesthetics and vasoconstrictors prior to inserting the NG tube. Sinusitis may occur from the NG tube obstructing the sinus ostia. These complications are usually of no clinical significance.

A more serious consequence of NG intubation is misplacement into the respiratory tree. This is estimated to occur in up to 15% of cases.[10] The incidence increases in frequency with the patient who has a diminished gag reflex or a decreased level of consciousness. **The presence of a cuffed endotracheal tube does not preclude passage into the respiratory tree.** The NG tube will pass the cuff of the endotracheal tube without significant resistance. Advancing the NG tube into the airway can result in perforation of a bronchus or the lung and result in a pneumothorax, hydropneumothorax, pulmonary hemorrhage, empyema, or bronchopulmonary fistula.[10] These complications are increased if medication or alimentation is infused into the respiratory tree.

The most serious complication of NG tube placement is esophageal perforation. This most often occurs in the posterior wall of the cervical portion of the esophagus and through the cricopharyngeus muscle. Risk factors for esophageal perforation include a preexisting esophageal abnormality, altered mental status, cervical osteophytes, cardiomegaly, tracheal intubation, a stiff NG tube, and multiple attempts.[6] Other risk factors for esophageal perforation include esophageal cancer or the ingestion of alkaline substances. Perforation often results in mediastinitis with a subsequent mortality rate of up to 30%.[6] Prompt recognition, surgical repair, and parenteral antibiotics can reduce the mortality rate to less than 10%. The use of softer and smaller NG tubes with generous lubrication can reduce the risk of esophageal perforation.

Use caution when inserting a NG tube in patients who have suffered trauma to the face, neck, and/or skull, or if they have medical conditions affecting these areas.[18,19] Fractures of the base of the skull, cribriform plate, maxilla, nasal walls, orbital floors, and palate may allow a nasally inserted tube to exit the nasal cavity and cause further injury. The NG tube may exit traumatic or medical wounds and penetrate neighboring vascular structures.[19]

SUMMARY

NG intubation is a widely used procedure in the Emergency Department. It is primarily used to evacuate air and stomach contents in the poisoned, intubated, or bowel obstructed patient. Placement is generally considered easy, although it can be uncomfortable. Recent studies suggest that topical anesthetics and vasoconstrictors, along with generous lubrication, can diminish the discomfort and reduce the chance of misplacement.

Placement of the NG tube into the airway or coiled in the esophagus can result in serious complications. Although auscultation of air has been classically used to determine correct placement, radiographic confirmation of gastric placement is considered the gold standard. Postintubation patients should be carefully observed for signs of esophageal perforation.

59 Activated Charcoal Administration

Jenny J. Lu

INTRODUCTION

The adsorptive capacity of charcoal has been documented since the time of Hippocrates and has been known for centuries. Two independent researchers were responsible for its wide acceptance in the early nineteenth century when each of them performed a demonstration of its effectiveness by ingesting lethal doses of strychnine and arsenic, respectively, followed by charcoal. Both of them survived. The twentieth century has seen charcoal come into wide medical use as further investigation showed its effectiveness at adsorbing a wide variety of compounds.[1] Activated charcoal is currently the most commonly used mode of decontamination in the Emergency Department for poisoned patients.[2]

ANATOMY AND PATHOPHYSIOLOGY

Charcoal is produced by the distillation of the pyrolysis products of vegetable matter or wood. It works by directly adsorbing toxicants via a variety of chemical binding properties, and thus preventing substances in the gastrointestinal tract from being absorbed into the circulation. Enhancement of the adsorptive capability of charcoal is achieved by heating it to a temperature of 900°C and then subjecting it to a stream of oxidizing gas such as carbon dioxide gas or steam. This process is termed "activation" and creates an internal pore structure, which increases the surface area from 2 to 4 square meters per gram to greater than 2000 square meters per gram.[2] A typical dose of 50 g of activated charcoal has the surface area of 10 football fields. Charcoal is not absorbed from the intestinal lumen nor is it modified by the numerous enzymes that aid in the digestion of food. It passes through the intestinal tract unchanged and is expelled as a sticky black substance.

Some charcoal preparations contain sorbitol. Sorbitol is typically used as a flavoring agent to make food, drinks, and medications more palatable. It is also used as a hyperosmotic laxative agent. It is poorly absorbed from the gastrointestinal tract and converted into fructose by the liver. Its limited absorption results in an increased volume of water being secreted into the intestine causing an increased intraluminal pressure that stimulates a catharsis.

Charcoal can help enhance the elimination of certain compounds by disrupting the enteroenteric or enterohepatic circulation. A diffusion gradient is created in the intestine due to the enormous adsorptive ability of charcoal to bind free toxicants. The intestinal mucosa essentially functions as a semipermeable membrane allowing absorbed drug or toxin to diffuse from the capillaries back into the lumen of the intestine. Charcoal can adsorb and "trap" it within the intestinal lumen to be subsequently eliminated.[3,4] This mechanism essentially dialyzes the blood in the capillaries of the intestinal circulation, hence the term "gastrointestinal dialysis." Similarly, drugs and drug metabolites secreted into the bile may be absorbed and trapped by charcoal within the intestinal lumen. By adsorbing these substances, activated charcoal may shorten the half-life, although evidence for clinical benefit of doing so remains limited. Substances that may benefit from multiple dosing of charcoal for

enhanced elimination include phenobarbital, theophylline, dapsone, diazepam, amitriptyline, carbamazepine, phenytoin, quinine, salicylates, piroxicam, digoxin, doxepin, quinine, tricyclic antidepressants, and meprobamate.[3,4]

INDICATIONS

Activated charcoal binds to most commonly ingested substances and is currently considered the modality of choice for gastrointestinal decontamination.[5] It is generally indicated for an ingestion of toxic materials that are adsorbable to charcoal. Charcoal may be used to enhance the elimination of toxicants that are metabolized by the liver and secreted into the bile.

Charcoal has an excellent safety profile. It can be used in pregnancy, in lactation, and in the pediatric population. Its use is widely accepted even though no good randomized controlled clinical studies have been performed.[4] Animal and volunteer studies have repeatedly shown activated charcoal's efficacy. Activated charcoal has been found in clinical studies to be as efficacious and safer when compared with emetics or gastric lavage as a single modality for decontamination purposes. A large randomized controlled trial examined gastric emptying procedures, comparing ipecac-induced emesis, gastric lavage and activated charcoal, and activated charcoal alone in patients with drug overdoses.[6] No significant differences in clinical severity, length of hospital stay, morbidity, or mortality among the treatment groups were found. These findings are similar to those found in other studies.[7,8]

Ipecac-induced emesis, activated charcoal, and gastric lavage were compared in volunteers 1 hour after the ingestion of ampicillin.[9] Activated charcoal was found to be superior in decreasing the absorption of blood ampicillin levels by 57%. Gastric lavage decreased absorption by 32% and emesis decreased it by 38%. The authors concluded that activated charcoal without a gastric emptying procedure may be the preferred method of gastrointestinal decontamination. Limitations of the study included using subtoxic doses of ampicillin on volunteers and the small sample size.

The optimal timing for administration of charcoal remains controversial. None of the studies demonstrating efficacy of activated charcoal administered it more than 1 hour after the ingestion.[10] The American Academy of Clinical Toxicology has noted that there is insufficient evidence to support or exclude the use of activated charcoal more than 1 hour after a toxic ingestion.[11] Additionally, there is no evidence that the use of activated charcoal decreases mortality or improves clinical outcome.[11] This does not mean that activated charcoal should not be given if the patient presents later than 1 hour after ingestion. It simply means that this has not been studied and not enough evidence exists to make a firm decision.

CONTRAINDICATIONS

One absolute contraindication to the use of activated charcoal is in the patient with an unprotected airway. The patient must be able to maintain an intact gag reflex or should be endotracheally intubated to protect against aspiration, although it is not recommended that patients be intubated solely for the purpose of decontamination. Patients with depressed levels of consciousness and those at risk for seizures from their toxic ingestions should not be given activated charcoal. Patients with absent bowel sounds, evidence of gastrointestinal obstruction, or recent gastrointestinal surgery should not be given charcoal secondary to the risk of bezoar formation or perforation and leakage of charcoal into the abdominal cavity.

Activated charcoal is not effective against xenobiotics such as acids and alkalis, alcohols, fluoride, heavy metals, inorganic salts, iron, lithium, or potassium. Its use is limited in liquid ingestions where absorption is rapid. It is unlikely to be helpful in hydrocarbon and pesticide ingestions. Besides being minimally effective in preventing the absorption of caustics, administration of charcoal can render endoscopic visualization technically difficult. However, for most other ingestions, including mixed ingestions, a dose of activated charcoal can be given, if no contraindications exist. **Charcoal combined with cathartics is contraindicated in young children due to the risk of severe electrolyte imbalances and it should be used with caution in renally impaired patients.[12]**

EQUIPMENT

Several charcoal preparations are available.[13] These include capsules, tablets, powder, oral suspensions, and suspensions containing sorbitol. Powder, premixed oral suspensions, and suspensions with sorbitol are the only preparations indicated for use in an acute poisoning. Powder is available in doses from 15 to 500 g that must be mixed with water to make a slurry. The premixed suspension is available in strengths of 12.5 g/60 mL to 50 g/240 mL. Charcoal suspensions with sorbitol are available containing 25 to 50 g of activated charcoal and 25 to 96 g of sorbitol in a volume of 120 to 150 mL.

PATIENT PREPARATION

A cuffed endotracheal tube should be placed prior to the administration of activated charcoal in patients who are comatose, drowsy, obtunded, unconscious, or have an absent or impaired gag reflex. Endotracheal intubation should be strongly considered in any patient who has ingested a central nervous system depressant, tricyclic antidepressants, a sympathomimetic or other agent that may result in seizures, or any substances that can cause an altered mental status. A patient may become nauseous and vomit due to the ingested substances, the nasogastric tube, or the activated charcoal slurry. This can be controlled with the intravenous administration of an antiemetic medication.

Thoroughly mix the charcoal slurry prior to opening the container. Some preparations settle with the charcoal in the bottom of the container. Activated charcoal suspensions are gritty and unpleasant to swallow but have no taste. Some newer charcoal preparations dissolve completely when added to water to form a solution that is not gritty (Paddock Laboratories, Minneapolis, MN). The addition of sorbitol causes the suspension to be less gritty and have a sweet taste. This may enhance the palatability of the charcoal. Some manufacturers supply cherry or other flavorings to make the charcoal more palatable.

TECHNIQUE

Charcoal should be administered as early as possible after the ingestion and optimally within the first hour after an ingestion as its efficacy is reduced with the passage of time. An aqueous slurry should be used rather than tablets or powder. A single dose is typically administered. Multiple doses may be considered if the xenobiotic is expected to be absorbed slowly (e.g., massive ingestions or sustained release preparations) or if enhanced elimination of amenable substances is the objective. The recommended dose for the single or initial dose is five to 10 times the amount (in grams) of toxicant ingested, although standard practice is to give 1 g/kg (50 to 100 g to an adult or 10 to 25 g child <5 years).[13] An alert patient typically tolerates drinking the slurry well. Repeated doses may range from 15 to 30 g every 2 to 4 hours, although optimal dosing is not known.[13] A cathartic may be used in special circumstances with alternating doses as long as hydration and electrolyte levels are vigorously monitored.[13]

Sorbitol may be premixed with the charcoal. The sorbitol will decrease gastrointestinal transit time and may prevent bezoar formation. However, it may also increase nausea and vomiting and the

risk of aspiration. **Sorbitol-containing charcoal should be given only to adults and only with the first dose.** Attention should be paid to verify whether or not the charcoal preparation contains sorbitol, especially where multiple doses are given.

A nasogastric tube can be placed in the cooperative or uncooperative patient to facilitate administration of the charcoal. **Correct placement of the nasogastric tube in the gastrointestinal tract is absolutely essential prior to charcoal administration.** Confirmation of gastric placement can be done by auscultation of insufflated air into the stomach over the epigastrium, by the aspiration of stomach contents through the nasogastric tube, or radiographically by demonstrating the tube below the level of the diaphragm. Please refer to Chapter 58 for the details regarding the placement of a nasogastric tube. Attempts should be made to minimize gastric pressures by the overly aggressive administration, which can increase the risk of aspiration.[14]

COMPLICATIONS

The most feared complication of activated charcoal use is pulmonary aspiration. Activated charcoal can cause severe pneumonitis that can lead to respiratory failure, prolonged ventilatory support, and death. In addition to pneumonitis, an empyema and bronchiolitis obliterans can occur. **Avoiding aspiration is paramount when giving charcoal.** The patient must be awake and have an intact gag reflex in order to protect against aspiration. Errant placement of a nasogastric tube into the trachea or bronchi, and even past the inflated cuff of a properly placed endotracheal tube, can result in aspiration.[12] **The proper placement of nasogastric tubes must be confirmed prior to instilling activated charcoal.** Reports of life-threatening pulmonary complications as a result of aspiration have also been reported with the removal of the nasogastric tube subsequent to charcoal administration.[15] Aspiration of activated charcoal can occur in the intubated patient with an inflated endotracheal cuff and a properly placed nasogastric tube.[16]

Charcoal containing or administered with sorbitol or magnesium decreases the risk of intestinal obstruction and constipation. Yet, this can induce its own set of problems. Electrolyte disturbances can result despite the benefits of decreasing transit time through the gut and the concomitant decrease in toxicant absorption. Cathartic-induced hypernatremia, typically a complication seen in the very young, can lead to serious central nervous system damage, brain swelling, long-term morbidity, and death. Sorbitol dosing in children is not clearly established, and the typical premixed preparations are not appropriate in the pediatric population. Hypermagnesemia is seen in the adult population when a magnesium-containing cathartic is given in a patient with gastrointestinal abnormalities or renal compromise. Dehydration is a problem encountered in the elderly and young. Osmotic volume loss from the gastrointestinal tract can cause these fragile populations to decompensate.[12]

Intestinal obstruction is a rare complication but carries significant morbidity. Case reports of obstruction and perforation requiring laparotomy have been documented. Charcoal bezoars are the usual culprits. Bezoars can form when intestinal motility is compromised allowing continued absorption of water from the intestinal contents. Once sufficient water has been absorbed, bonds form between charcoal particles and the mass continues to harden. Ingestions of anticholinergic substances, antiperistaltic coingestions, or medications administered during the hospital course have also been implicated. Caution should therefore be used when giving these patients narcotic or anticholinergic medications. Typically, patients receiving multiple-dose activated charcoal therapy or activated charcoal without cathartics are at the greater risk. Constipation is a milder form of this complication and is uncommon and rarely of clinical significance.[12]

SUMMARY

Activated charcoal is currently the most commonly used modality of gastrointestinal decontamination in the acutely poisoned patient. This is despite limited evidence demonstrating improved clinical outcomes or decreased mortality rates. Administration of charcoal is relatively straightforward and is generally well tolerated orally. The usual dose of activated charcoal is 50 to 100 g in an adult and 1 g/kg in a child. Preparations containing a cathartic such as sorbitol can be used with the first dose in the adult unless contraindicated. Cathartics and charcoal preparations containing sorbitol should not be used in children or those with renal impairment due to the risk of electrolyte disturbances. The most significant complications occur as a result of aspiration and can be minimized by paying close attention to the patients at risk (i.e., those with a decreased level of consciousness or a weakened gag reflex) and by checking placement of the nasogastric tube prior to administration of charcoal. The risks and benefits of multiple dosing must be carefully weighed when considering to prevent the absorption or to enhance the elimination of the toxicants. Activated charcoal may be judiciously administered in appropriately selected acutely poisoned patients as long as there are no contraindications.

Should the use of activated charcoal continue because there may be some benefit despite the potential complications?[17–19] Should activated charcoal not be used until it is proven to be beneficial compared to the potential complications? This continuing controversy in toxicology will persist until more evidence becomes available. The decision to use activated charcoal should be determined on a case-by-case basis by the treating Emergency Physician, with possible consultation from a poison control center.

60 Gastric Lavage

Jenny J. Lu

INTRODUCTION

Gastric lavage is a method of gastrointestinal decontamination, performed in the setting of an acute poisoning by ingestion, to decrease the absorption of substances in the stomach. This technique was first described in 1812 and has been used for nearly 200 years.[1] It was repopularized in the 1950s and 1960s and thrived during the heyday of the "tricyclic era" of the 1970s and 1980s. The use of gastric lavage in the Emergency Department has decreased greatly in modern toxicology for several reasons. Most notable is the trend toward evidence-based medicine and the growing body of experimental and clinical data pointing to the limited efficacy of gastric lavage. Gastric lavage was performed in approximately 10.3% of all ED-treated poisoning cases between 1998 and 2003, a decrease from 18.7% during the period of 1993 through 1997.[2] The increasing use of other modalities for gut decontamination, especially activated charcoal, has further limited the role of gastric lavage.[1,3]

ANATOMY AND PATHOPHYSIOLOGY

With the widespread administration of activated charcoal as the current decontamination measure of choice, there remain very few indications for performing gastric lavage for decontamination, if any. These rare indications would include a highly toxic or potentially lethal ingestion presenting acutely where no antidote exists or where other usual therapies are ineffective, unavailable, or nonexistent.

The optimal timing of gastric lavage is also controversial. Any benefit of gastric lavage would likely be gained if performed promptly and within 1 hour of an oral ingestion.[3] Authors agree that the sooner it is instituted, the better. The range of recovered ingestant is highly variable at each time point following an ingestion in volunteer and overdose studies. The trend for mean removal of ingestants is 90% recovery at 5 minutes postingestion, 45% recovery at 10 minutes, 30% recovery at 19 minutes, and as little as 8% recovery at 60 minutes.[3]

Undoubtedly, the efficacy of gastric lavage diminishes rapidly over time. Some toxicants or coingestants may cause delayed gastric emptying, while others may form masses or concretions in the stomach. Removal of only a small percentage of the ingested dose may theoretically lessen the severity of the poisoning in some cases, but these benefits remain unproven. Gastric lavage has never been demonstrated to decrease mortality. **A reasonable approach when considering gastric lavage is in the acutely poisoned patient who presents within 1 hour of a life-threatening ingestion.** The decision should be made with consideration to the specifics of the ingestion. Delayed gastric lavage should be considered only in a severely toxic poisoning or where delayed gastric emptying is suspected (e.g., anticholinergic or opioid coingestant). It would be prudent to consult a poison control center or a Medical Toxicologist when considering gastric lavage in any poisoned patient.

Nasogastric placement of a gastric lavage tube is not advised. The orogastric route should be used to avoid traumatic injury to the nasal mucosa, nasal turbinates, and nasal septum. The use of a small-bore nasogastric tube is discouraged if the objective is gastric emptying. If an appropriately sized nasogastric tube is placed for other reasons and if the ingestant is in liquid form, aspiration of gastric contents can be attempted through a nasogastric tube. Lavage fluid can be instilled through a nasogastric tube with the expectation that the return of gastric contents may be inadequate. Lavage fluid that does not return through the nasogastric tube will pass through the pyloric sphincter and could potentially allow increased absorption of the toxicant.[4] Sustained-release tablets or capsules are particularly large in size and unlikely to be removed through a nasogastric tube or through the fenestrae of a 40 French orogastric lavage tube (**Figure 60-1**).

Placement of gastric lavage tubes in the pediatric population is precarious and may result in complications (**Figure 60-2**).[5] A formula for the depth of insertion has been prospectively evaluated to ensure adequate placement in this population and is depicted graphically in **Figure 60-3**.[5,6] Moreover, the size of the oropharyngeal aperture and esophagus are proportional to the size of the individual. **Appropriate tube diameter is essential to minimizing complications.**

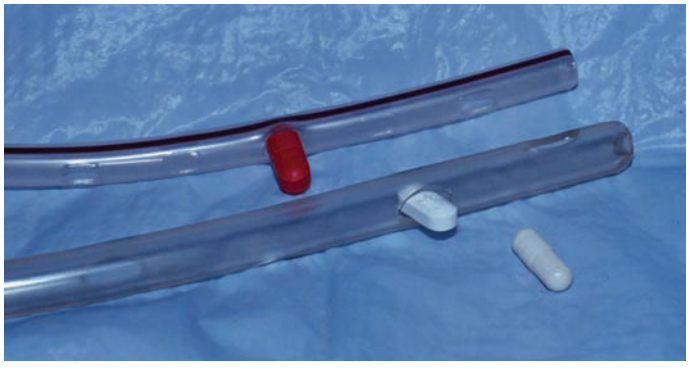


FIGURE 60-1. Orogastric lavage tubes demonstrating sideport size. A 36 French tube with a Stresstab™ 600 multivitamin in the sideport (*top*). A 40 French tube with a 450 mg sustained-release theophylline tablet in the side port (*middle*). A generic 250 mg ampicillin tablet (*bottom*) (Courtesy of F.P. Paloucek, PharmD).

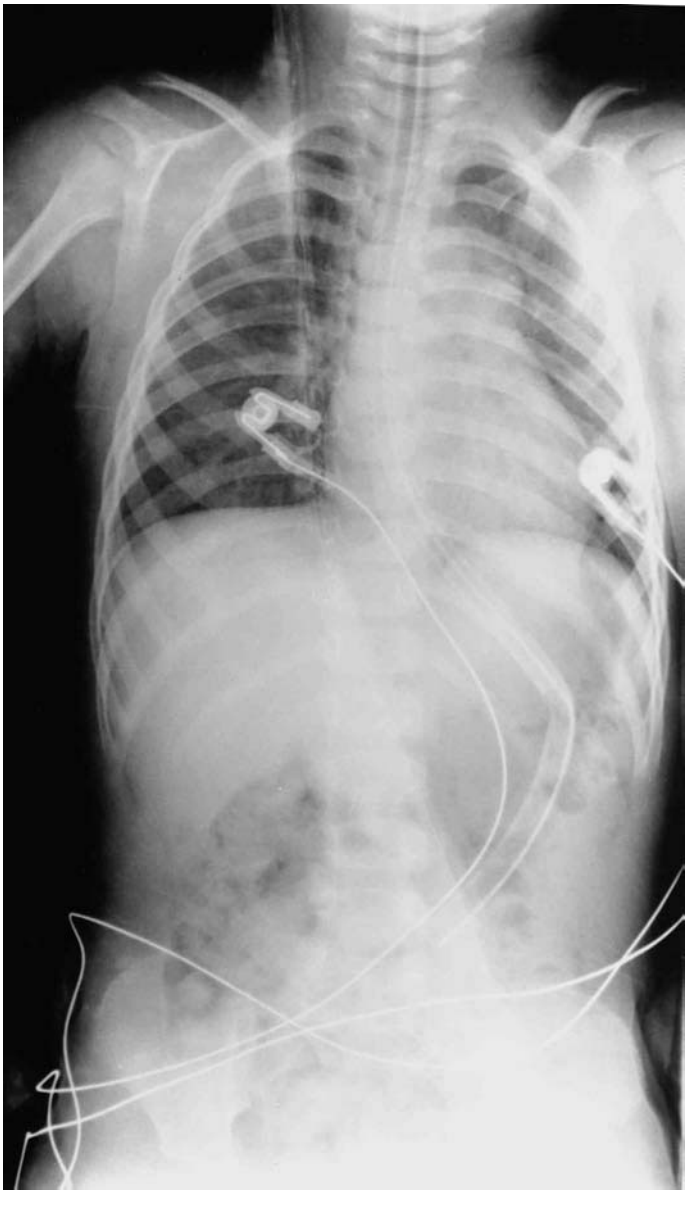


FIGURE 60-2. Malposition of an orogastric tube placed for gastric lavage in a pediatric patient (Courtesy of Ann E. Klasner, MD, MPH).

INDICATIONS

Gastric lavage is indicated for immediate stomach emptying within 1 hour after an orally ingested overdose or poisoning and when not contraindicated. Consideration should first be given to other less invasive modalities of gastrointestinal decontamination such as activated charcoal or whole bowel irrigation. Consideration should be given to the specific characteristics of the toxicant, the ingested dose, and the risks versus benefits of performing the procedure. **Gastric lavage should be considered only where there is risk of significant toxicity or imminent fatality and where antidotal or other supportive modalities are inadequate (Table 60-1).** It may be considered beyond 1 hour in patients with known or suspected delayed gastric motility (e.g., in the setting of anticholinergic or opioid ingestion) or where the evidence of a durable mass (concretion) of pill fragments is a concern.

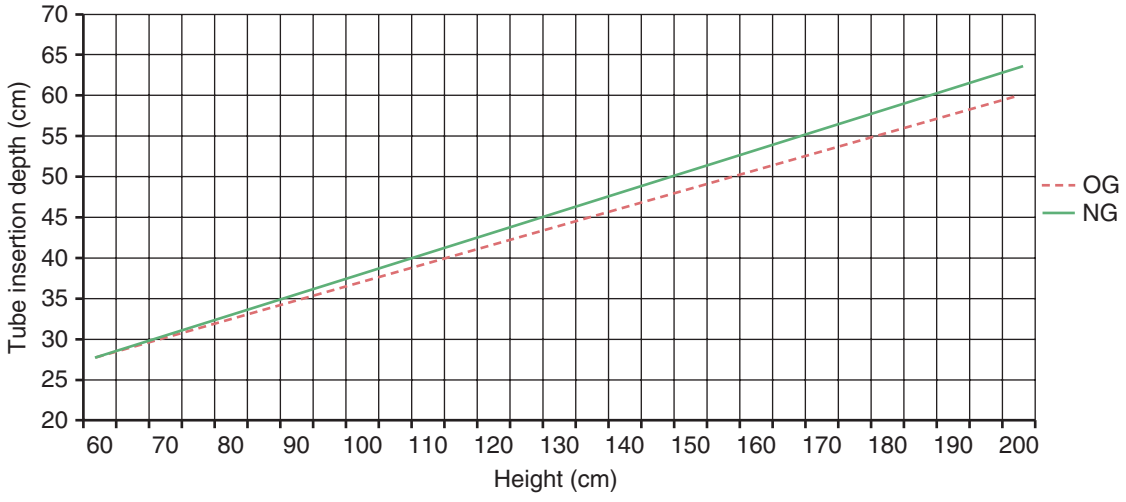


FIGURE 60-3. Estimated lavage tube insertion depth in children based on their height. The lengths for both nasogastric (NG) and orogastric (OG) tubes are represented on the graph (Reprinted from Scalzo et al.,[5] with permission from Elsevier Science).

CONTRAINDICATIONS

The contraindications to performing a gastric lavage are summarized in **Table 60-2**. **An absolute contraindication to gastric lavage is in a patient with a depressed level of consciousness who is at risk of losing protective airway reflexes.** Gastric lavage should also not be performed in combative patients, patients at high risk of seizures, and in those who may be expected to deteriorate rapidly. Gastric lavage can be performed, as indicated, if the airway is protected, but intubating a patient solely for the purpose of gastric lavage is not recommended. Gastric lavage is contraindicated in caustic ingestions. Local mucosal damage amplifies the risk for traumatic perforation. Gastric lavage should not be performed to retrieve large pills, large foreign bodies, or sharp foreign bodies. It is relatively contraindicated in hydrocarbon ingestions, especially where there is high pulmonary aspiration potential. Significantly abnormal upper airway or upper gastrointestinal anatomy (i.e., anomalies, strictures, or a fresh interposition graft) may restrict the use of gastric lavage in rare circumstances.

Vomiting is common after many overdoses and may serve as a "natural" decontamination measure. Multiple episodes of emesis may clear the majority of a toxicant from the stomach and obviate the need for gastric lavage. Vomiting in the setting of caustic ingestions, however, can cause further harm by re-exposing the gastrointestinal mucosa to the caustic substance. Attempts at gastric intubation in the setting of an actively vomiting patient are likely to be met with minimal success and may cause injury.[7] Gastric lavage is thus contraindicated in the vomiting patient due to the risk of aspiration and perforation in a setting where it is unlikely to be beneficial.

Gastric lavage is unlikely to change the outcome of a nontoxic or minimally toxic ingestion. It must be ascertained that significant toxicity or death may result if the patient is not lavaged. Otherwise, the risk–benefit ratio is unacceptably high. The determination of whether or not to perform a gastric lavage must be individualized and rests upon the evaluating Emergency Physician. Consult a Medical Toxicologist or a poison control center in questionable cases.

EQUIPMENT

- Pulse oximeter
- Cardiac monitor
- Noninvasive blood pressure monitor
- Protective clothing
- Bite block
- Oral airway

TABLE 60-1 Indications for Performing a Gastric Lavage

Acute presentation (within 1 h) and:

1. *Evident or high risk of morbidity or mortality*
   - Beta-blockers
   - Calcium channel blockers
   - Chloroquine
   - Colchicine
   - Cyanide
   - Heavy metals
   - Heterocyclic antidepressants
   - Iron
   - Paraquat
   - Salicylates
   - Selenious acid
2. *Poor absorption by activated charcoal*
   - Heavy metals
   - Iron
   - Lithium
   - Toxic alcohols
3. *Evidence of formed concretion*
   - Enteric-coated preparations
   - Iron
   - Phenothiazines
   - Salicylates
4. *Ineffective or no antidotal therapy available*
   - Cellular poisons (e.g., colchicine)
   - Paraquat
   - Selenious acid

TABLE 60-2 Contraindications to Performing a Gastric Lavage

- Abnormal or absent pharyngeal or upper gastrointestinal anatomy
- Active or substantial antecedent vomiting
- Caustic ingestion
- Coagulopathy
- Combative or uncooperative patient
- Decreased level of consciousness
- Diminished or absent airway reflexes
- Large pills
- Large or sharp foreign body
- Nontoxic or minimally toxic ingestion
- Significant aspiration risk (e.g., hydrocarbon ingestion)
- Seizures or high risk of seizures

- Emesis basin
- Suction source
- Yankauer suction catheter
- Suction tubing
- Funnel or large (50 to 100 mL) syringe
- Tap water or normal saline
- Bulb suction device or large syringe
- Water-soluble lubricant
- Orogastric lavage tube
- Resuscitative equipment readily available

All required instrumentation should be gathered at the bedside prior to initiating the procedure. A variety of orogastric lavage tubes are available. Most have a distal port and at least one sideport. A semirigid tube is preferable to soft rubber or polyvinyl chloride collapsible tubes. Several additional ports should be cut in the sides of the tube near the tip to maximize the return of pill fragments if the tube has only a single sideport. Examples of rigid tubing are shown in **Figures 60-1 & 60-4**. A larger tube diameter provides less flexibility, so that the tube is less likely to kink, collapse, or curl back on itself. Larger-diameter tubes are more likely to facilitate retrieval of larger pill fragments. A 30 to 50 French lavage tube is preferred in an adult. A 30 to 34 French tube is adequate for an adolescent. Small children can generally accommodate 24 French tubes. Gastric lavage is generally contraindicated in neonates and infants.

There are numerous types of gastric lavage systems. Open systems are less expensive, messy, and time-consuming to use. A passive open system uses gravity to instill and drain the lavage fluid. An active open system uses a large syringe to inject and aspirate lavage fluid through the orogastric tube. The syringe must be removed from the orogastric tube to be filled with fresh lavage fluid, and used lavage fluid must be discarded after each lavage cycle. Closed systems are commercially available, single-patient use devices, self-contained, easy to use, and do not cause a mess (**Figure 60-4**). The Emergency Physician should be familiar with the type of system available at their institution.



FIGURE 60-4. Example of a closed lavage pump system (Courtesy of Kimberly-Clark Corporation).

Gastric lavage solution typically consists of tap water or normal saline. **Do not use tap water in small children, as this can result in electrolyte abnormalities.** Specialized lavage solutions may be indicated if the ingested substance is fluoride, formaldehyde, iodine, iron, or oxalic acid. Fluoride ingestions may be lavaged with 15 to 30 g/L of calcium gluconate to produce an insoluble calcium fluoride. Formaldehyde ingestions may be lavaged with 10 mg/L of ammonium acetate to produce the nontoxic substance methenamine. Iodine ingestions may be lavaged with 75 g of cornstarch in 1 L of water. Iron ingestions may be lavaged with 2% sodium bicarbonate (50 mEq in 150 mL of normal saline) to produce the insoluble ferrous carbonate. Oxalic acid ingestions may be lavaged with 15 to 30 g/L of calcium gluconate to form the insoluble calcium oxalate. **These specialized lavage solutions should be used only in consultation with a Medical Toxicologist or a poison control center.**

PATIENT PREPARATION

Explain the indications, details of the procedure, risks and benefits, and alternative modalities with the patient and/or their representative when possible. Informed consent should be obtained or may be presumed in the setting of a suicidal overdose.

Place the patient in the left lateral decubitus position and in 15° to 20° of Trendelenburg. This position is intended to maximize gastric emptying.[7,8] However, the removal of ingestants by gastric lavage in the overdose setting is modest, and other circumstances may intervene, such as an uncooperative patient or technical factors.[3] The supine and lateral decubitus positions are associated with a higher risk of pulmonary aspiration in comatose and mechanically ventilated patients.[9–12] It is assumed that this positioning risk is similarly increased in patients who are not mechanically ventilated and undergoing gastric lavage. Most gastric lavages can be performed safely and effectively with the conscious patient placed in the semi-upright position. The use of a topical anesthetic spray into the oropharynx may decrease the patient's gag reflex and allow easier passage of the orogastric tube. Unfortunately, this can also increase the risk of aspiration.

It is recommended that a cardiac monitor, noninvasive blood pressure cuff, and pulse oximeter be placed on the patient prior to performing gastric lavage. This equipment may also be required based upon the patient's physiologic status, the nature of the ingestant or toxicant, and/or other underlying problems.

TECHNIQUE

Measure the length of the orogastric lavage tube to be inserted (**Figure 60-5**). The length should be marked with a permanent marker or a piece of surgical tape. Liberally lubricate the tip of the lavage tube. Place a bite block into the patient's mouth if they are conscious. A bite block or oral airway may preclude biting of the tube by an uncooperative or stuporous patient.[13]

Gently insert the lavage tube into the patient's mouth and direct it into the hypopharynx. Flexion of the patient's neck may facilitate passage of the tube into the esophagus and avoid endotracheal insertion. Conscious and cooperative patients may be asked to swallow water through a straw or their saliva to facilitate passage of the tube. Stridor, cough, or cyanosis indicates that the lavage tube is in the airway and should prompt removal of the tube. If significant resistance

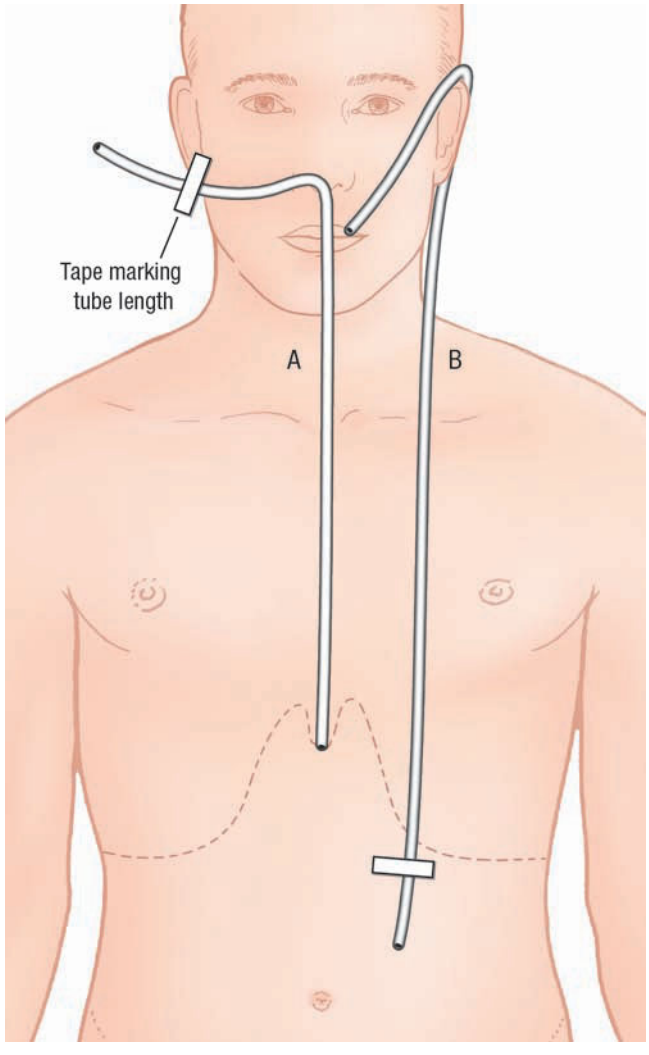


FIGURE 60-5. Determining the proper length of an orogastric tube to insert. **A.** The length is determined by the distance from the xiphoid process to the tip of the nose to the earlobe. **B.** The length is determined by the distance from the tip of the nose or lip, around the left ear, and to just below the left costal margin. A piece of tape is used to mark the distance on the orogastric tube.

is met in the hypopharynx, applying gentle pressure to the tube while instructing the patient to swallow should allow passage through the upper esophageal sphincter. **The tube should not be forced, as misplacement may damage the larynx or perforate the pyriform sinus.** Slowly advance the tube to the premeasured depth.

Confirmation of intragastric tube placement must precede instillation of any fluid through the tube. Proper placement should be confirmed by aspiration of gastric contents, auscultation of insufflated air over the epigastrium (from a 50 mL Toomey syringe), and/or by radiography. Gastric irrigation should be preceded by aspiration of available gastric contents. The initial aspirate may be sent for toxicologic assay.

Perform the gastric lavage. Instill normal saline or tap water through the lavage tube. The lavage fluid should ideally be warmed to body temperature. This is often not practical, and room temperature lavage fluid is satisfactory. Instill aliquots of 10 to 15 mL/kg to a maximum of 300 mL of the irrigant solution. Instillation of larger volumes may result in vomiting, with pulmonary aspiration and the passage of gastric contents past the pyloric sphincter where subsequent absorption may occur.[2] Lavage aliquots may be instilled by placing a funnel in the free end of the lavage tube and allowing gravity instillation or they may be infused with a Toomey syringe. Remove the lavage fluid after a brief (i.e., 1 to 2 minutes) equilibration period by either gravity drainage into an emesis basin or aspiration with a syringe or suction bulb. Repeat the lavage process until 2 to 3 L of irrigant has been used in the adult or the lavage fluid is free of particulate matter and pill fragments. Some authors have suggested that agitation of the stomach by manual massage of the epigastrium during the equilibration period will ensure mixing of the gastric contents.[13] No substantive data support this approach. Alternatively, closed systems are available for both instilling and suctioning lavage fluids through a common tube (**Figure 60-4**).

Activated charcoal may be administered, if indicated, through the lavage tube before it is removed. A dose of 1 g/kg of body weight is typically recommended, either in a premixed slurry or diluted in normal saline or tap water (30 g charcoal per 240 mL of diluent). Refer to Chapter 59 regarding the details of administering activated charcoal.

Remove the lavage tube. It is recommended for the Emergency Physician to wear gloves, a mask with an eye shield, and a gown to prevent being contaminated during the removal. Place towels or pads over the patient's neck and chest. Have an emesis basin, tissues, and Yankauer suction immediately available. Disconnect the lavage tube from its proximal attachment. Fold over the proximal end of the lavage tube and hold it tightly. Ask the patient to slightly flex their neck, breath in, and hold it. Place a drape or towel around the lavage tube as it is exiting the patient's mouth. Firmly squeeze the drape around the lavage tube. Briskly withdraw the lavage tube through the drape. The drape will contain all the secretions and bodily fluids and prevent them from splashing on the patient or the Emergency Physician. Discard the lavage tube and the drape.

Further gastric access, when needed, should be provided by the subsequent placement of a smaller-bore nasogastric tube.

ALTERNATIVE TECHNIQUES

Because of concern over toxicants passing or being pushed through the pyloric valve during the gastric lavage procedure, an alternative sequence could be considered. Administer activated charcoal after the initial aspiration of gastric contents through the lavage tube. Perform the gastric lavage anticipating that a significant amount of activated charcoal will be removed along with the ingestant. Infuse a second dose of activated charcoal through the lavage tube before it is removed. The rationale here is an attempt to make charcoal available to adsorb toxicant from any gastric contents pushed into the small bowel during the lavage procedure.[1] While no human data support this technique, it is reasonable to consider.

ASSESSMENT

The patient should be continuously monitored and reassessed throughout the procedure so as to avoid complications. Strict adherence to the procedures noted will help minimize the risk of complications. Prompt removal of the lavage tube at the end of the procedure will help decrease the risk of delayed complications.

AFTERCARE

Most patients who require gastric lavage for an overdose or poisoning will require inpatient monitoring for complications of the ingestion. A situation wherein a patient requires gastric lavage and is then sent home immediately is conceivable though unlikely. An observation period of 6 to 8 hours for the immediate complications of gastric lavage and the effects of the ingested substance is probably appropriate. Delayed complications related to the perforation of the upper gastrointestinal tract may occur.[14]

TABLE 60-3 Complications Associated with Gastric Lavage

Cardiac dysrhythmias
Electrolyte abnormalities
Empyema
Esophageal tear or perforation
Gastric perforation
Hypothermia
Laryngospasm
Nasal, oral, or pharyngeal injury
Pneumothorax
Pulmonary aspiration
Pyriform sinus perforation
Tracheal placement
Tube impaction

COMPLICATIONS

The complications associated with gastric lavage can be minimized by careful patient selection and technique[7] (**Table 60-3**). Placement of the lavage tube can result in mucosal injury, bleeding, esophageal perforation, gastric perforation, or endotracheal placement. The patient should be monitored, as the procedure may result in cardiac arrhythmias, hypoxemia, and tachycardia.[1,7] No more than 15 mL/kg or 300 mL aliquots of lavage fluid should be used to prevent vomiting, aspiration, or pushing of gastric contents into the small bowel. The impaction of a lavage tube may prevent its removal.[1,7,14] **Do not use force to remove the lavage tube, as this may injure or rupture the stomach or esophagus.** Evaluate the tube using fluoroscopy or plain radiographs. A lavage tube that is kinked or knotted will require endoscopically aided or surgical removal.

Gastric lavage with large volumes of cold fluid can result in hypothermia. Warmed lavage fluid should be used if available, although this is somewhat controversial. Warm lavage fluid may dissolve more of the intoxicant and allow rapid access of gastric contents past the pylorus, to be absorbed into the systemic circulation. Electrolyte abnormalities may result, especially in children, if the lavage fluid is hypotonic (i.e., tap water). The use of normal saline for lavage is recommended.

There are definite risks and complications associated with gastric lavage. It is usually unknown if pills and/or pill fragments remain within the patients stomach when they present to the Emergency Department. Two recent case reports used CT scans to determine that pills and/or pill fragments remained in the stomach and subsequently performed gastric lavage.[15,16] The use of CT scans to identify pills and/or pill fragments in the stomach cannot be recommended. There is no evidence that the expense and radiation exposure prevent any morbidity or mortality nor provides any benefit to the patient.

SUMMARY

Gastric lavage is an invasive procedure to decontaminate the stomach of patients following an ingested overdose or poisoning. While its use has significantly decreased as a mode of decontamination, there are a few specific indications in an acute poisoning or overdose in which it should be considered. Complications can be minimized if the procedure is performed cautiously. Maximal efficacy can be expected if it is performed within 1 hour of an acute ingestion. Gastric lavage is not indicated in the setting of a nontoxic or minimally toxic ingestion or where specific and less invasive antidotes exist and are readily available. Consultation with a Medical Toxicologist or a poison control center is prudent and can provide valuable information regarding the indications, contraindications, complications, and techniques associated with gastric lavage.

61 Whole Bowel Irrigation

Steven E. Aks and David D. Gummin

INTRODUCTION

Whole bowel irrigation is the infusion of polyethylene glycol electrolyte lavage solution into the stomach at flow rates higher than are otherwise commonly used. This technique can be used to decontaminate the gastrointestinal tract after an acute toxic ingestion or overdose. Most of the literature supporting its use is in the form of case reports or case series.[1] While available reports are compelling, the indications for whole bowel irrigation are mostly theoretical and will be refined as more extensive data become available. The role of whole bowel irrigation currently remains limited.

ANATOMY AND PATHOPHYSIOLOGY

Current methods of gastrointestinal decontamination (i.e., emesis, gastric lavage, and activated charcoal administration) focus primarily on decontaminating the stomach. Absorption of most toxicants occurs principally in the proximal small bowel. Sustained- or delayed-release preparations continue to liberate drug during intestinal transit that is then available for absorption throughout the bowel. Infusion of polyethylene glycol electrolyte lavage solution decreases the enteric transit time, attenuating the contact time of a toxicant with the gastrointestinal mucosa.[2] This reduces absorption of the drug or toxin throughout the gastrointestinal tract. The 3500 Da molecular weight polyethylene glycol solution is specifically designed to prevent electrolyte and fluid shifts.

INDICATIONS

Whole bowel irrigation may be indicated for acute ingestions where severe or potentially fatal toxicity is anticipated (Table 61-1). Other decontamination methods, such as activated charcoal, should be employed if they are known to be effective rather than whole bowel irrigation. Whole bowel irrigation may be indicated in situations where activated charcoal is known to be ineffective. Whole bowel irrigation has been safely utilized to decrease bioavailability of ingested iron, lithium, and heavy metals.[3–7] Whole bowel irrigation has been proposed to be effective in flushing the gastrointestinal tract free of toxicant before absorption can be affected by sustained-release preparations.[8] Whole bowel irrigation may speed gastrointestinal transit of ingested packets or vials of illicit drugs ingested by a "body packer."[9] Recently, the role of whole bowel irrigation in the "body stuffing syndrome" has recently been questioned.[10] While the indications are limited, additional settings may be envisioned where whole bowel irrigation might be useful. Unfortunately, there is not yet data to support broader indications.

TABLE 61-1 Conditions in Which Whole Bowel Irrigation Can Be Considered

1. Acute, life-threatening, or serious ingestion and hemodynamically stable
2. Any of the following:
Delayed or enteric-coated preparation
Heavy metals
Ingested packets of illicit drug
Iron
Lithium
Toxin or toxicant poorly adsorbed by activated charcoal

TABLE 61-2 Contraindications to Performing Whole Bowel Irrigation

Bowel obstruction or perforation
Hypotension or hemodynamic instability
Ileus
Intractable vomiting
Nontoxic ingestion
Potentially compromised or unprotected airway
Significant gastrointestinal bleeding

CONTRAINDICATIONS

There are few contraindications to performing whole bowel irrigation (**Table 61-2**). **It should not be used in the setting of a patient with a potentially compromised or unprotected airway.** Whole bowel irrigation could result in pulmonary aspiration.[11,12] Significant vomiting will hinder the ability to perform whole bowel irrigation. It should not be performed in the hypotensive or hemodynamically unstable patient.[11] Other contraindications include abnormal upper airway or upper gastrointestinal anatomy (e.g., anomalies, strictures, or fresh interposition graft). Ingestion of toxic substances that markedly slow gastrointestinal motility (e.g., anticholinergics or opioids) may cause an ileus, diminishing the ability to perform whole bowel irrigation effectively. The administration of polyethylene glycol in a patient with a bowel obstruction will result in vomiting with the potential for aspiration. This solution should not be used in patients with an actual or suspected perforated bowel. The risk of whole bowel irrigation is quite small but the procedure is not without effort, expense, and risk of complications. In this light, the risk–benefit ratio would be high if whole bowel irrigation were used to treat a nontoxic ingestion.

EQUIPMENT

- Nasogastric or enteral feeding tube, size 10 to 12 French
- Water-soluble lubricant
- Nasal decongestant and anesthetic
- Enteral feeding reservoir and tubing
- Polyethylene glycol electrolyte lavage solution (packets or reconstituted)
- Emesis basin
- Stethoscope
- Toomey syringe
- Intravenous extension tubing

The equipment required for whole bowel irrigation is readily available in most Emergency Departments. A small-bore, 10 to 12 French, nasogastric tube is sufficient for an adult or adolescent. An enteral feeding tube can be substituted if a sufficient flow rate can be ensured. A smaller tube is required in infants or very small children. Infants will tolerate an 8 French tube and a 10 to 12 French tube is adequate beyond the first year.[13,14]

Standard enteral feeding reservoirs and tubing are typically available as packaged kits. An enteral feeding or an enema bag with enteral feed tubing may be substituted. Enteral feeding pumps, however, are not useful, as the flow rate through the pump is typically inadequate to perform whole bowel irrigation effectively. Alternatively, an empty 1 L intravenous fluid bag with intravenous extension tubing can be used for the procedure.

PATIENT PREPARATION

Explain the procedure, its risks, its benefits, and alternatives to the patient and/or their representative. Informed consent should be obtained. Informed consent can be assumed in the case of suicidal ingestions. Inspect the nasal passages and oropharynx to rule out any anatomic abnormalities or obstruction that would preclude the passage of a nasogastric tube.

Place the patient in the upright or semi-upright position (**Figure 61-1**).[14] The supine and lateral decubitus positions are associated with a higher risk of pulmonary aspiration in comatose and mechanically ventilated patients.[15–18] It can be assumed that this positioning risk is similarly increased in patients undergoing whole bowel irrigation.

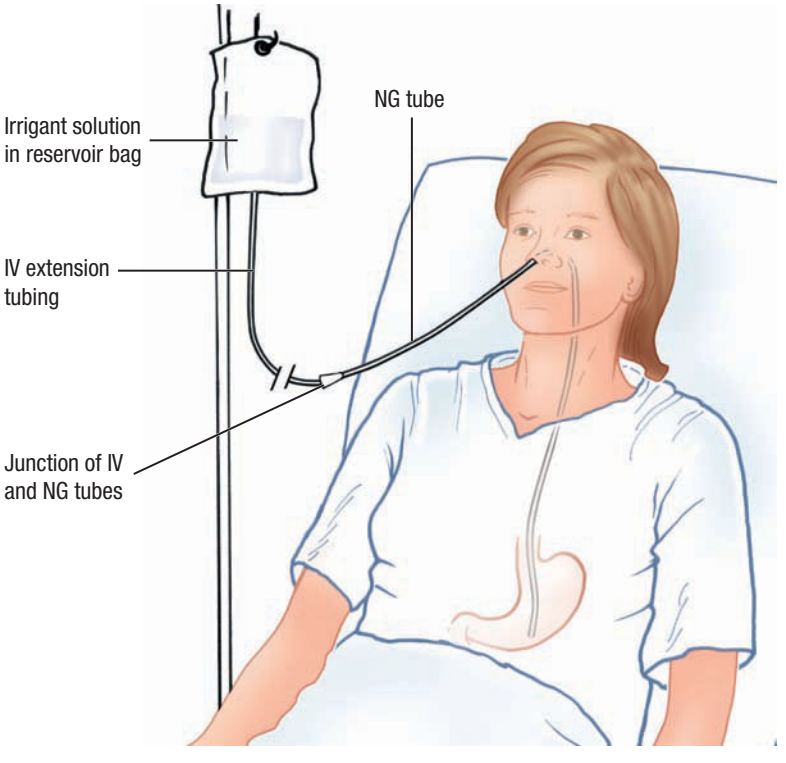


FIGURE 61-1. Setup required to perform whole bowel irrigation.

It is recommended that a cardiac monitor, noninvasive blood pressure cuff, and pulse oximeter be placed on the patient prior to performing gastric lavage. This equipment may also be required based upon the patient's physiologic status, the nature of the ingestant or toxicant, and/or other underlying problems.

Choose the smallest diameter nasogastric or feeding tube that will allow adequate flow of polyethylene glycol electrolyte lavage solution into the stomach. All necessary equipment should be placed at the bedside and assembled prior to beginning the procedure.

A cuffed endotracheal tube should be placed prior to performing whole bowel irrigation in patients who are comatose, drowsy, obtunded, unconscious, or have an absent or impaired gag reflex. Endotracheal intubation should be strongly considered in any patient who has ingested a central nervous system depressant, tricyclic antidepressants, a sympathomimetic or other agent that may result in seizures, or any substances that can cause an altered mental status.

TECHNIQUE

Insert a nasogastric tube. Refer to Chapter 58 for the complete details regarding nasogastric tube placement. Measure the length of the nasogastric tube to be inserted. Place the tip of the nasogastric tube over the xiphoid process. Extend the tube over the anterior chest, lateral neck, behind the angle of the mandible, and to the tip of the nose. Mark this length with a permanent marker or a piece of surgical tape. Liberally lubricate the tip of the nasogastric tube. The application of a nasal anesthetic and decongestant is optional but can facilitate the passage of the nasogastric tube.

Gently insert the nasogastric tube into the naris. Advance it posteriorly along the nasal floor into the nasopharynx and through to the hypopharynx. Flexion of the neck may facilitate passage of the tube into the esophagus and avoid endotracheal insertion. The conscious and cooperative patient may be asked to swallow water through a straw or to swallow their saliva to facilitate passage of the tube. Stridor, cough, or cyanosis may indicate endotracheal passage and should prompt removal of the tube. Gentle pressure and patient swallowing should allow passage through the upper esophageal sphincter if significant resistance is met in the hypopharynx. **Do not force the nasogastric tube as misplacement may damage the larynx or perforate the pyriform sinus.** Advance the nasogastric tube to the marked level. Confirm proper placement by the aspiration of gastric contents, by auscultation of insufflated air over the epigastrium (from a 50 mL syringe), and/or by radiography. **Confirmation of intragastric placement must precede administration of any fluids through the nasogastric tube. A radiograph must be obtained prior to using the nasogastric tube if any question exists regarding its position.**

Instill the polyethylene glycol electrolyte lavage solution through a setup such as that shown in **Figure 61-1**. Flow rates are dependent upon the size of the patient. Begin instillation at an initial rate of 25 to 30 mL of polyethylene glycol electrolyte lavage solution per kilogram per hour. Adults may tolerate more than 3 L of solution per hour. The rate may be adjusted somewhat to accommodate patient tolerance (e.g., vomiting, abdominal distension). Irrigation should be continued until the patient passes the ingestant in the stool or until clear liquid rectal effluent is passed. Liquid stools will continue to be passed after discontinuing whole bowel irrigation. **Stop the irrigation if the patient vomits, develops an ileus, or if gastrointestinal perforation is suspected.**

ALTERNATIVE TECHNIQUES

Some Emergency Physicians may attempt whole bowel irrigation by offering the patient polyethylene glycol electrolyte lavage solution to drink. This is rarely successful. Experience shows that whole bowel irrigation is ineffectively performed if a nasogastric tube is not placed. Even the most cooperative patient is unlikely to drink the solution at the required administration rate.

ASSESSMENT

Patient assessment must be continuous throughout the process of whole bowel irrigation. Mild abdominal distention, gassiness, and mild abdominal discomfort are common side effects and do not require the discontinuation of the infusion. Providers must be vigilant in monitoring the patient's bowel sounds. If bowel sounds cease or significant abdominal distension is noted, the irrigation should be held for 30 to 90 minutes and the patient reassessed. Resume the irrigation at a reduced rate if bowel sounds return, if the clinical status improves, and if the patient then tolerates the infusion. Significant electrolyte or osmotic shifts do not occur solely from whole bowel irrigation. Electrolytes may be monitored if otherwise indicated for the type of ingestion or for overall patient status. Of greater concern is vomiting with the risk of aspiration. The patient's posture should be maintained in the upright sitting or the semi-upright position to facilitate passage of irrigant solution into the small bowel and to protect against aspiration. Discontinue whole bowel irrigation if the patent develops an altered mental status or hemodynamic instability.

AFTERCARE

Patients who undergo whole bowel irrigation must all be admitted to the hospital for ongoing assessment of the intervention and the underlying ingestion or overdose. In most cases, intensive care or step-down monitoring will be required to ensure adequacy of the intervention and to monitor for complications of the ingestion or overdose. Delayed complications from whole bowel irrigation are unlikely once the procedure is completed.

COMPLICATIONS

Documented complications from whole bowel irrigation include pulmonary aspiration of the irrigant solution and/or ingestant.[11,12] This would be especially concerning in the patient with an unprotected and potentially compromised airway. An ileus and intestinal distension has been documented in a hypotensive patient receiving whole bowel irrigation.[12]

Osmotic and electrolyte abnormalities will not occur with the standard preparations of high molecular weight (c. 3500 Da) polyethylene glycol electrolyte lavage solutions (e.g., Colyte, GoLYTELY, NuLYTELY). Complications of nasogastric tube placement are well described and can occur. Refer to Chapter 58 for the complications associated with nasogastric intubation. These are unlikely if proper technique is employed and can be minimized by use of the smallest effective diameter nasogastric tube.

SUMMARY

Whole bowel irrigation is a technique performed to speed gastrointestinal transit and decontaminate the gut after an acute toxic ingestion. Available reports suggest that whole bowel irrigation can decrease bioavailability of toxicants by two-thirds in volunteers.[4,14] It may be useful where activated charcoal is not expected to adequately bind ingestants (e.g., iron, lithium). Efficacy is still undefined in the setting of sustained- or delayed-release preparations. Whole bowel irrigation is not the method of choice, however, when more effective methods of gastrointestinal decontamination are possible (e.g., repetitive-dose activated charcoal for sustained-release theophylline). Until further data emerge, whole bowel irrigation's role in managing the toxic ingestion remains limited.

62 Esophageal Foreign Body Removal

Bashar M. Attar

INTRODUCTION

Most foreign bodies (90%) that are ingested enter the gastrointestinal tract while 10% enter the tracheobronchial tree.[1] Approximately 1500 people die annually in the United States from ingested foreign bodies in the upper gastrointestinal tract.[2] Most objects (80% to 90%) usually pass spontaneously but about 10% to 20% must be removed endoscopically. Approximately 1% require surgical removal.[3] Most (80%) esophageal foreign bodies occur in children followed by edentulous adults, prisoners, and psychiatric patients.[4] Recurrent episodes of foreign body ingestion occur in 5% to 10% of patients, especially prisoners and psychiatric patients.[1]

The presentations are best divided according to accidental and deliberate ingestors.[1–5] The accidental ingestion patient is usually cooperative and has a single foreign body. Conversely, the deliberate ingestion patient is often uncooperative and the foreign bodies are multiple and often unusual. It is important to identify such individuals at their initial presentation since foreign body removal is usually performed under procedural sedation or general anesthesia.

The patient's history is the most important part of the diagnostic evaluation.[3] The identity of the object ingested is usually known to the patient. **Persistent odynophagia, dysphagia, or foreign body sensation may indicate the presence of an esophageal foreign body despite negative radiographic results.** A high index of suspicion must be maintained in younger children and mentally retarded adults. Patients with a history of eosinophilic esophagitis have a higher incidence of food impaction and higher risk of perforation associated with interventions.[6]

The physical examination is most likely negative unless complications are present. Stridor, wheezing, signs of consolidation, and the absence of breath sounds should be sought. Subcutaneous emphysema in the neck or chest indicates perforation of the esophagus or the stomach. The most common sites for a foreign body to get trapped are where the esophagus is narrow: at the cricopharyngeus muscle, where the aortic arch crosses the esophagus, and at the gastroesophageal junction.

Radiographic evaluation is often helpful in the evaluation of an esophageal foreign body.[3–5,7] Obtain plain radiographs of the neck and chest in the posteroanterior and lateral positions. Evaluate the radiographs for the presence of a foreign body in all planes. Air in the subcutaneous tissues, mediastinum, and/or beneath the diaphragm is indicative of a perforation. Barium studies are undesirable in patients with a food bolus impaction and obscure endoscopic visualization. Esophagrams performed using a minimal amount of thin barium may be necessary in situations where the foreign body is made of wood, thin metals, aluminum can tops, and plastics. **Meglumine diatrizoate (Gastrografin) is contraindicated in food bolus impactions because it is highly hypertonic and can lead to severe chemical pneumonitis if aspirated into the lungs.**[5] Toothpicks, wood, and fishbones may not be seen on radiographs. Food or meat bolus impaction may not be evident radiographically unless it contains bony tissue. **Failure to locate an object on radiologic examination should not rule out its presence.** Computerized tomography may be useful, especially in cases where the foreign body could not be detected as it may have become embedded in or penetrated the esophageal wall.[7]

Endoscopy is important for both the diagnosis and possible removal of an esophageal foreign body. Extraction with the flexible endoscope is successful in 84% to 98% of cases and with no associated complications.[8,9] Success is more likely and complications are minimized with proper patient preparation.

INDICATIONS

Esophageal foreign body extraction is required in a minority of patients, as most foreign bodies will pass spontaneously into the stomach. The indications for removal depend upon the type of foreign body and whether it impacts in the esophagus. Sharp objects impacted above the cricopharyngeus should be removed under direct vision using a laryngoscope to elevate the soft tissues and a Magill forcep to grasp it.

Meat boluses are commonly impacted in the esophagus. Patients will swallow large pieces that may or may not be well chewed. **Impaction of a meat bolus, or another foreign body, at or just below the cricopharyngeus muscle with tracheal compression and resultant respiratory obstruction is a true emergency.** The Heimlich maneuver may be lifesaving in this situation.[10] The patient should be immediately orotracheally intubated or a cricothyroidotomy performed if the Heimlich maneuver is unsuccessful. Early removal of a meat bolus impaction is recommended, even when the bolus is located in the distal third of the esophagus. Delays in extraction allow the food to soften, making extraction more difficult. The administration of glucagon intravenously may lead to esophageal relaxation and facilitate spontaneous passage of the food bolus to the stomach. If this fails, it must be endoscopically removed.

Blunt and round objects may become impacted in the esophagus. Earlier removal is necessary if a blunt object is impacted higher in the esophagus with associated sialorrhea and the potential for pulmonary aspiration. Esophageal obstruction at lower levels requires prompt, but not emergent, treatment. Most rounded objects in the lower third of the esophagus will pass spontaneously into the stomach. Therefore, a 12-hour period of observation is permissible in this situation.[11] It is common for sharp, pointed, and elongated objects to become impacted in the esophagus. Toothpicks, open safety pins, nails, and chicken bones are associated with up to a 35% incidence of esophageal perforation and should be removed.[12,13] Toothpicks should be removed promptly from the esophagus or stomach even if they are not impacted because they are particularly prone to penetration of the gastrointestinal wall. Toothpicks may migrate into surrounding structures, leading to vascular and other serious complications.[12]

Numerous other objects can also become impacted in the esophagus. Elongated, narrow foreign bodies such as stiff wires are prone to penetration and perforation of the esophageal wall. They should be removed even if they passed through the esophagus and into the stomach. These objects may become trapped by the retroperitoneally fixed angles of the duodenum and eventually result in perforation. Plastic bag clips, although not sharp and pointed, should be removed before they pass from the esophagus into the stomach and through the pylorus. They have claws that can attach to the small bowel mucosa leading to ulceration, stricture formation, and bleeding.[14] Toxic foreign bodies such as button batteries that become impacted in the esophagus should be removed promptly to prevent perforation and systemic toxicity.

CONTRAINDICATIONS

There are no absolute contraindications to the removal of an esophageal foreign body. Serious, life- and limb-threatening injuries should be treated prior to esophageal foreign body removal. The patient's airway, breathing, and circulation should be evaluated and supported as necessary prior to removing the foreign body.

EQUIPMENT

- Flexible upper gastrointestinal endoscope
- Rigid gastroscope
- Through-the-scope-balloon
- Stiegmann-Goff friction-fit adaptor of the esophageal variceal rubber banding ligating kit
- Glucagon
- 44 French Maloney rubber dilator
- Lubricant gel
- Endoscopic overtube, for use with sharp or pointed foreign bodies
- Soft latex protector hood for the flexible scope
- Rat-tooth or alligator forceps
- Retrieval nets or Dormia baskets
- Polypectomy snares
- Laryngoscope
- Laryngoscope blades, Miller and Macintosh of various sizes
- Curved clamp
- Medications for providing procedural sedation (Chapter 129)
- Cardiac monitoring
- Pulse oximetry
- Supplemental oxygen
- Foley catheters, 14 to 16 French
- Topical anesthetic spray
- Water-soluble contrast material
- 5 mL syringe
- Fluoroscopy machine, optional

PATIENT PREPARATION

If possible, obtain a duplicate sample of the ingested foreign body. Manipulate the duplicate object with available foreign body forceps and snares. Determine which instrument is best suited to grasping the foreign body. Instruments that are most useful include alligator and rat-toothed forceps, polypectomy snares, and Dormia baskets.

Explain the risks, benefits, and aftercare of the procedure to the patient and/or their representative. Obtain an informed consent for the procedure. Place the patient supine. Obtain intravenous access. Apply the cardiac monitor, pulse oximeter, and supplemental oxygen to the patient. Administer intravenous sedation or procedural sedation (Chapter 129) as necessary.

TECHNIQUES

GENERAL PRINCIPLES

The flexible upper gastrointestinal endoscope should be inserted under direct visualization to avoid inadvertently striking an object and further impacting it or causing it to penetrate the esophageal wall. Blunt foreign bodies such as coins can be securely grasped with a forceps or a snare. **A firm grasp on the foreign body is required before withdrawal is attempted.** Otherwise, the foreign body may become dislodged as it is withdrawn through points of anatomic narrowing. This can result in aspiration of the foreign body. An overtube should be used if multiple insertions and withdrawals of the endoscope are needed. Pointed foreign bodies should be withdrawn with the point trailing to avoid perforating any structures. Objects with sharp edges, such as razor blades, should be extracted through an overtube to prevent secondary injury. Elongated foreign bodies such as wires or pens should be grasped with a snare close to the cephalad end of the object so it can align itself with the long axis of the esophagus during withdrawal. Foreign bodies that penetrate the mucosa can be safely extracted with the endoscope if frank perforation or vascular penetration has not occurred.

FOOD IMPACTIONS

ENDOSCOPY

Food impactions are more likely to occur in the distal esophagus. If the patient is symptomatic, there is no need for barium studies because it will obscure visualization during endoscopy. **Endoscopic intervention should be carried out immediately to prevent aspiration if the patient is salivating and unable to handle oral secretions. The impacted food bolus should not remain in the esophagus for more than 12 hours. Thereafter, the risk of complications increases significantly.**

Underlying esophageal disease is found in 65% to 97% of adults presenting with an esophageal food impaction.[8,15] **Endoscopic removal is the procedure of choice if a meat bolus does not pass spontaneously or after an unsuccessful trial of gas-forming agents, glucagon, nifedipine, or nitroglycerine.** The entire bolus could be removed slowly with a polypectomy snare or Dormia basket under direct visualization. When the endoscope is just below the cricopharyngeus muscle, snugly pull the snare with the food bolus against the tip of the endoscope. Extend the patient's head and quickly remove the endoscope.[16]

If the food bolus is soft, a piecemeal approach can be accomplished with several passages of the endoscope through an overtube.[17] The overtube will facilitate reinsertion of the endoscope. Insert a Maloney rubber dilator (44 French) into the esophagus and proximal to the foreign body. Pass the overtube, lubricated internally and externally, over the Maloney dilator. Remove the Maloney dilator. Introduce the flexible endoscope through the overtube.

Another method, the push technique, has been useful in dealing with an impacted food bolus.[9] A small-caliber flexible endoscope may be used to bypass the food bolus and evaluate the area distal to the obstruction. If the endoscope is able to pass into the stomach successfully, pull it back until it is just proximal to the food bolus. Use the endoscope to gently push the food bolus into the stomach. It is preferable to push from the right side of the food bolus rather than straight, especially in patients with a hiatal hernia, since the gastroesophageal junction usually takes a left turn as it enters the hernia. The presence of a bone spicule should always be considered, whether the meat bolus is being extracted or pushed into the stomach.

A newer technique is accomplished by attaching the Stiegmann-Goff friction-fit adaptor of the esophageal variceal rubber banding ligating kit to the tip of the endoscope.[18] The tip of the endoscope is replaced with a screw-on drum from the variceal ligation kit. After placing an esophageal overtube proximal to the food bolus, the endoscope is passed through the overtube.[19–22] To avoid the risk of dropping the food in the trachea, a Roth retrieval net may be passed through the endoscope to retrieve food from the esophagus.[23,24]

A last resort approach is the use of Nd:YAG laser to burn an opening in the center of an impacted meat bolus. This method is expensive and carries a high risk of complications.[25] Finally, if a food impaction of the esophagus cannot successfully be removed using the flexible endoscope, rigid endoscopy under general anesthesia should be considered.[26]

GAS-FORMING AGENTS

Gas-forming agents can be used to relieve a distal esophageal food impaction. They are occasionally used in an attempt to relieve a

food impaction in the proximal and middle thirds of the esophagus. These agents produce carbon dioxide gas that distends the esophagus, relaxes the lower esophageal sphincter, and "pushes" the food bolus through the gastroesophageal junction with the aid of esophageal peristalsis. Gas-forming agents may be used in conjunction with glucagon, nifedipine, or nitroglycerine to help relieve the impacted food bolus. Complications associated with gas-forming agents include aspiration, vomiting, forceful vomiting, and esophageal perforation due to distention and/or vomiting. Many physicians do not use these agents due to the risk of perforation.

Three classes of gas-forming agents have been used. Commonly used are commercially available agents that are used by Radiologists for upper gastrointestinal contrast studies. A mixture of tartaric acid (1.5 to 3.0 g in 15 mL H_2O) immediately followed by sodium bicarbonate (1.5 to 3.0 g in 15 mL H_2O) has been successfully used. A final agent is carbonated soda pop.

GLUCAGON

A trial of intravenous glucagon before endoscopic therapy is a reasonable approach. It may disimpact a food bolus in the distal esophagus and allow it to pass into the stomach. Glucagon relaxes the smooth muscle of the lower esophagus and decreases lower-esophageal sphincter tone. It relaxes the esophageal smooth muscle within 1 minute of intravenous injection, and its effects last approximately 20 to 25 minutes. Glucagon has no effect on the proximal third of the esophagus that is composed of skeletal muscle. It has a minimal effect on the middle third of the esophagus that is composed of both skeletal and smooth muscle. Glucagon has an overall success rate of ≤50%. Glucagon has been also combined with gas-forming agents to enhance esophageal clearance.

The dose of glucagon is 0.03 to 0.1 mg/kg intravenously with a maximum dose of 1 mg in children and 2 mg in adults. It should be administered over 1 to 2 minutes. **It is recommended to give a test dose (1/10 of the full dose) and observe the patient for 5 minutes for signs of hypersensitivity or hypotension before giving the full dose.** Have the patient take one to two sips of water after the administration of glucagon to stimulate lower esophageal peristalsis. Administer a second dose of glucagon if the food bolus impaction is not relieved within 10 to 20 minutes.

Glucagon is a relatively safe medication. It should not be administered to patients with known hypersensitivity to glucagon, esophageal fibrosis, esophageal rings, esophageal strictures, insulinomas, pheochromocytomas, sharp or irregular foreign bodies, or Zollinger–Ellison syndrome. Exogenous glucagon stimulates the release of catecholamines. It can stimulate a pheochromocytoma to release catecholamines resulting in marked hypertension and tachycardia. The hypertension can be controlled using 5 to 10 mg of intravenous phentolamine. Glucagon's hyperglycemic effect can cause an insulinoma to release insulin and cause subsequent hypoglycemia. Common complications associated with glucagon include nausea, vomiting, transient hyperglycemia, allergic reactions, tachycardia, and hypertension. Glucagon is a polypeptide hormone synthesized in nonpathogenic *Escherichia coli* that have been genetically altered. This is the basis of the allergic/hypersensitivity reactions. A transient rise in blood pressure and heart rate is often seen after administration of glucagon. Patients taking β-blockers may be more susceptible to transient hypertension and tachycardia. These side effects are short-lived as the half-life of glucagon is 8 to 18 minutes.

NIFEDIPINE

Nifedipine is a calcium channel blocker that decreases lower esophageal sphincter tone. It has been administered to allow an impacted food bolus to pass into the stomach. It should not be administered if the patient has an allergy to calcium channel blockers, has hypotension, or ingested a sharp or irregular shaped foreign body. With a single dose, nifedipine has few side effects. These are usually minimal (i.e., dizziness, flushing, headache, hypotension, lightheadedness, muscle cramps, nausea, nervousness, and palpitations) and do not preclude its use. **The most significant effect of nifedipine is hypotension that may last 6 to 8 hours.** Some patients will have a significant hypotensive response to nifedipine and there is no way to predict which patients will be affected. For these reasons, many physicians will not use nifedipine in the elderly or in patients with a history of cardiac disease, coronary artery disease, stroke, or who are concurrently taking antihypertensive medications. The typical dose is 10 mg of oral nifedipine. The medication may be chewed then held in the mouth and subsequently swallowed. Alternatively, open the capsule, place the medicine sublingually, and have the patient hold it in their mouth and then swallow the dissolved nifedipine. Attempt another technique if the food bolus does not pass with one dose of nifedipine.

NITROGLYCERINE

Sublingual nitroglycerine (0.3, 0.4, or 0.5 mg) relaxes vascular smooth muscle and the smooth muscle contained within the middle and distal thirds of the esophagus. The use of sublingual nitroglycerine may allow the esophagus to dilate enough so that a food bolus can pass into the stomach. **Nitroglycerine should not be administered if the patient is hypotensive or has ingested a sharp or irregular shaped foreign body. It should also not be administered if the patient is taking prescription medications for erectile dysfunction (e.g., Levitra, Cialis, and Viagra). The combination of these medications with nitroglycerine can result in life-threatening hypotension.** The onset of action is within 1 to 3 minutes with a maximum effect by 4 to 5 minutes. The major side effect of nitroglycerine is hypotension, but that is short-lived. Administer one pill sublingually and allow 4 to 5 minutes for an effect. The dose may be repeated a second time. Attempt another technique if the food bolus does not pass after two doses of nitroglycerine.

PAPAIN

Papain is a proteolytic enzyme that has been used to dissolve an impacted food bolus. It is available in markets as meat tenderizer and in health food stores as a digestive supplement. It will dissolve the esophageal mucosa and continue to work its way through the esophageal wall and into the mediastinum if it does not first dissolve the food bolus. The use of papain to dissolve an impacted food bolus may be associated with a fatal esophageal perforation and, if aspirated, hemorrhagic pulmonary edema. **Papain should never be used to dissolve an impacted food bolus.**

SUMATRIPTAN

Sumatriptan is a 5-HT1 agonist that reduces fasting fundic tone, prolongs fundic relaxation, and delays gastric emptying.[27] It also increases the number of esophageal motor waves. This may be useful in cases of distal esophageal food boluses and coins, although no formal studies have been conducted.

SHARP AND POINTED FOREIGN BODIES

Removal of sharp and pointed objects requires extreme caution due to potential life-threatening complications, higher morbidity, and higher mortality. An experienced Endoscopist should manage these cases. It may be safer, in some cases, to consider surgical intervention. Toothpicks and bones are the most common foreign bodies requiring surgical removal.[28–30] Nails, needles, razor blades, safety pins, and dental prostheses may be removed endoscopically.[28–30] It is important to remember that "advancing points puncture while trailing points do not."[31] Objects longer than 5 cm and wider than

2 cm require removal as they will rarely pass through the pylorus.[32] Intravenous glucagon (0.4 to 0.6 mg in adults) may be used to facilitate extraction from the stomach and duodenum.

An alligator forceps or snares are needed to grasp the object over the feeding tube. A plastic overtube should be considered for the removal of any sharp object.[19,33] The overtube should be at least 60 cm long to remove a sharp object from the stomach. This will limit objects for endoscopic removal to those smaller than 11 to 15 mm in diameter that fit within the overtube.[34] A soft latex protector hood may be used for the removal of large objects.

Razor blade ingestions may be managed with the flexible esophagoscope in adults. An alligator forceps, a snare, and an overtube will be needed. A razor blade that has passed the pylorus will often traverse through the intestinal tract without difficulty.

Safety pins and toothpicks pose additional risks due to their sharp ends that may perforate the esophagus. An open safety pin in the esophagus, with the open end proximal, should be pushed into the stomach with the flexible endoscope. Once in the stomach, the object is turned and the hinged end is grasped and pulled out first. A closed safety pin in the stomach will often pass without difficulty. Grasp a toothpick with an alligator forceps or snare very close to the tip so that the longitudinal axis of the toothpick is parallel to the scope as it is withdrawn into the overtube.[16]

Numerous other sharp objects are often encountered in the esophagus. Pens, pencils, thermometers, and wires are extracted in a fashion similar to a toothpick with a snare grasping the end of the object.[15] Glass may be withdrawn similarly or by using an end-hood attachment.[33,35]

Attempts should be made to remove all sharp and pointed foreign bodies before they pass from the stomach. Approximately 15% to 35% of sharp or pointed foreign bodies will cause intestinal perforation, especially in the area of the ileocecal valve.[36,37]

BUTTON BATTERIES

Most button batteries ingested (96%) are small and 7.9 to 11.6 mm in diameter.[39] Batteries less than 15 mm in diameter almost never lodge in the esophagus. Only 3% of button batteries are larger than 20 mm but are responsible for the severe esophageal injuries.[39,50–53] Guidelines for the evaluation and treatment of button battery ingestions are available from the National Capital Poison Center.[54]

Button batteries cause injury by multiple methods. Their electrical discharge causes hydrolysis and the creation of hydroxide ions in tissue, which causes alkali burns. Leakage of the high pH contents can result in alkali burns. Their physical presence cause direct pressure necrosis. Some button batteries contain mercuric oxide. Mercury toxicity can result if the mercuric oxide leaks from the batteries.

The majority of these batteries contain manganese dioxide, silver oxide, mercuric oxide, zinc air, or lithium. Obtain anteroposterior and lateral abdominal and chest radiographs to distinguish between coins and button batteries. A double density shadow is suggestive of batteries. The coin has a much sharper edge.

A button battery lodged in the esophagus is a true emergency and immediate removal is indicated to avoid the rapid corrosive action of the alkaline substance on the mucosa and subsequent complications.[38,40] Endotracheal intubation is usually necessary to protect the airway prior to endoscopic removal. The battery is removed from the esophagus under direct viewing using a through-the-scope balloon. A biopsy forceps may be needed to free the edge of the battery prior to removal. Alternatively, the battery may be pushed to the stomach and then removed using a polypectomy snare or a Dormia basket. **Do not use a Foley catheter or a magnet to remove a button battery without the aid of endotracheal intubation and general anesthesia due to the possibility of the button battery falling into the airway.** The patient should be admitted to the intensive care unit and monitored for signs of perforation and sepsis if they suffered severe esophageal injury when evaluated by endoscopy after removal of the button battery. If the injury is localized to the anterior wall of the esophagus, bronchoscopy may be performed to evaluate the extent of injury.

Generally, a button battery in the stomach need not be removed unless the patient is symptomatic with abdominal pain, tenderness, or gastrointestinal bleeding. Asymptomatic patients with button batteries less than 15 mm in diameter in their stomachs need follow-up abdominal radiographs every 24 hours to document forward progress until it is expelled. In a child less than 6 years old, the battery should be endoscopically removed if it is larger in size and has not passed within 48 hours.[38,41] Patients may be placed on H_2 blockers and/or proton pump inhibitors to decrease the acid in the stomach and therefore decrease the battery reaction. If mercury poisoning is expected, serum and urine mercury levels should be obtained and monitored.

MAGNETS

Magnets are commonly found in homes and are easily accessible to children. They are contained in appliances, jewelry, and toys. The ingestion of a single magnet is usually not problematic. The ingestion of multiple magnets should be considered an emergency requiring removal. The magnets can move separately through the gastrointestinal tract. They then have the potential to attract each other and trap bowel between them. This can result in pressure necrosis, fistula formation, and perforation.

Perform plain radiographs to determine the number and the location of the magnets. A single magnet should be treated as any other small, nonsharp, foreign body ingestion. Multiple magnets require removal. Remove them endoscopically if they are located within the esophagus and/or stomach. If they have passed the pylorus, consult a Surgeon for urgent removal versus careful inpatient monitoring by the Surgeon and frequent radiographs to localize the magnets.

FOLEY CATHETER TECHNIQUE

A Foley catheter has been successfully used to remove recently ingested, radiographically opaque, smooth and blunt foreign bodies from the esophagus. This technique is inexpensive, has a high success rate, does not require hospitalization, and avoids the complications associated with endotracheal intubation and general anesthesia. Coins are the foreign bodies primarily removed with a Foley catheter. The technique has also been used to remove button batteries, food boluses, and other smooth foreign bodies.

This technique cannot be used on all patients with an esophageal foreign body. This technique should not be attempted in patients who are confused or uncooperative. Patients with an altered mental status, airway compromise, or potential airway compromise should be endotracheally intubated prior to Foley catheter removal of the foreign body. Sharp or irregular shaped objects can lacerate or perforate the esophagus upon removal. Known or suspected esophageal perforation is a contraindication to this technique. Patients with complete esophageal obstruction, as demonstrated by an esophageal air-fluid level on radiographs, are not candidates. Esophageal fibrosis, esophageal tumors, anatomic anomalies, or a history of prior esophageal surgery is also a contraindication.

The equipment required for the technique is minimal. This includes topical anesthetic spray, a bite block, and a size 12 to 16 Foley catheter with a 5 to 10 mL balloon. The technique may be performed ideally in a fluoroscopy suite or blindly in the Emergency Department. A water-soluble contrast agent is required if using

fluoroscopy. **The most dangerous and immediate complication of this technique is airway obstruction. Airway and emergency equipment must be available if this technique is to be performed.**

Explain the procedure to the patient, including the sensations they will experience. The use of a topical anesthetic spray for the oropharynx is beneficial but optional. Its use may increase the risk of aspiration. The use of physical restraints, procedural sedation, and/or intubation may be required as needed on a case-by-case basis. Preinflate the Foley catheter balloon with 5 to 10 mL of water-soluble contrast material. Inspect the integrity of the balloon. Withdraw the contrast material back into the syringe to deflate the balloon. The small amount of contrast material left in the balloon will facilitate identification under fluoroscopy. Place the patient prone in 10° to 20° of Trendelenburg or in the left lateral decubitus position in 10° to 20° of Trendelenburg. The fluoroscopy technique and then the blind technique are described in the following paragraphs.

Insert the Foley catheter. Some physicians insert a bite block and place the Foley catheter through the mouth (**Figure 62-1**). Others use the nasal route. The oral route avoids the potential problem of lodging the foreign body in the nasopharynx with subsequent aspiration. Advance the Foley catheter under fluoroscopy until the balloon is just distal to the foreign body (**Figure 62-1A**). Slowly inflate the balloon with 5 mL of contrast material (**Figure 62-1B**). Stop inflating the balloon if the patient complains of pain; deflate the balloon, then reposition the catheter before reinflating. Withdraw the catheter with moderate and steady traction until it exits the mouth (**Figures 62-1C & D**). **Stop withdrawing the catheter if resistance is met to prevent an esophageal tear or perforation.** The balloon may occasionally slide past the foreign body as the catheter is being withdrawn. Reinsert the catheter and inflate the balloon with 7 to 8 mL of contrast material and then withdraw the catheter. **Do not overinflate the balloon as it can rupture the esophagus.**

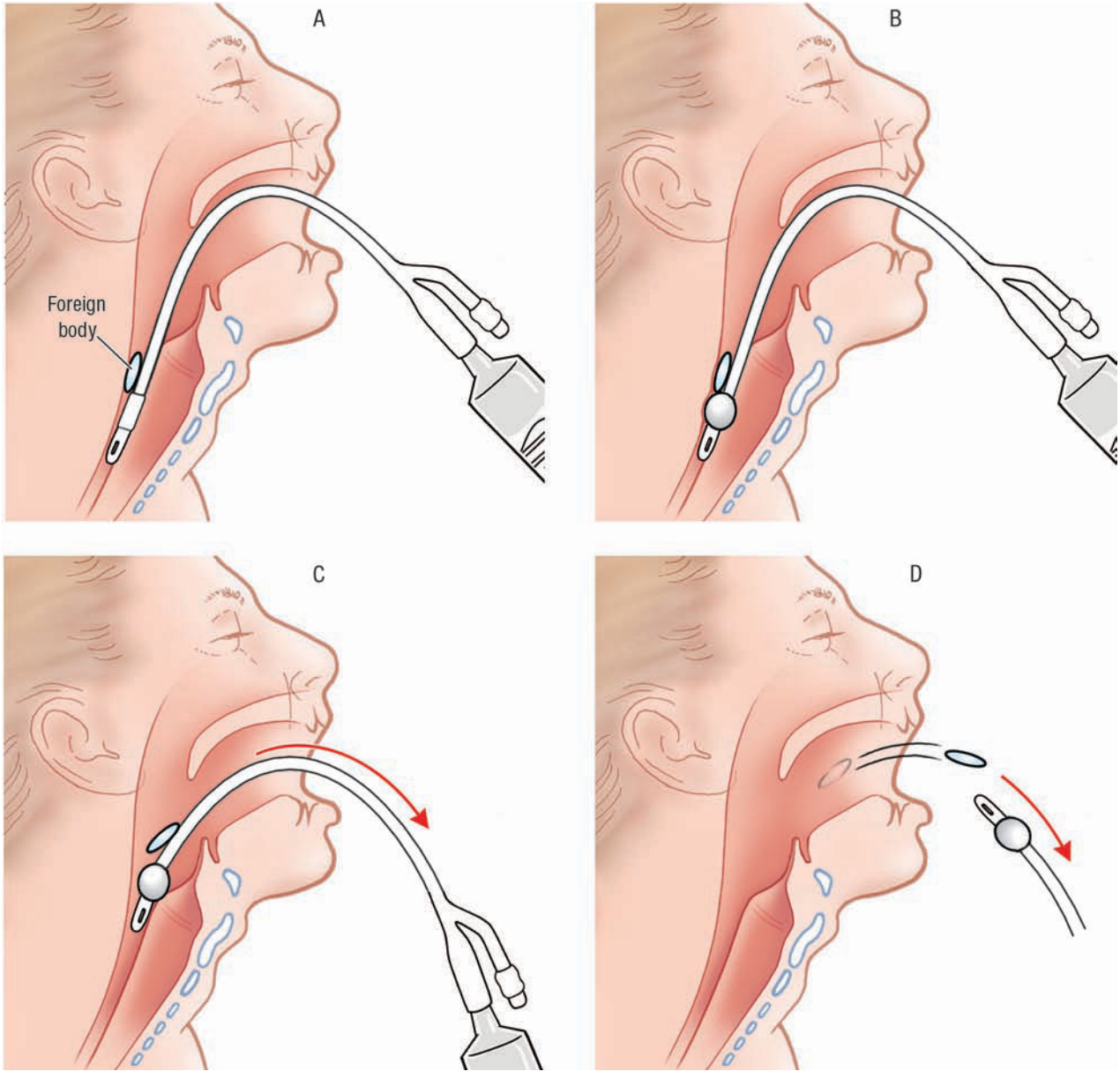


FIGURE 62-1. The Foley catheter technique to remove an esophageal foreign body. This illustration demonstrates the oral route for catheter insertion. The nasal route may also be utilized. **A.** The catheter is inserted and advanced until the balloon is just distal to the foreign body. **B.** The balloon is inflated. **C.** The catheter is withdrawn and pulls the foreign body into the hypopharynx. **D.** Completely withdrawing the catheter will pull the foreign body into and out the mouth. Steps (**C**) and (**D**) are performed in one smooth motion.

Do not attempt this technique more than twice. The balloon will pull the foreign body ahead of it into the hypopharynx and then the mouth. Tell the patient to spit out the foreign body; or you can grasp it with fingers, forceps, or a hemostat.

This technique may also be used "blindly" if fluoroscopy is not available. Estimate the distance, on the radiographs, from the mouth or nose to the foreign body. Place the Foley catheter over the radiograph with the balloon just distal to the foreign body. Mark the distance with tape on the catheter as it exits the mouth or nose. The catheter will then be inserted into the patient until the tape is positioned at their mouth or nose. Use saline rather than contrast material to inflate the balloon. Obtain repeat radiographs if the foreign body is not expelled with the catheter as it may have been pushed into the stomach. The remainder of the technique is the same as described for removal under fluoroscopy.

Complications with this technique are uncommon but do occur. This technique may not be able to remove the foreign body. Insertion of the catheter can cause laryngospasm or vomiting. The Foley catheter may enter the airway, resulting in coughing and laryngospasm. The esophagus may be lacerated or perforated if the foreign body is large, completely impacted, sharp, irregular, or has been in place for over 12 to 24 hours. Overinflation of the balloon can rupture the esophagus. Removal through the nose may result in epistaxis or impaction of the foreign body in the nasopharynx or nasal cavity. The most feared complication is complete or partial airway obstruction if the foreign body falls into the larynx.

BOUGIENAGE

The use of a Bougie dilator to push an esophageal foreign body into the stomach has been used in children.[42–44] The technique has been successfully used in asymptomatic children who have radiographs documenting a coin in the esophagus, no history of esophageal disease, and less than 24 hours has passed from the time of ingestion. The advantages of this technique are that it is quick, simple to perform, does not require sedation, does not require intravenous access, decreases length of stay, and saves money when compared to endoscopy.[55]

Apply a topical anesthetic spray to the child's oropharynx. Select an appropriate size Bougie dilator. Physically restrain the patient while they are sitting upright or standing on the bed. Place the tip of the Bougie dilator at the mouth and run the rest of the dilator to the earlobe and to just below the left costal margin. Place a piece of tape on the Bougie dilator 3 to 4 cm below the costal margin. Insert the Bougie dilator through the mouth and advance it in one smooth motion until the tape is at the mouth. Remove the Bougie dilator. Obtain a repeat radiograph to confirm that the coin is now in the stomach.

Complications can occur and are avoided with proper patient selection. Esophageal perforation may occur if the patient has known esophageal disease, prior esophageal surgery or manipulation, a sharp foreign body, or an irregular shaped foreign body. A foreign body present for more than 24 hours can cause pressure necrosis to the esophagus and increase the risk of perforation.

OROGASTRIC TUBE MAGNET

The orogastric tube magnet (OGTM) is an orogastric tube that has a magnet sealed within the distal end. It may be used to retrieve smooth, metallic foreign bodies from the esophagus and stomach under fluoroscopy. Place the patient in the lateral decubitus position. Apply a topical anesthetic spray to the oropharynx. Insert the OGTM through the mouth. Advance the OGTM under fluoroscopy into the esophagus and directed toward the foreign body until it makes contact. Withdraw the OGTM and the foreign body out the mouth. This is a rarely used technique.

ALTERNATIVE TECHNIQUES

Numerous other methods for the removal of esophageal foreign bodies have been tried and reported in the literature. Surgical removal is rarely indicated except when complications such as perforation or vascular penetration have occurred. **Do not blindly push food boluses into the stomach.** This is hazardous because many patients have underlying esophageal disease. **Blind maneuvers can result in esophageal perforation.**

PEDIATRIC CONSIDERATIONS

Children less than 4 years of age are predisposed to occasionally have an esophageal foreign body. They explore objects with their mouth, have a high curiosity level, lack molars to chew food, and have poor motor and sensory coordination. Common esophageal foreign bodies include balls, button batteries, buttons, candies, coins, gumballs, jacks, marbles, partially chewed food, and pen caps. **A high index of suspicion must be maintained as a history of an ingestion may not be obtained.**

Children may present asymptomatically or with cough, drooling, dysphagia, respiratory distress, unwillingness to eat, or vomiting. An asymptomatic child with an esophageal coin or round object, except button batteries, can be admitted to the hospital and watched for 24 hours to see if the object will spontaneously pass into the stomach. The object should be removed with a Bougie dilator, a Foley catheter, or an endoscope if the child is or becomes symptomatic, or if the object does not pass within 24 hours. Foreign bodies in a mainstem bronchus require removal by an Otolaryngologist in the operating room with a rigid bronchoscope. Turning the child upside down or performing the Heimlich maneuver may move the foreign body into the trachea or larynx and cause a complete airway obstruction.

Waltzman et al. reported that 25% to 30% of esophageal coins in children pass spontaneously without complications.[45] Treatment of these patients may reasonably include a period of observation (e.g., 8 to 16 hours), especially in older children with coins in the distal esophagus. A "combination" technique using fluoroscopy and endoscopic forceps, called the "penny-pincher," has been described to remove coins in children.[46] In this technique, grasping endoscopic forceps are covered by a soft rubber catheter and fluoroscopically guided into place. The forceps firmly hold the coin while the catheter protects the oropharynx and aligns the device with the coin. When the tip of the catheter is close to the upper edge of the coin, the retracted radiopaque prongs of the forceps are deployed. At this point, the coin edge is grasped, and the coin is extracted.

It is important not to attempt these techniques or bougienage with patients with known anomalies of the gastrointestinal tract. These anomalies may be anatomic, functional, or postsurgical. They can lead to the coin again becoming lodged, this time in a position that would require a more invasive intervention than endoscopy.[47]

ASSESSMENT

The patient should be observed until the effects of the sedation have resolved. This includes monitoring the vital signs as per protocol of the hospital. The patients should be given a trial of liquids to swallow prior to discharge. The patient may be safely discharged after they tolerate oral fluids, are awake and oriented, and are able to ambulate without difficulty. The patient should be driven home by another person if sedation was used to extract the foreign body.

Admission is required in a few instances. The inability to tolerate oral fluids is a contraindication to discharge. Foreign bodies that are

not retrievable must be removed. These patients should be admitted for observation, further endoscopy, or operative removal. Any patient with evidence of esophageal perforation should be admitted, observed, and evaluated by a Surgeon.

The esophagus should be endoscopically examined after removal of most foreign bodies. A Gastroenterologist should be consulted on anyone with an esophageal foreign body. All patients discharged from the Emergency Department should follow up with a Gastroenterologist in 24 to 48 hours. The presence of any lacerations, perforations, or erosions should be noted and may require repair. Any strictures will require dilation in the future. Some recommend a second endoscopic follow-up in 3 to 6 weeks for reevaluation of the esophagus. This is Endoscopist-specific.

AFTERCARE

Instruct the patient to only ingest liquids for the first 12 to 18 hours. A soft diet should begin after this trial period of liquid and advanced to a general diet over 24 hours. Instruct the patient to take small bites of food and completely chew it before swallowing. They should immediately return to the Emergency Department if they experience abdominal pain, chest pain, dysphagia, hematemesis, hemoptysis, melena, odynophagia, or if they have any concerns.

COMPLICATIONS

Esophageal perforation can occur due to the foreign body or the extraction procedure. The patient may present with fever, tachycardia, shortness of breath, chest pain, abdominal pain, and crepitation in the neck. An immediate chest radiograph and/or a radiographic contrast study should be performed if the extraction of the foreign body has been difficult.[1–3] An aortoesophageal fistula can form due to sharp foreign bodies in the esophagus that erode through the esophageal wall. This should be considered when the patient presents with dysphagia and significant hematemesis.[9,33] A latency period between the ingestion of the foreign body and hematemesis is usually 1 to 3 weeks, though it can occur years later.[15] Tracheoesophageal fistulas can occur more than a year after ingestion of the foreign body.[3]

Other life-threatening cardiopulmonary emergencies include mediastinitis, lung abscess, pericarditis, cardiac tamponade, pneumothorax, and pneumomediastinum. These complications mostly result from a delay in recognizing an esophageal perforation.[8,9,15] The remaining complications are discussed with each of the individual techniques of foreign body removal.

SUMMARY

Foreign body ingestion and food bolus impaction in the upper gastrointestinal tract are relatively common problems seen in the Emergency Department. Several studies have shown that 80% to 90% of foreign bodies in the gastrointestinal tract will pass spontaneously. Approximately 10% to 20% will require nonoperative intervention while 1% will require surgical removal.[3,48] The most common presenting symptoms are chest or pharyngeal pain, odynophagia, dysphagia, foreign body sensation, and sialorrhea.[48] Despite performing emergent upper endoscopy, no foreign body could be found in almost half of patients.[49] The urgency for the endoscopic examination depends upon the potential risk of aspiration or perforation, the type and size of the foreign body, the degree of obstruction, and the inability to manage secretions.[9] The presence of dysphagia and the immediate onset of symptoms would increase the probability of a positive foreign body finding on endoscopy.

Numerous techniques may be used to remove an esophageal foreign body. The technique of choice depends upon the level of patient cooperation, the type of foreign body, the time since ingestion, physician experience and comfort, Gastroenterology consultation, and presenting symptoms. Complications can be minimized by the proper selection of the removal technique and the appropriate patient for the technique.

63 Balloon Tamponade of Gastrointestinal Bleeding

Bashar M. Attar

INTRODUCTION

Gastroesophageal varices are among the most dangerous complications associated with cirrhosis. They are present in 50% to 60% of cirrhotic patients, and about 30% of them will experience an episode of variceal hemorrhage within 2 years of the diagnosis of varices.[1] The major factors that determine the risk of bleeding are variceal size and the degree of liver dysfunction.[1–3] While variceal bleeding stops spontaneously in 20% to 30% of cases, it recurs in 70% within 1 year of the initial episode.[1–4] Mortality is as high as 50% in the first year.[5] Variceal bleeding accounts for almost one-third of deaths in cirrhotic patients. Variceal hemorrhage has a poor prognosis if it is associated with coexisting or subsequent complications including rebleeding, infection, hepatic dysfunction, and portal pressure ≥12 mmHg.[6,7] Somatostatin and its analogs cause splanchnic vasoconstriction leading to reduced portal pressure and portal blood flow while venodilators reduce portal pressure by reducing resistance to portal flow.[7,8]

Doctors Sengstaken and Blakemore developed the concept of balloon tamponade to control bleeding esophageal and gastric varices in 1950. They developed a triple-lumen and double-balloon system that bears their names. The Sengstaken–Blakemore (SB) tube is used as a temporizing measure to stop variceal bleeding until more definitive means are available. A variant of the SB tube is the Minnesota tube. It is a quadruple-lumen, double-balloon system. These tubes are rarely used today due to the significant complications and the widespread availability of endoscopy and its therapeutic interventions. Removal of the balloon after its initial control of the bleeding results in a 50% rebleeding rate. It is also associated with serious complications such as esophageal ulceration and perforation.[9] Emergency Physicians should become familiar with the SB and Minnesota tubes, as they can be potentially lifesaving in an emergent setting, especially when endoscopy is not available or contraindicated.

ANATOMY AND PATHOPHYSIOLOGY

Cirrhosis results in portal venous hypertension and a decrease in blood flow through the portal system. Collateral circulation develops, so that the blood in the portal vein can find an alternative route to the inferior vena cava. Large collateral systems include the esophageal, gastric, paraumbilical, and rectal veins. The left gastric and esophageal veins form one of the larger collateral circulation channels due to the pressure generated from the portal venous system and the large volume of blood flow through them. The collateral veins distend from the pressure and large volume of blood flow, resulting in weakening of the walls of the vein. Ulceration and rupture of these veins can result in large amounts of blood entering

the esophagus and stomach. Patients may present with bright red blood per rectum, hematemesis, hemorrhagic shock, hypotension, or complications associated with hypotension and hemorrhage (e.g., cerebrovascular accidents and myocardial infarction).

The inflated balloons will control most bleeding. The esophageal balloon exerts lateral pressure to tamponade esophageal varices. The gastric balloon exerts pressure on the gastric cardia to tamponade varices. When both are inflated, they meet to compress the gastric cardia against the diaphragm and block the upward flow of collateral blood from feeding the esophageal varices.

INDICATIONS

Balloon tamponade should be considered in patients with acute bleeding from esophageal and/or gastric varices if medical therapy (e.g., somatostatin, octreotide, and vasopressin) or emergent endoscopic therapy (i.e., banding or sclerotherapy) is not available, contraindicated, or unsuccessful.

CONTRAINDICATIONS

Absolute contraindications to balloon tamponade of variceal bleeding include a history of esophageal stricture, a history of recent surgery involving the gastroesophageal junction, or if the hemorrhage has terminated based upon nasogastric lavage and aspiration.

There are numerous relative contraindications to balloon tamponade of variceal bleeding. The procedure should not be performed if the equipment required is defective or missing components. Untrained support staff make the procedure, as well as the aftercare, more difficult. Significant active medical problems (e.g., respiratory failure, congestive heart failure, and cardiac arrhythmias) preclude the use of balloon devices. Incomplete gastric lavage leaving particulates in the stomach can cause retching and elevated intraabdominal pressure. The balloons will not properly position and may perforate the esophagus if the patient has a hiatal hernia. Esophageal ulcerations preclude the use of the esophageal balloon (a gastric balloon may be used). The device is not helpful if a variceal source of bleeding cannot be demonstrated by examination, history, and/or nasogastric aspiration. Patients with altered mental status, confusion, diminished gag reflexes, hypoxemia, or who are uncooperative should have their airway secured by endotracheal intubation prior to this procedure. Recurrent bleeding after the initial successful tamponade should be followed by endoscopic or operative intervention.

EQUIPMENT

- SB tube (or Minnesota tube)
- Topical anesthetic spray
- Tongue blades
- Lidocaine or water-soluble jelly
- 60 mL syringe
- Catheter tips for the syringe
- Two wall-suction setups with plastic connectors and suction tubing
- Adhesive tape
- Rubber shod clamps, hemostats, or plugs
- Scissors
- Y-adapter or three-way stopcock
- Intravenous extension tubing
- Pressure bulb
- Mercury manometer or handheld manometer
- Bite block
- Nasogastric tube
- Football helmet, catcher's mask, or endotracheal tube holder

The SB tube is a triple-lumen and double-balloon system (**Figures 63-1 & 63-2**). It is available in a variety of sizes, including pediatric sizes. The proximal end contains three ports. A syringe attaches to the esophageal balloon inflation port to inflate the esophageal balloon. A syringe attaches to the gastric balloon inflation port to inflate the gastric balloon. The gastric aspiration port may be used to aspirate gastric contents, instill fluid into the stomach, or lavage the stomach. The ports may be opened and closed by the application of rubber shod clamps, hemostats, or plugs. The tube is made of a soft rubber and is extremely flexible. The proximal or esophageal balloon is elongated. The distal or gastric balloon is round. The maximum volume to inflate each balloon is manufacturer- and size-specific. Numerous perforations in the distal end of the tube allow for gastric aspiration and lavage.

The Minnesota tube is a quadruple-lumen and double-balloon system (**Figure 63-3**). It is similar to the SB tube with the exception of an additional port and lumen. The esophageal aspiration port allows saliva and esophageal secretions to be aspirated from a perforation just above the esophageal balloon. The only advantage of this tube over the SB tube is that the SB tube requires a nasogastric tube to be passed nasally or orally into the esophagus to aspirate secretions.

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. An informed consent should be obtained for the procedure. Thoroughly assess the patient's airway and breathing. Have a low threshold to protect the airway by endotracheal intubation. Endotracheal intubation is required before performing the

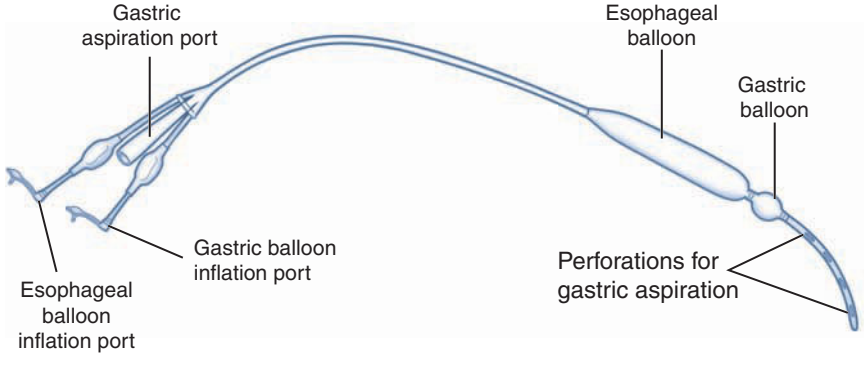


FIGURE 63-1. Schematic illustration of the Sengstaken–Blakemore tube.

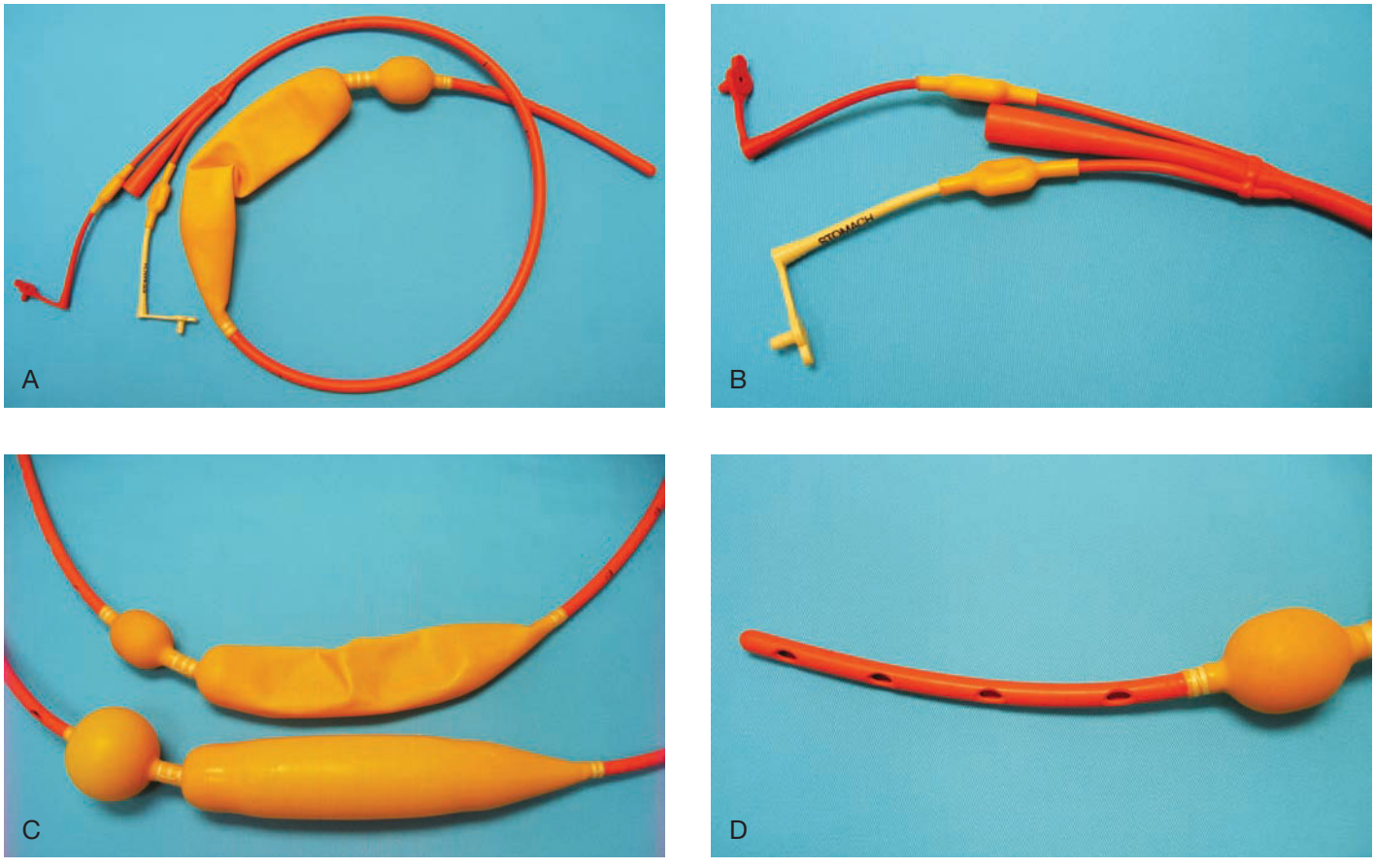


FIGURE 63-2. The Sengstaken–Blakemore tube. **A.** Overall view of the SB tube. **B.** The proximal ports. **C.** The esophageal and gastric balloons in the inflated and deflated states. **D.** The distal end.

procedure if the patient has altered mental status, airway compromise, or the potential for airway compromise. Patients are often ill and require intubation anyway. The procedure and the tube are not well tolerated, and intubation makes it easier. Endotracheal intubation reduces the risk of aspiration.

The patient should have intravenous access established with at least two large-bore catheters. Cardiac monitoring, continuous pulse oximetry, and supplemental oxygen should be applied. The patient may require the judicious use of intravenous sedatives and soft restraints during the insertion and inflation of the tube. The patient should be resuscitated, including blood transfusion, to stabilize them hemodynamically.

Place the patient sitting upright to semi-upright by elevating the head of the bed at least 45°. This is the ideal position. The procedure can be performed with the patient in the left lateral decubitus position if they cannot sit upright. The procedure can be performed with the patient supine if they are is endotracheally intubated.

Apply topical anesthetic spray to the nostrils and pharynx. Insert a nasogastric tube or an Ewald tube. Aspirate the stomach contents. Evacuate the stomach with tap-water lavage through the nasogastric tube (or Ewald tube), then remove the nasogastric tube.

Prepare the equipment. Flush the aspiration ports with air to ensure their patency. Inflate the balloons with the maximum recommended volume of air and check for leaks. It is advisable to inflate the balloons under water to look for small leaks. Connect the mercury manometer to the balloon ports and inflate the balloons to the recommended pressures and check for leaks. Completely

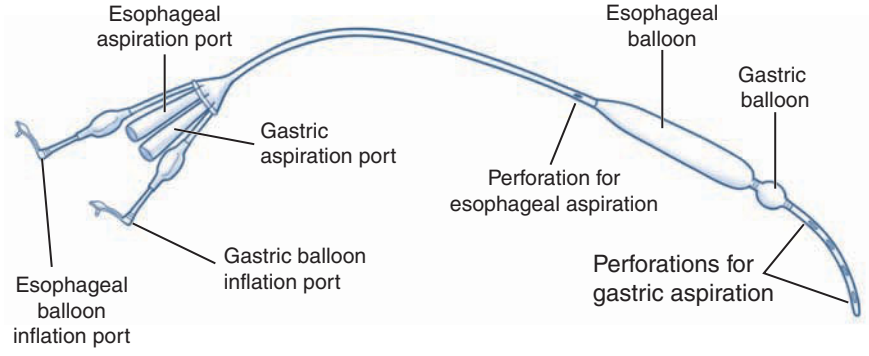


FIGURE 63-3. Schematic illustration of the Minnesota tube.

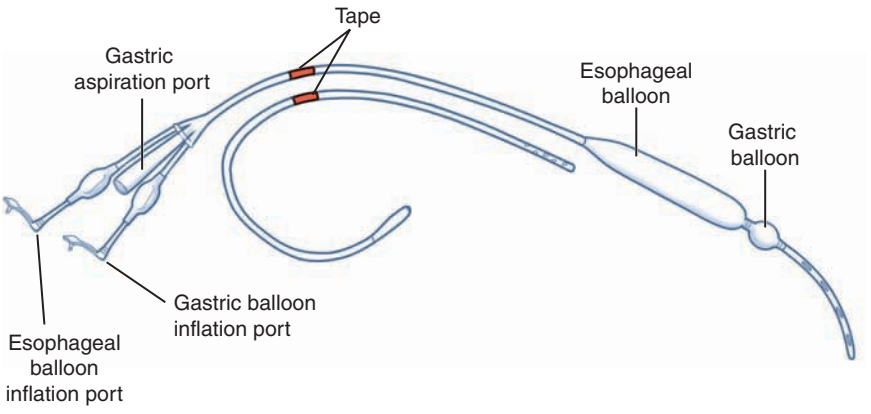


FIGURE 63-4. Preparing the nasogastric tube. Place the nasogastric tube alongside of the SB tube with the tip just above the esophageal balloon. Place tape on both tubes to mark a common point proximal to the 50 cm mark on the SB tube.

deflate the balloons. Record the manometric pressure of each balloon when it is deflated. Insert the plastic plugs in the balloon inflation ports or loosely clamp each port with a hemostat or rubber shod clamp.[10–12] Lubricate the SB tube with a water-soluble lubricant. Place the SB tube on a table. Position a nasogastric tube next to the SB tube so that the tip of the nasogastric tube is just above the esophageal balloon (**Figure 63-4**). Place a piece of tape on both tubes to mark a common point, proximal to the 50 cm mark of the SB tube, that will be outside of the patient. The nasogastric tube will be inserted after the SB tube is placed. Alternatively, position the tubes as above and tape both tubes together at two or three sites. This allows the nasogastric tube to be inserted simultaneously with the SB tube.

The SB tube may be inserted through the nose or through the mouth. The nasal route is more difficult to use and may be associated with a higher rate of complications. Despite this, many physicians recommend this route in the awake patient. The oral route is the preferred route of insertion by some physicians, especially if the patient is intubated. Apply topical anesthetic spray into the nasal cavity and oropharynx if the SB tube will be placed nasogastrically. Apply topical anesthetic spray into the oropharynx if the SB tube will be placed orally. Place a bite block in the patient's mouth if the SB tube will be placed orally to prevent the patient from biting the SB tube.

TECHNIQUE

Insert the lubricated SB tube until the 50 cm mark is located just outside the nares, or outside the teeth if inserted through the mouth. Flush the gastric aspiration port with air while auscultating over the epigastrium (**Figure 63-5**). A rush of air should be heard to ensure that the distal end of the SB tube is properly positioned within the stomach. If possible, confirm the position of the SB tube with portable plain radiographs or fluoroscopy. **It is imperative to know that the gastric balloon is within the stomach before it is inflated.** Apply suction to the gastric aspiration port.

Remove the rubber shod clamp and plastic plug from the gastric balloon inflation port. Connect the Y-adapter with a handheld or mercury manometer and a pressure bulb or a 50 mL syringe with a catheter tip to the gastric balloon inflation port (**Figure 63-6**). Measure the intragastric balloon pressure. **If the intragastric balloon pressure after intubation is 15 mmHg greater than that prior to the intubation, deflate the balloon, as it may be located within the esophagus.** Inflate the gastric balloon in increments with 50 to 100 mL boluses of air (**Figure 63-7**). **Deflate the balloon immediately if the patient experiences chest pain. This signifies that the gastric balloon is in the esophagus.** Clamp the gastric balloon inflation port when the gastric balloon is inflated initially with 200 to 250 mL of air. Gently pull the SB tube back until resistance is felt as the gastric balloon lodges against the gastroesophageal junction (**Figure 63-8**).

Apply slight tension to the SB tube to occlude the veins at the gastroesophageal junction. This tension must be maintained by one of several methods. Fix the upper end of the SB tube as it exits from the mouth or nose to the crossbar of a football helmet or a catcher's mask (**Figure 63-9**). Apply over-the-bed traction with a one pound weight. Alternatively, fix the upper end of the SB tube, if it emerges from the nostril, by a cuff of sponge rubber held in place by an adhesive tape band. Insert the nasogastric tube until the tape is at the level of the tape on the SB tube (**Figure 63-10**).

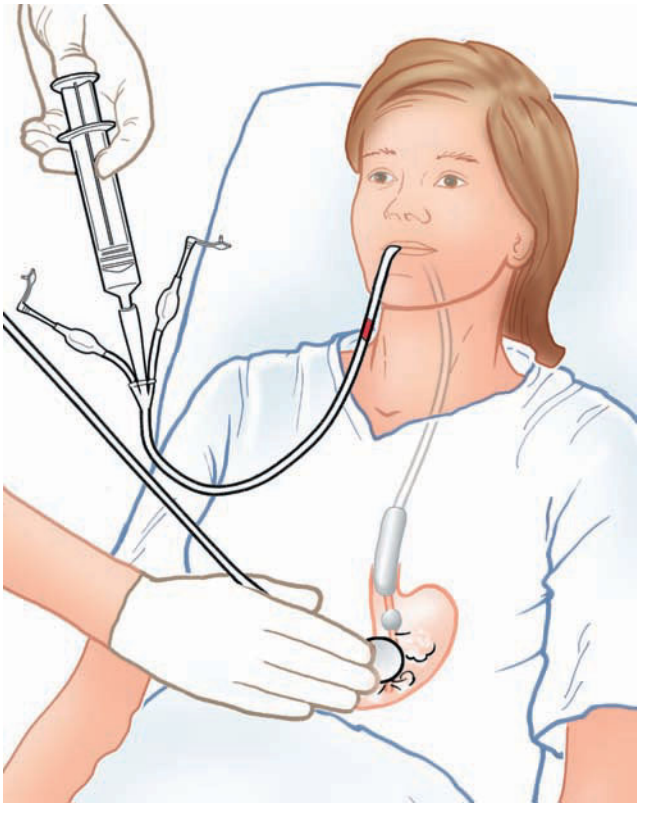


FIGURE 63-5. The SB tube has been inserted until the 50 cm mark is just outside the teeth. Inject 50 mL of air while auscultating over the epigastric area. A rush of air should be heard if the distal end of the SB tube is within the stomach.

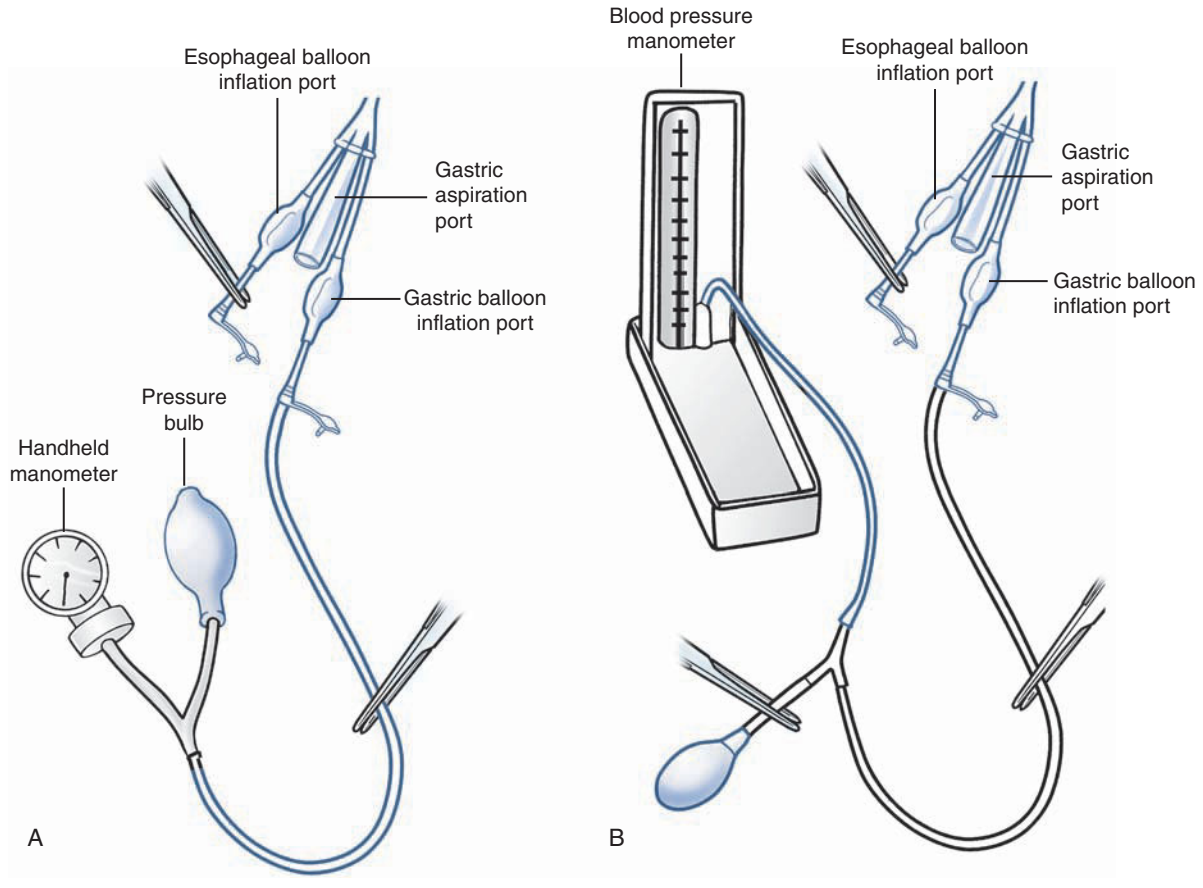


FIGURE 63-6. Connecting the handheld manometer (**A**) or mercury manometer (**B**) to the gastric aspiration port. A 50 mL syringe may be used if a handheld pressure bulb is not available.

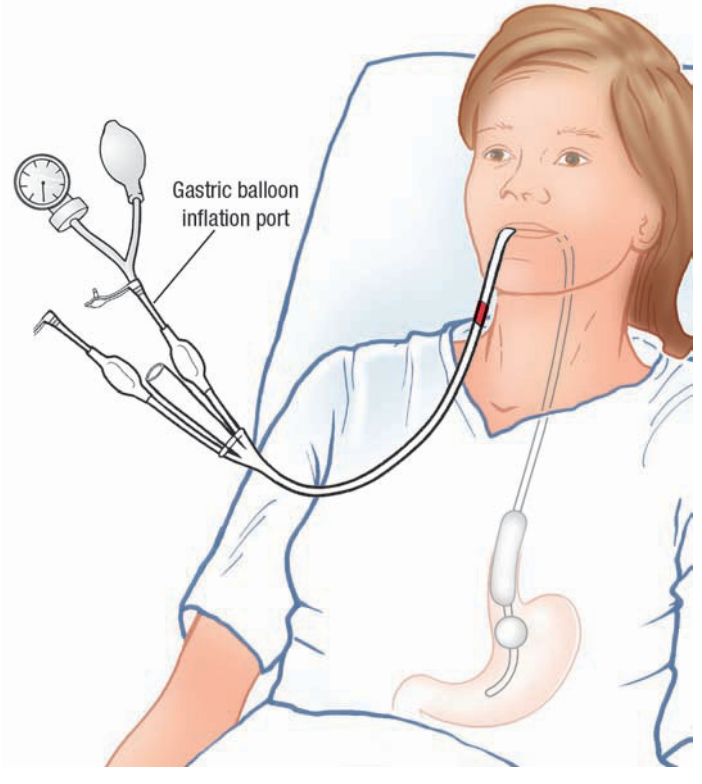


FIGURE 63-7. The gastric balloon is inflated with 50 to 100 mL increments of air to a volume of 250 to 300 mL.

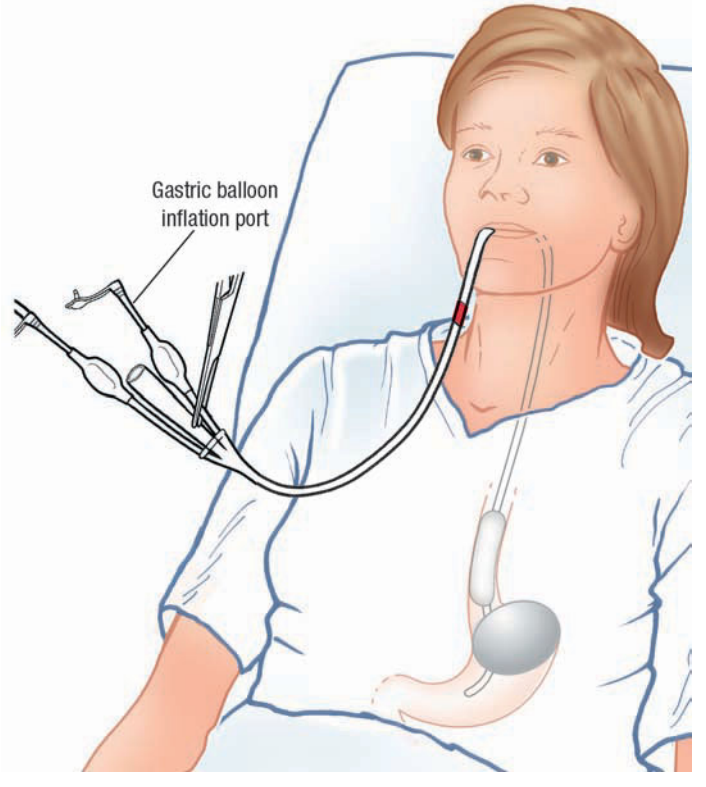


FIGURE 63-8. Tension is applied to the SB tube to lodge the gastric balloon against the gastroesophageal junction.

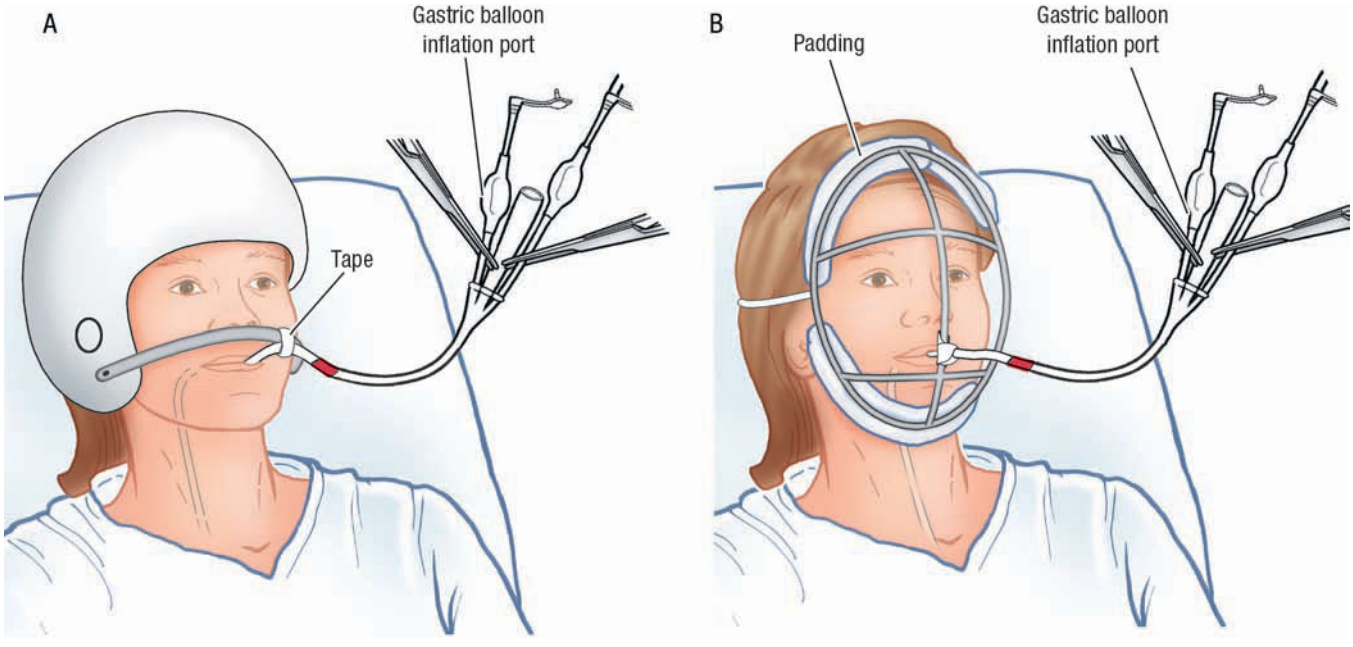


FIGURE 63-9. The SB tube is commonly secured to the faceguard of a football helmet (**A**) or to a catcher's mask (**B**).

Connect the gastric aspiration port and the nasogastric tube to the suction source (**Figure 63-11**). Place the gastric aspiration port and the nasogastric tube on low intermittent suction. Unclamp the esophageal balloon port clamp. Attach the Y tubing, manometer, and pressure bulb (or 50 mL syringe) to the esophageal balloon port (**Figure 63-11**). Inflate the esophageal balloon to a pressure of 25 mmHg if bleeding continues through the gastric aspiration port or the nasogastric tube. If bleeding continues to persist, increase the esophageal balloon pressure in 5 mmHg increments until 45 mmHg is achieved or the bleeding stops. Double clamp the SB tube to prevent accidental deflation of the balloons. If bleeding continues despite maintaining the esophageal balloon pressure at 45 mmHg, this is suggestive of a gastric wall varix. In this case, check that the tube is snugged up on the nose firmly and taped securely. Finally, fill the gastric balloon with more air gradually up to a total volume of 300 mL of air.

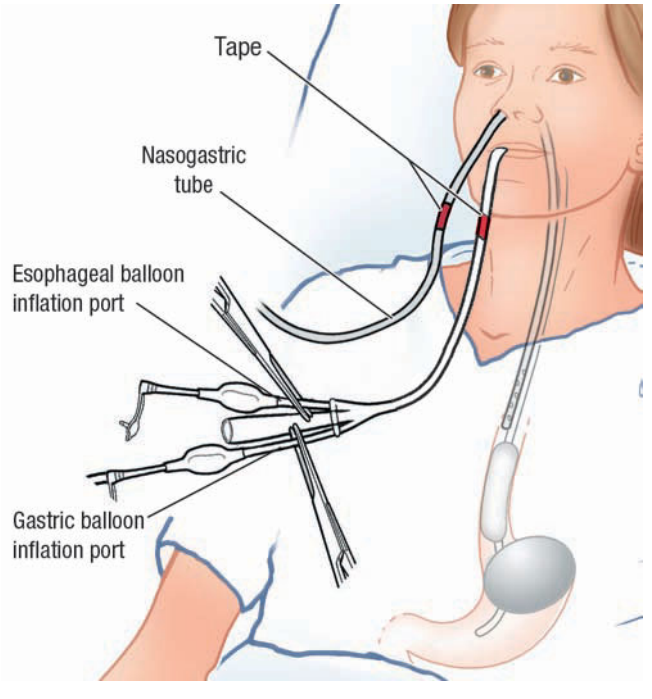


FIGURE 63-10. The nasogastric tube is inserted until the tape mark lines up with the tape mark on the SB tube. The football helmet/catcher's mask is omitted from this illustration for the sake of clarity.

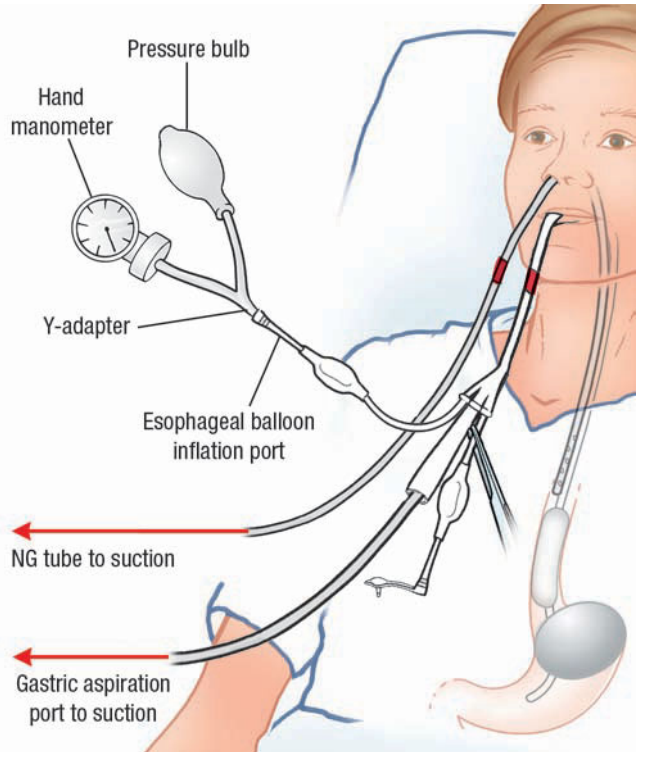


FIGURE 63-11. The esophageal balloon is inflated after the gastric aspiration port and the nasogastric tube have been attached to a suction source. The football helmet/catcher's mask is omitted from this illustration for the sake of clarity.

ALTERNATIVE TECHNIQUE

The above technique is also applicable to the four-lumen esophagogastric tamponade (Minnesota) tube. This tube is a modification of the triple-lumen SB tube that incorporates a separate esophageal suction port to the existing gastric suction port.[13,14] The design of the Minnesota tube may help prevent aspiration of esophageal contents.[15] Always check the manufacturer characteristics regarding the maximum inflation volume of both the gastric and esophageal balloons, as these are dependent upon the tube manufacturers.

Recently proposed is an effective methodology for placement of the SB tube endoscopically.[16] This method will avoid the need to obtain radiologic confirmation of the gastric balloon within the stomach.[16] Delay in treatment while waiting for a radiologic confirmation may put patients at risk, as they are almost always in critical condition and require immediate attention.[4–6] If endoscopic intervention is not successful, pass an SB tube and confirm the position of the gastric balloon under direct visualization through the endoscope. The balloons are inflated and secured in the usual fashion.[16]

ASSESSMENT

Check the pressure in the balloons periodically with the mercury manometer or keep the manometer attached for constant monitoring. Obtain a portable radiograph to confirm proper placement of the SB tube and the inflated balloons. The patient may be reclined, but always maintain at least 6 to 10 in. of head elevation on the bed to prevent aspiration in the awake patient. Tape a scissors to the head of the bed for quick access in case the balloon requires emergent deflation (**Figure 63-12**).

AFTERCARE

If the bleeding is controlled, reduce the esophageal balloon pressure by 5 mmHg every 3 hours until 25 mmHg is reached without bleeding from the nasogastric tube in the esophagus or the gastric aspiration port. Deflate the esophageal balloon for 5 minutes every 6 hours to avoid esophageal pressure necrosis. Give the patient nothing by mouth. Oral medications, if required, may be administered through the gastric aspiration port. Check the tension on the SB tube every 3 hours and adjust it as necessary. Verify patency of the SB and nasogastric tubes by checking the gastric and esophageal return regularly and periodically flushing both lumens.

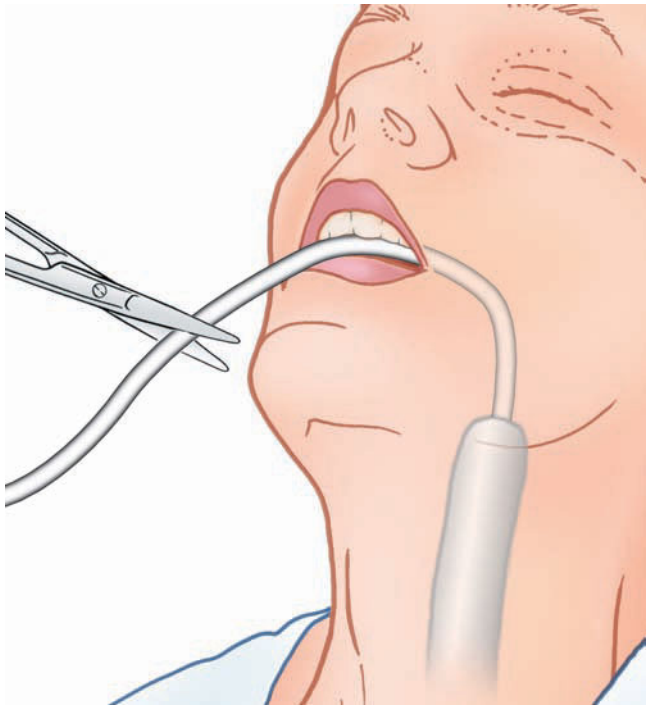


FIGURE 63-12. Emergent removal of the SB tube. Cut the SB tube between the ports and the patient to deflate both balloons rapidly.

Monitor the patient continuously for signs of chest pain, respiratory distress, and aspiration. Migration of the esophageal balloon into the hypopharynx of an awake patient will result in respiratory distress. **This situation is a true emergency and the tube should be removed immediately.** Cut the SB tube between the ports and the patient with a scissors (**Figure 63-12**). The balloons will immediately deflate and allow the removal of the SB tube.

The esophageal balloon should not remain inflated for more than 24 hours to avoid mucosal necrosis. The SB tube is usually left in place with the gastric or gastric and esophageal balloons inflated for 24 hours if variceal bleeding is controlled. If there is no bleeding after 24 hours, deflate the esophageal balloon and leave the gastric balloon inflated for an additional 24 hours. The SB tube may be left in place for an additional 24 hours after both balloons are deflated. If variceal hemorrhage recurs, the appropriate balloons should be reinflated while alternative therapy to control bleeding is sought. Patients who rebleed have a higher mortality rate. Therefore, other therapeutic interventions—such as rubber banding, sclerotherapy, transjugular intrahepatic portocaval shunt, or surgery—should be considered. Remove the SB tube if hemostasis persists for 24 hours after deflation of both balloons. Control of esophageal variceal bleeding can be achieved by balloon tamponade in 50% to 94% of patients.[18–22] However, rebleeding occurs in 38%.

COMPLICATIONS

Major complications occur in up to 15% of patients and lethal complications have been described in up to 6.5% of patients.[18–22] **Complications associated with the SB tube are often life-threatening.** The airway may become occluded due to proximal migration of the esophageal balloon into the hypopharynx of the awake patient from traction on the SB tube.[17] The patient will begin choking and gagging if not intubated. Cut the SB tube distal to the ports to immediately deflate the balloons and allow the SB tube to be removed. Pulmonary aspiration, and subsequent pneumonia, may occur during SB tube insertion. Airway protection by endotracheal intubation should be considered in all patients prior to insertion of the SB tube.[18]

Despite endotracheal intubation, the SB tube may still become malpositioned and end up in the airway.[27] Inflation of the balloons in the airway can result in respiratory distress, respiratory tract obstruction, tracheal or bronchial rupture, or tracheoesophageal fistulas from pressure necrosis. **This is why it is essential to confirm proper placement prior to inflating the balloons.**

Excessive balloon pressure or prolonged balloon inflation may lead to pressure necrosis and ulcerations of the esophagus, gastroesophageal junction, and/or stomach. Periodic deflation of the esophageal balloon every 6 hours will help prevent this. Rupture or lacerations of the esophagus, stomach, or small intestine may occur.[19] Esophageal rupture can result in mediastinitis, abscess formation, and sepsis. These can be prevented by adhering to proper balloon inflation techniques with pressure monitoring. Cardiac arrhythmias and pulmonary edema can occur and require continuous monitoring in the setting of an intensive care unit. Pulmonary edema is often due to pressure from the esophageal balloon on mediastinal structures.

Numerous other complications are associated with the use of the SB or Minnesota tube. Unintentional deflation of the balloons can

be prevented by the application of rubber shod clamps or hemostats to the balloon inflation ports after the balloons are inflated. Cut the SB tube distal to the ports if the balloons will not deflate. The patient may become agitated from the discomfort of the tube, migration of the tube into the hypopharynx resulting in hypoxemia and asphyxiation, or as chest and back pain is experienced from a misplaced or overdistended balloon. Hiccoughs are due to pressure on the diaphragm by the balloons. Excessive traction on the tube can result in epistaxis or pressure necrosis of the lips, nose, or tongue. Use air and not a liquid to inflate the balloons. Liquid in the balloons causes them to be heavy, increases the risk of pressure necrosis, and makes them hard to deflate.

SUMMARY

Balloon tamponade of variceal bleeding is an uncommonly performed procedure in the Emergency Department. The SB tube plays an important role in the temporary control of hemorrhage from esophageal or gastric varices.[20–22] It is used in cases of variceal bleeding, usually documented by endoscopy, that continues despite aggressive medical management including lavage, correction of blood clotting abnormalities, intravenous somatostatin or vasopressin infusion, rubber banding, and emergent sclerotherapy.[16,23–25] The SB tube can also be placed if these methods are contraindicated or unavailable. Despite the initial success of balloon tamponade in the control of variceal hemorrhage, sustained control of bleeding occurs in only 40% to 50% of patients.[26] Balloon tamponade has been shown to be as effective as intravenous vasopressin in controlling esophageal variceal bleeding. Only 25% of patients with ascites, jaundice, and encephalopathy achieve lasting hemostasis with balloon tamponade. Long-term efficacy in terms of rebleeding depends in part on the patient's underlying liver disease.[16] Maintain a low threshold to intubate the patient endotracheally in order to prevent aspiration, protect the airway, and prevent airway occlusion from migration of the esophageal balloon.

64 Gastrostomy Tube Replacement

Maggie Ferng and Ryan C. Headley

INTRODUCTION

Gastrostomy tubes are commonly used devices that provide prolonged enteral support in patients who are unable to obtain sufficient nutrition orally. Simplified techniques for their placement and improved materials have made gastrostomies common in the outpatient setting. Emergency Physicians fill a valuable role in solving gastrostomy tube problems as many patients present to Emergency Departments with various gastrostomy tube complaints. This chapter reviews the methods and materials used in gastrostomies and the approaches to replacing displaced or malfunctioning gastrostomy tubes.

ANATOMY AND PATHOPHYSIOLOGY

Familiarity with the basic techniques used to create gastrostomies and the characteristics of common gastrostomy tubes is helpful in solving problems with their function and replacing tubes when appropriate.

PLACEMENT OF GASTROSTOMY TUBES

Feeding tubes have been surgically placed in patients for more than a century. Three main procedures that remain in use today are the Stamm (described in 1894), the Witzel (described in 1891), and the Dupage and Janeway (described in 1913)[1–6] (**Figure 64-1**). They all require a laparotomy under general anesthesia and provide long-term access to the stomach for feedings or decompression while attempting to minimize the potential for gastric leakage.

Each of the techniques attempts to create a leakproof interface between the stomach, the feeding tube, and the anterior abdominal wall. The Stamm gastrostomy secures the stomach to a gastrostomy tube using a double purse-string suture to invaginate the stomach about the feeding tube (**Figure 64-1A**). The Witzel technique places the gastrostomy tube through a seromuscular tunnel in the stomach wall (**Figure 64-1B**). The Janeway technique creates a formal tunnel from a gastric flap to envelop the gastrostomy tube and form a gastrocutaneous stoma (**Figure 64-1C**). Importantly, all three techniques involve suturing the stomach wall to the undersurface of the abdominal wall. This is significant because if a surgically placed gastrostomy tube is accidentally dislodged in the early postoperative period, the stomach wall remains attached to the abdominal wall and the chance of intraperitoneal contamination is decreased. These surgical gastrostomies are considered long-term, semipermanent stomas.

Modern endoscopic techniques have provided a less invasive option for the placement of percutaneous feeding tubes (also known as gastrostomy tubes, percutaneous endoscopic gastrostomies, or PEGs).[7] Distinct advantages of endoscopically placed gastrostomy tubes over surgically placed tubes include relative ease of placement, avoidance of general anesthesia, smaller incision, and a lower morbidity rate.[2,7,8] The disadvantages of endoscopic techniques include the inability to place tubes in patients with thick abdominal walls, a history of multiple previous operations, and the presence of abdominal wall hernias, as well as an increased risk of injuring overlying viscera during the "blind" placement of the PEG tube. Another disadvantage is the unique danger of accidental dislodgement of a newly placed PEG tube. If a new PEG tube is dislodged, the stomach wall gastrotomy can pull away from the abdominal wall allowing the escape of gastric secretions and feedings with resultant peritonitis.

Popular endoscopic techniques in use today require two persons—an endoscopist and an operator at skin level. An endoscope is first advanced into the stomach (**Figure 64-2A**). The stomach is then insufflated with air to displace adjacent or overlying loops of bowel and appose the stomach wall to the anterior abdominal wall (**Figure 64-2B**). The endoscopist then visualizes the light of the endoscope as it transilluminates the abdominal wall. They then pierce the anterior abdominal wall with a hollow-bore needle (**Figure 64-2C**). The endoscopist confirms placement of the device into the gastric lumen (**Figure 64-2C**).

The gastrostomy tube is then placed. A guidewire is fed into the stomach through the needle, grasped with an endoscopic snare, and pulled out of the patient's mouth (**Figure 64-2C**). The "Ponsky pull" technique uses this guidewire as a means for pulling the gastrostomy tube into position through the patient's mouth (**Figure 64-3A**). The guidewire is secured around a gastrostomy tube and pulled retrograde from the mouth to the exit site on the anterior abdominal wall. The "Ponsky push" technique involves pushing the tube down and over the guidewire toward the gastrostomy site[9] (**Figure 64-3B**). A third technique, the "Russell poke" eliminates the need to direct the gastrostomy tube through the mouth.[10] Under direct visualization, a dilator is used to enlarge the skin puncture site. An introducer and a peel-away sheath are then used to place the gastrostomy

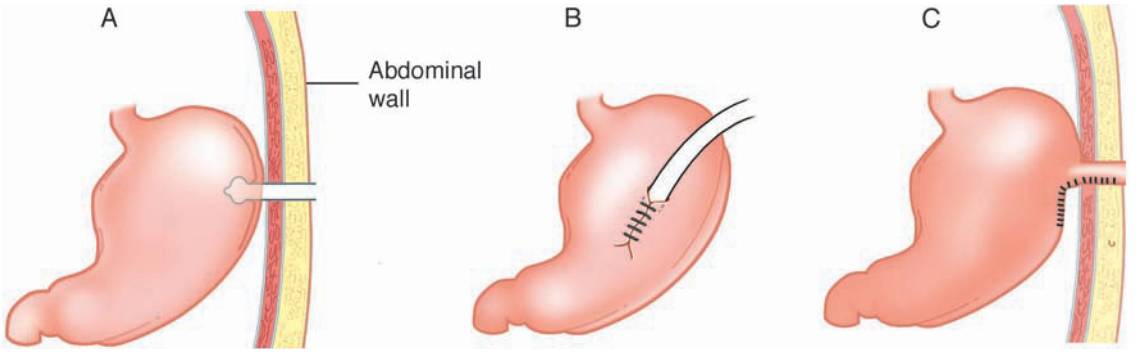


FIGURE 64-1. Surgical gastrostomies. **A.** The Stamm technique. **B.** The Witzel technique. **C.** The Janeway technique.

tube directly through the anterior abdominal wall (**Figure 64-3C**). **Regardless of which technique is used to establish the gastrostomy, the stomach is not sutured to the abdominal wall.** Instead, a fibrous tract eventually forms between the anterior abdominal wall and the stomach. **The maturation of this tract is an important consideration in assessing gastrostomy tubes.**

TYPES OF GASTROSTOMY TUBES

Although there are many types available, a basic understanding of gastrostomy tubes is all that is needed to diagnose and treat most problems. Familiarity with the characteristics of gastrostomy tubes is helpful in assessing tube function and determining appropriate replacements.

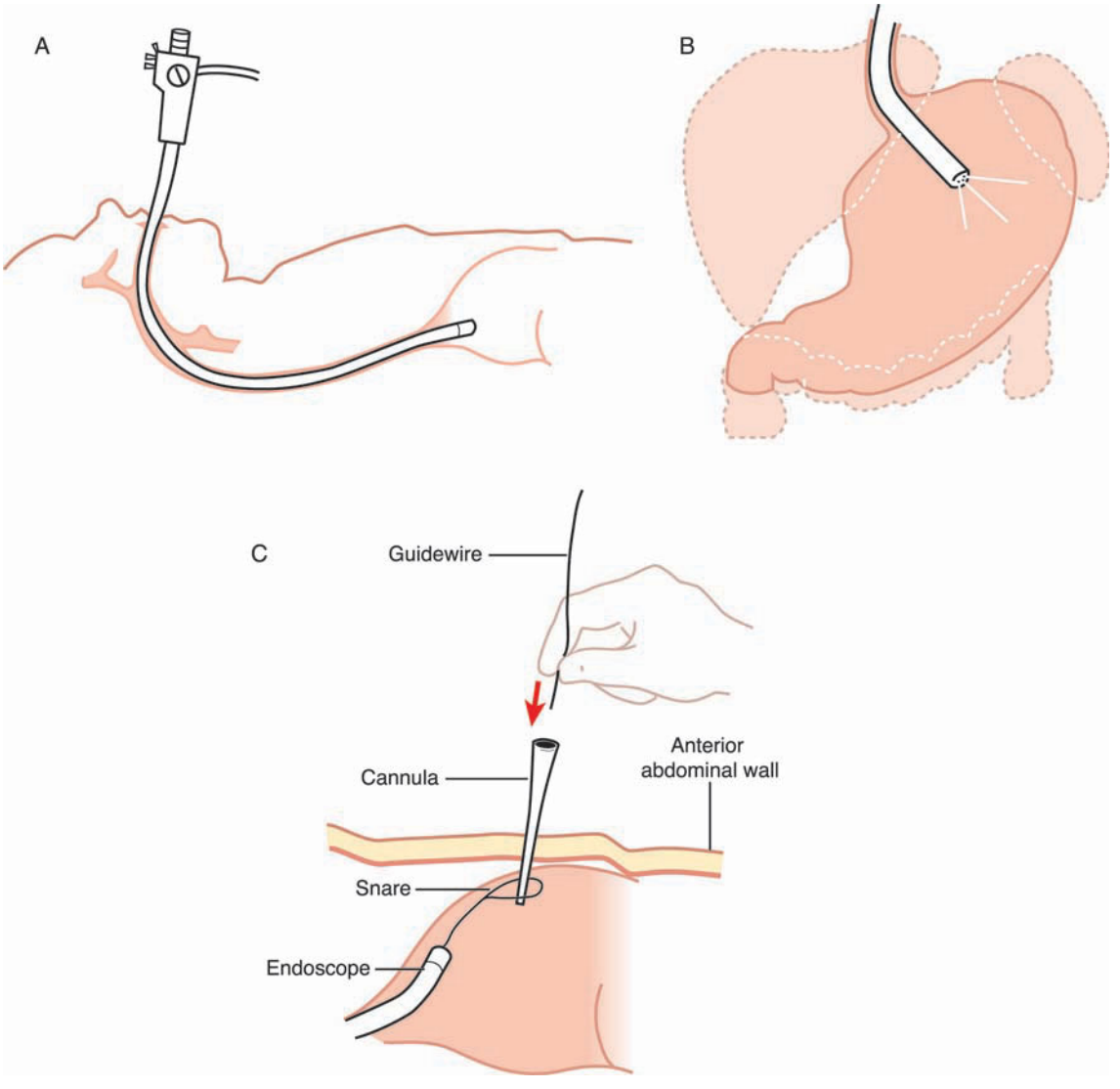


FIGURE 64-2. Endoscopic gastrostomy tube placement. **A.** The endoscope is inserted. **B.** The stomach is inflated with air and transilluminated. **C.** The anterior abdominal wall is pierced with a cannula or needle under endoscopic guidance. A suture or guidewire is then introduced into the gastric lumen and grasped with a snare.

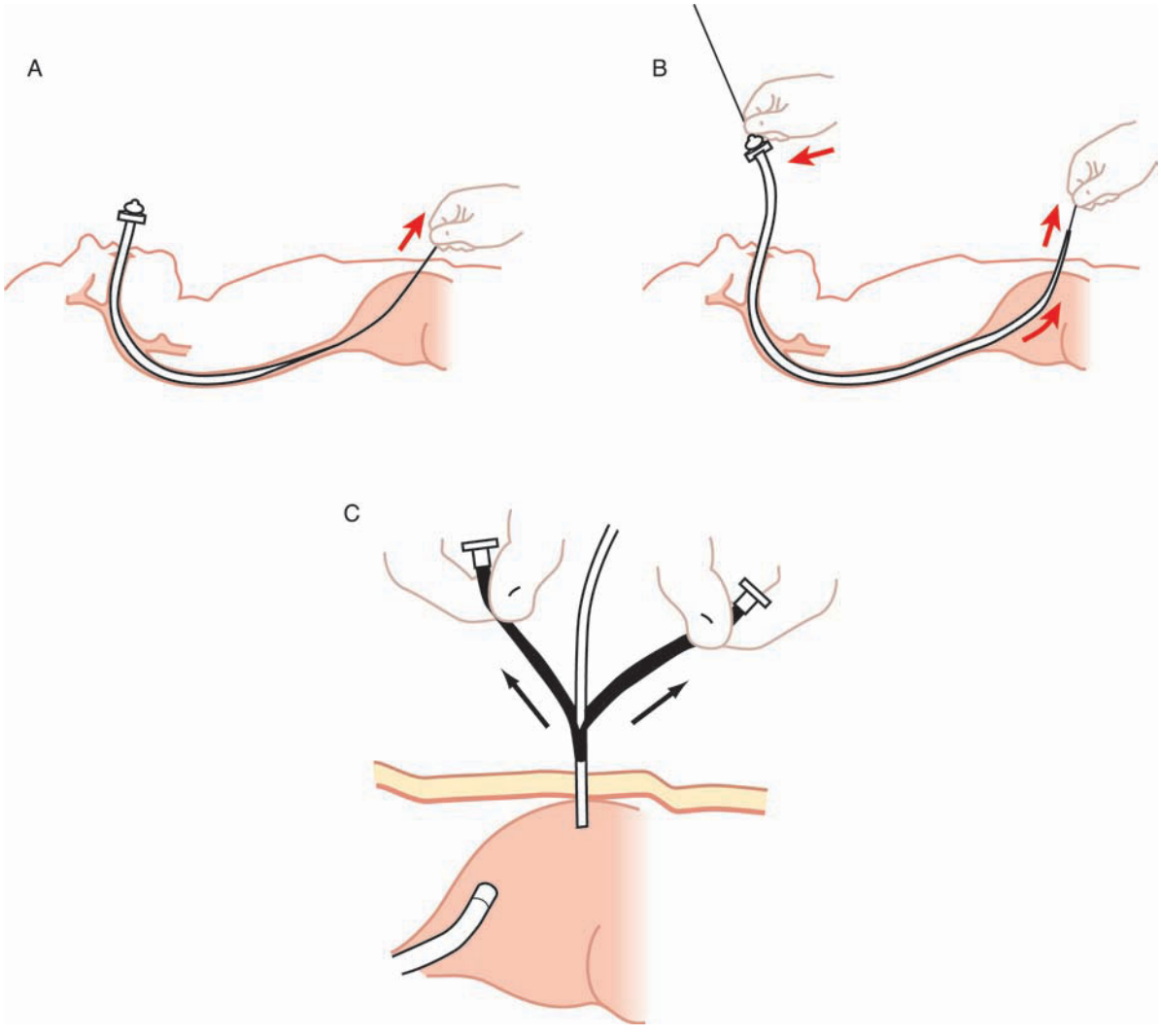


FIGURE 64-3. Endoscopic gastrostomy tube placement. **A.** The "Ponsky pull." A suture is attached to a modified gastrostomy tube and pulled in a retrograde direction through the anterior abdominal wall. **B.** The "Ponsky push." A guidewire serves as a trolley for the gastrostomy tube to be pushed over. **C.** The "Russell poke." The gastrostomy tube is inserted through a peel-away sheath.

The gastrostomy tube is simply a conduit for enteral feedings. The essential features of the gastrostomy tube include four components: the tube itself, an internal bolster, an external fixation (bolster or retention) device, and the ports (**Figure 64-4**). The main body of the gastrostomy tube is made of silicone or polyurethane. It is designed to minimize tissue reactions and optimize patient comfort. Gastrostomy tubes come in a variety of sizes ranging from 12 to 24 French. Some are reinforced with an inner steel wire. Many come with external identification marks to denote caliber, commercial brand name, centimeter markings to aid in positioning, and radiopaque lines to aid in radiographic identification (**Figure 64-4**).

The internal bolster fixes the gastrostomy tube within the lumen of the stomach and creates a seal to discourage leaking (**Figure 64-4**). Commercially available PEG catheters come with a variety of choices for internal bolsters including balloons, crossbars, T-bars, flanges, round disks, three-leaf retainers, soft domes, and others (**Figure 64-5**). The most basic tubes use a balloon as an internal bolster. Surgical gastrostomies commonly use Foley balloon catheters, mushroom-tip de Pezzer catheters, or Malecot catheters. Some internal bolsters are deformable and allow removal with gentle traction on the external tube. Others are not intended to give way with traction and require more invasive techniques for removal. The nature of the internal bolster will determine if a gastrostomy tube can be removed at the bedside or requires endoscopic removal.

External bolsters are devices at the skin exit site that secure the gastrostomy tube to the abdominal wall and prevent its inward migration (**Figure 64-4**). Surgical gastrostomies frequently rely on only a silk suture. PEGs typically use a T-bar or retention disk. The external bolster has little impact on the function of the gastrostomy tube or the technique used to place it. The external bolster may cause the gastrostomy tube to kink, fracture, or clog if it is too tight. Additionally, an external bolster that pulls the internal bolster too tightly toward itself may cause stomach wall and/or abdominal wall necrosis. Conversely, the gastrostomy tube may migrate inward with peristalsis and cause a bowel obstruction if the external bolster is too loose. Inappropriate care of the external bolster may lead to problems that contribute to the need for replacement, although it does not affect the ability to remove the gastrostomy tube. Identification and correction of problems with the external bolster can prevent unnecessary damage to the gastrostomy tube.

The external end of the gastrostomy tube contains the port(s) to access the lumen(s). Many tubes have a Y port, with one port for enteral feedings and a pop-off valve port to access a balloon (**Figure 64-4**). Some tubes have multiple ports to access each

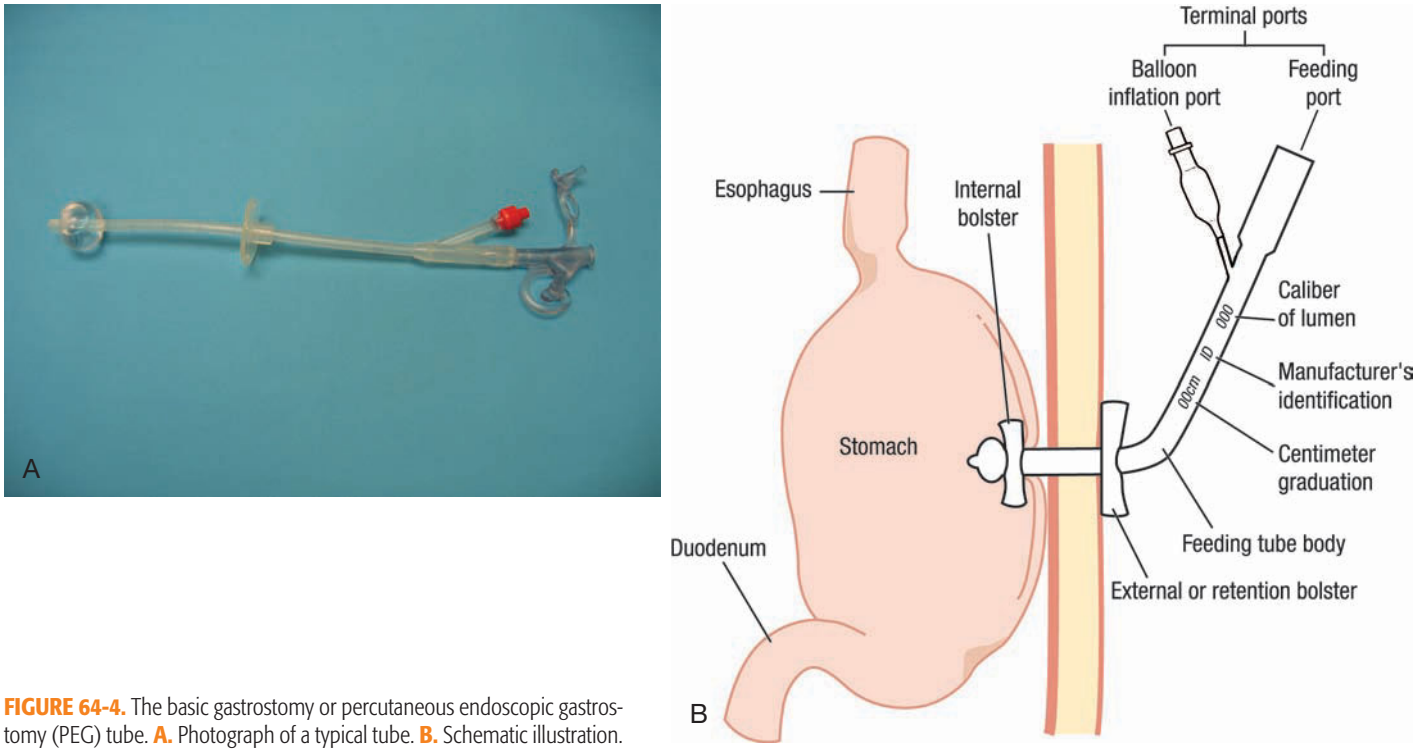


FIGURE 64-4. The basic gastrostomy or percutaneous endoscopic gastrostomy (PEG) tube. **A.** Photograph of a typical tube. **B.** Schematic illustration.

separate lumen that is designated for a specific purpose, such as medication administration. Others have a suction port for gastric suctioning and a port for distal feeding.

In an effort to improve patient comfort and acceptance, some manufacturers now supply skin-level devices. These are also referred to as low-profile systems or buttons. These tubes combine the external access port and the external bolster to provide a more cosmetically appealing look without a dangling tube.

INDICATIONS

There is no need for routine removal or replacement of gastrostomy tubes. The most common indication for gastrostomy tube replacement is accidental removal. Occasionally, gastrostomy tubes require replacement because they wear out, kink, or fracture. They should be replaced if the lumen becomes clogged with precipitate and cannot be unclogged. Most of these problems can be avoided with diligent care of the gastrostomy tube. Feedings should never be forced—a common error that can weaken the tube. The feeding tube should be flushed with water after each use. Medications should never be mixed with enteral feeding solutions. Proper care of the gastrostomy tube should prevent premature loss. Family members and healthcare providers should receive detailed instructions regarding gastrostomy tube management so as to avoid common problems.

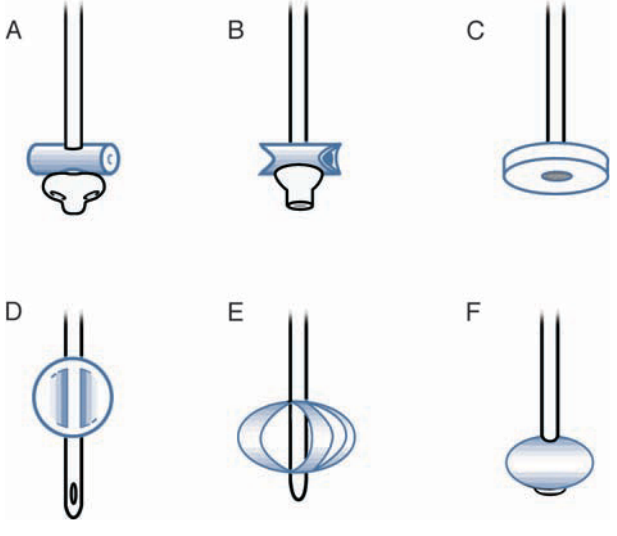


FIGURE 64-5. Examples of internal bolsters used in PEGs. **A.** Mushroom tip with de Pezzer flange. **B.** Crossbar. **C.** Round disk. **D.** Balloon tip. **E.** Malecot. **F.** Soft dome.

CONTRAINDICATIONS

A damaged, malfunctioning, or displaced gastrostomy tube should be replaced as soon as possible, with a few exceptions. **The existing tube should be left in place if the tract is immature. Premature removal of a tube in an immature tract, particularly if it is endoscopically placed, can lead to gastric spillage and peritonitis.** The exact time for a tract to mature depends upon the procedure used and the patient's nutritional status. A conservative approach is to consider any tract less than 4 weeks old to be immature. The specialist who performed the original procedure should be consulted prior to any manipulation of the immature tract. The gastrostomy tube and tract should be left alone and a Surgeon consulted if a patient has peritonitis at the time of presentation. If the patient has acute abdominal pain after manipulation of a gastrostomy site, feedings should be withheld until an investigation determines the source of the problem. Do not manipulate or change the gastrostomy tube if the patient has pain at the skin entry site or with movement of the tube. This may alert the clinician to an underlying abscess, infection, or intraabdominal pathology.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Commercial replacement gastrostomy tube kits
- Foley catheter of a similar caliber as the original tube

- 20 mL syringe with saline to fill the Foley balloon
- Water-soluble lubricant
- Toomey syringe or bulb syringe to aspirate gastric contents
- Some form of external bolster (see the text below)
- Adapter to cap off Foley catheter or attach it to feeding assembly
- Gloves

PATIENT PREPARATION

Explain the procedure to the patient and/or their representative. Gastrostomy tube replacement can usually be accomplished with little preparation or anesthesia. Place the patient supine. Clean the skin surrounding the entry site of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Anesthesia should not be necessary, as the gastrostomy site should not be tender. Significant pain at the site should alert the clinician to an infection, abscess, or intraabdominal pathology. **If anything more than minor discomfort occurs, the gastrostomy should not be manipulated.** Small children or anxious patients may benefit from mild sedation.

TECHNIQUES

The technique for replacing a gastrostomy tube will depend upon the original procedure used to place the tube, the maturity of the tract, and the nature of the internal bolster. Obtain as much information as possible about the age and nature of the existing tube. The following discussion reviews the procedure for replacing gastrostomy tubes in mature tracts, factors to consider prior to removing an existing but dysfunctional tube, and techniques to employ in fashioning replacement systems.

REPLACING A DISLODGED GASTROSTOMY TUBE

Every effort should be made to replace a dislodged gastrostomy tube as soon as possible. Gastrostomy sites begin to close as soon as the tube is removed. The tract will close within hours to days depending on its age, maturation, and size of the tube. If the original tube is in good condition, it can simply be reinserted to stent the tract until a permanent replacement is found. A commercially available replacement that is compatible with the original tube may be used. Foley catheters are simple to use, are widely available, and function well as temporary replacements.[8,11–13]

Select a tube of similar caliber to the patient's gastrostomy tube. Most commonly, a Foley catheter is used. A decision regarding the choice of external fixation should be made, and the tube adapted appropriately prior to its insertion (see discussion below). Lubricate the replacement tube liberally. Gently insert the replacement tube through the tract. **Do not advance the tube against any significant resistance. Advancement against more than mild resistance can result in complications.** Aspirate gastric contents to confirm proper placement. Inflate the Foley catheter balloon with saline. Pull the Foley catheter snug to lodge the balloon immediately behind the anterior abdominal wall. **The entire process should be painless and should not require dissection or force.** Inject the feeding port with water-soluble contrast and obtain a KUB to confirm proper placement

A few types of feeding tubes merit special attention. While many gastrostomies have a short, direct route to the stomach, the Witzel uses a more circuitous tunnel and a smaller tube. The tract may be difficult to maneuver. When problems replacing a surgical gastrostomy tube arise, obtain surgical consultation.

Not all feeding tubes terminate in the stomach. In some cases, the feeding tube enters the stomach, travels through the pylorus and duodenum, then terminates in the proximal jejunum. If a patient is known to have a jejunostomy (sometimes referred to as a percutaneous endoscopic jejunostomy, or PEJ), the tract may be stented with a replacement gastrostomy tube. More information should be obtained prior to resuming feedings.

Some catheters are not intended to be replaceable. Small needle jejunostomies may use 5 to 7 French catheters. Should such a catheter become disrupted or occluded, there is little one can do to correct it. Consult with the patient's primary care provider to discuss the variable options for management and follow-up.

PLACING AN EXTERNAL BOLSTER

After the successful insertion of a replacement tube, it needs to be secured in place. The tube should be kept 90° relative to the skin and fixed in some way to prevent migration into the distal bowel. A short-term solution is to dress the site with 4 × 4 gauze squares, building them up along the exit site to create a pyramid-shaped dressing several inches high. A strip of urethane foam can be used to bolster the tube[14] (**Figure 64-6A**). A 3 cm section of latex tubing can be wrapped about the base of the gastrostomy tube and secured with a plastic cable tie[15] (**Figure 64-6B**). A modification to a Foley catheter uses a retention disk and a plastic ring from a nasogastric tube to secure the Foley catheter (**Figure 64-6C**).[13]

Another option is to secure and bolster the tube with a suture (**Figure 64-7**). Some prefer to inject local anesthetic solution subcutaneously to minimize the discomfort of placing the single suture. Others believe placing the one suture is equal to the pain of injection of the local anesthetic agent and do not use it. This decision should be decided on a case-by-case basis after a discussion with the patient and/or their representative. Place a suture using a large bite of tissue near the skin exit site. This serves as a retention suture. Leave an open loop of 1 to 2 cm between the skin and the knot to avoid unnecessary traction on the skin. Wrap the ends of the suture up the gastrostomy tube in a laddered fashion and tie them securely. This method allows some room for the gastrostomy

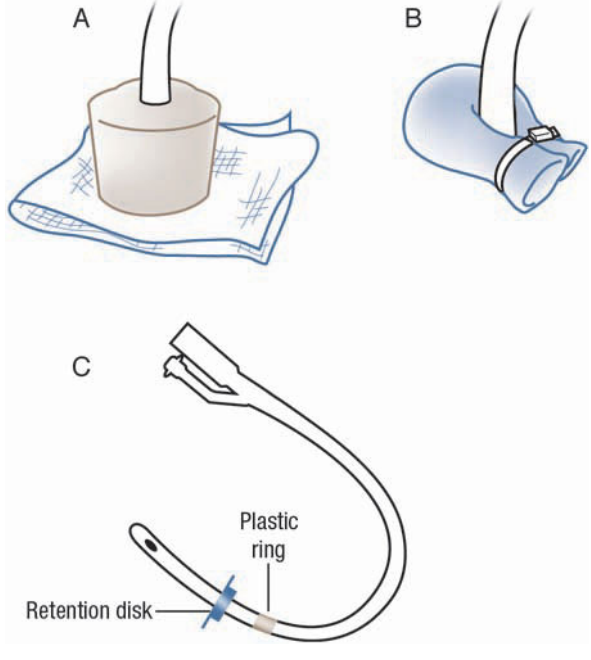


FIGURE 64-6. Types of external bolsters. **A.** Urethane foam dressing. **B.** Latex tubing wrapped about the base of the tube and secured with a plastic cable tie. **C.** A Foley catheter modified with a retention disk and plastic ring.

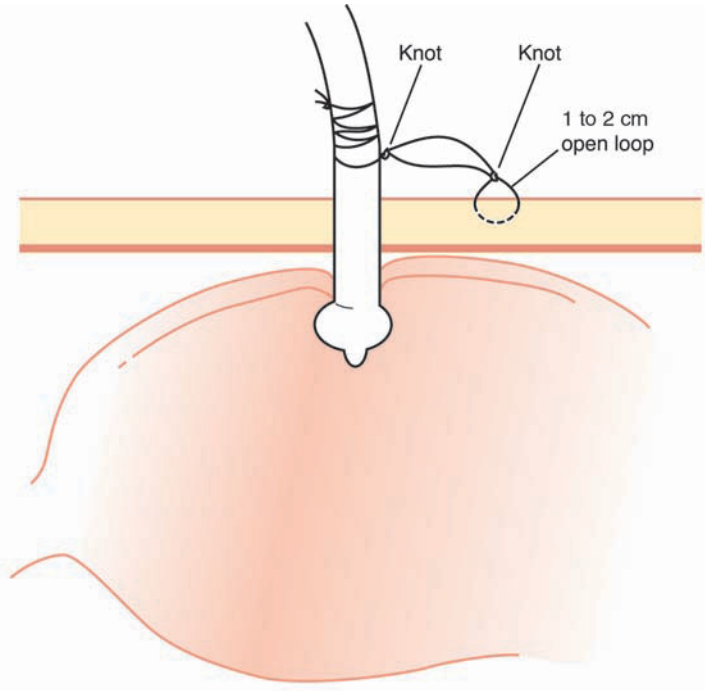


FIGURE 64-7. Simple external fixation using a silk suture laddered up the gastrostomy tube.

tube to move while preventing inward migration as the patient changes position.

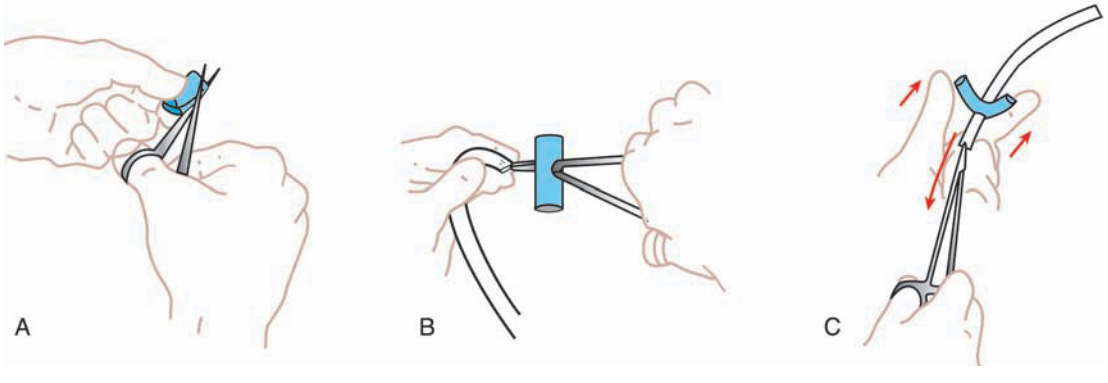
These techniques are adequate for short-term use, but a more permanent form of external fixation is desirable. A number of external bolsters have been described that can be fashioned from materials available in most healthcare facilities. A T-bar external bolster can be made by cutting a 3 cm piece of tubing from a latex or silicone Foley catheter or feeding tube[11] (**Figure 64-8**). Fold the piece of tubing in half. Make two diamond-shaped cuts placed on the sides of the fold and opposite each other (**Figure 64-8A**). Insert a hemostat through the holes and grasp the replacement Foley catheter (**Figure 64-8B**). Slide the latex T-bar along the catheter (**Figures 64-8C & D**). In order to function satisfactorily, the latex T-bar must be snug enough to prevent migration but not so snug as to compress the Foley catheter lumen. After placement of the Foley catheter, position the latex T-bar so that it is about 0.5 to 1.0 cm from the skin surface.

There are several commercially available products designed specifically for replacement gastrostomies. They are convenient. Unfortunately, they are expensive, may not be compatible with the original tube, and may not be on hand at the moment they are needed.

Once the replacement tube's position is confirmed and secured, the end of the tube should be clamped or fitted with an appropriate feeding adapter.

NONFUNCTIONING GASTROSTOMY TUBES

A patient may present with a clogged, leaking, cracked, or fractured gastrostomy tube. A number of factors should be considered prior to removing any existing tube. Is the tract mature? Is replacement actually necessary or can other measures remedy the problem? What is the type of internal bolster and can it be removed by external traction? **The most important factor is the age and maturity of the tract. Premature removal of the gastrostomy tube from a fresh tract may lead to peritoneal contamination with gastric contents and peritonitis. A new gastrostomy site should not be manipulated without consultation with the specialist who placed**



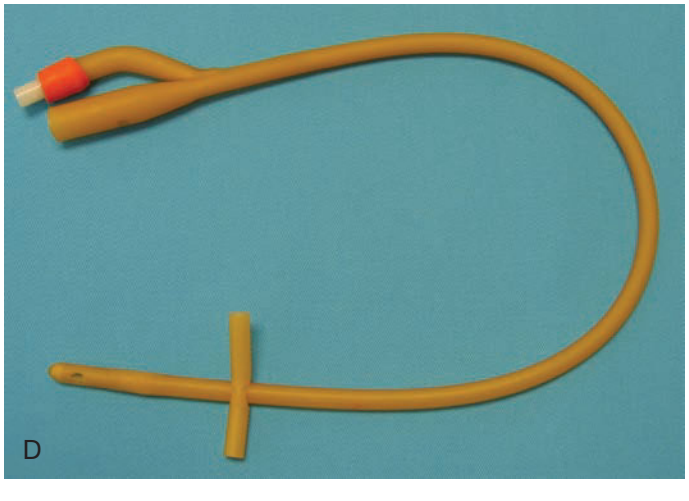


FIGURE 64-8. Fashioning an external bolster from a latex tube and a Foley catheter. **A.** The 3 cm piece of latex tube is folded and cut. **B.** A hemostat is inserted through the latex T-bar and grasps the distal end of the Foley catheter. **C.** The latex tube T-bar is advanced onto the catheter and pulled into position. **D.** The modified Foley catheter with a latex T-bar.

the original tube. A malfunctioning tube may have to remain in place to stent a fresh tract while alternative methods of nutritional support are provided to the patient.

The underlying problem with a nonfunctioning gastrostomy tube should be investigated prior to its removal and replacement. A fractured tube or a tube with a ruptured balloon will need replacement. A kinked tube may only need revision of the external bolster. A clogged tube should first be irrigated with warm tap water, saline, or a carbonated beverage in an attempt to open the lumen. **Do not force the irrigation fluid into the gastrostomy tube, as it may then rupture and injure the patient.** A variety of other options may be tried to open a clogged gastrostomy tube. These include the instillation of enzymes to break up or dislodge the clog with an endoscopic snare, biopsy forceps, or Fogarty catheter.[16,17] The latter methods are usually performed by a consultant and not the Emergency Physician.

A simple, quick, inexpensive, and easy to use device has been developed to declog a gastrostomy tube (Feeding Tube DeClogger®, Bionix Medical Technologies, Toledo, OH). These are flexible plastic wands with a basic screw thread. They come in lengths for gastrostomy and jejunostomy tubes, and various sizes (12 to 24 French). Insert the DeClogger® into the feeding port (**Figure 64-9**). Slowly advance it while rotating it clockwise. Once fully inserted, slowly remove the device from the feeding port. Aspirate and insufflate air to confirm the gastrostomy tube patency. This device may prevent the time and expense of replacing a clogged feeding tube. The patient and/or their caretaker can be taught how to use this device at home, which may prevent a trip to the physician or Emergency Department.

Once the decision has been made to replace a gastrostomy tube, information should be obtained regarding the type of tube in place. Many are removable by gentle external traction. **Never apply more than gentle traction when removing a gastrostomy tube.** If the internal bolster is a balloon, simply deflating the balloon will allow the tube to be removed. Other bolsters such as soft domes and T-bars may deform easily with gentle constant traction. If gentle traction is not sufficient to remove the gastrostomy tube, either the internal bolster is not intended to be removed externally or it may have become embedded within the gastric wall. When difficulty occurs trying to remove a gastrostomy tube, consult the physician who placed the tube. The most likely problems and alternate solutions are discussed below.

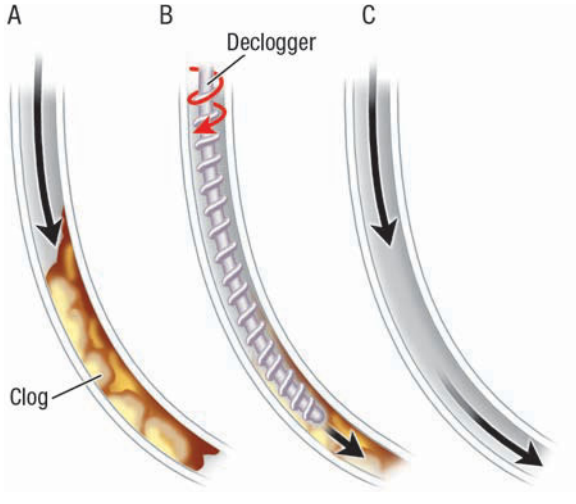


FIGURE 64-9. Using the Bionix Feeding Tube DeClogger. **A.** The clogged gastrostomy tube. **B.** The DeClogger is slowly advanced through the clog while being rotated clockwise. **C.** The clog has been removed and free flow reestablished.

THE BALLOON DOES NOT DEFLATE

The balloon may not deflate if the balloon inflation port is clogged or damaged. There are four options to remedy this situation. Simply cutting the gastrostomy tube may allow the balloon to deflate on its own. Cut the gastrostomy tube close to the ports. Maintain a firm hold, manually or with a hemostat, so that the cut tube does not migrate inside the patient and require endoscopic removal. The gastrostomy tube can be pulled taut to the skin and a needle advanced into the tract to puncture the balloon.[18–20] Alternatively, a guidewire may be advanced through the balloon port to puncture and deflate the balloon.[21] If these fail, the balloon may have to be ruptured internally with an endoscopic snare.

THE TUBE DOES NOT WITHDRAW WITH EASE

Although not universally recommended, one may simply cut the feeding tube at the skin level and push the remaining tube through the tract and into the stomach. This will allow the internal components to pass through the patient's gastrointestinal tract. Retained gastrostomy tube components have been known to cause bowel obstructions and perforations; however, the majority pass without incident.[22] This procedure works for many types of gastrostomy tubes, but it is not clear that this is a safe option for balloon bolsters that have not been deflated. **This option should be used only if a Primary Care Provider agrees with that choice and is available to follow the patient until the contents have passed.** Radiopaque components can be followed by plain radiographs at 24 to 48 hour intervals. The gastrostomy "hardware" may have to be retrieved endoscopically or surgically if it fails to pass within 2 to 3 weeks or the patient experiences obstructive symptoms. This option is not recommended for small children under the age of 6 years or weighing less than 20 kg.[23] These patients have a greater risk for complications.[23]

INADVERTENT REMOVAL OF THE TUBE FROM A FRESH OR IMMATURE TRACT

Whenever a fresh tract is disrupted, there is the possibility of gastric spillage and peritonitis. In such an event, all enteral feedings should be discontinued and the patient observed for the development of peritonitis. A number of replacement options have been described. The tract may be allowed to close spontaneously and a replacement PEG placed in 7 to 10 days if the patient remains well.[24] Alternatively, endoscopy can attempt to reintroduce a replacement tube under direct visualization through the original tract.[25] A General Surgeon should be consulted and laparotomy considered if peritonitis develops. Under these circumstances, the Surgeon may choose to place a surgical gastrostomy.

THE TRACT IS CLOSED

A gastrostomy tract that is not stented will begin to close within hours. A lost tract may require a repeat procedure. This problem requires consultation with an Endoscopist. Dilation of a closing gastrostomy site has been described using filiform catheters and followers or urethral sounds, a procedure adapted from Urology.[26] **This procedure should be performed with caution as it can result in numerous complications.** Interventional Radiologists can often replace dislodged tubes using special techniques.

EARLY BALLOON RUPTURE IN AN INTACT TUBE IN AN IMMATURE TRACT

In this instance, the tract is stented but there is the risk of gastric leakage about a deflated balloon. Esker and Hall report successful replacement using a guidewire to exchange the gastrostomy tube.[27] This technique is performed using endoscopic guidance to snare the guidewire and withdraw the original gastrostomy tube.

ASSESSMENT

The replacement gastrostomy tube should be placed to gravity drainage or the stomach contents should be aspirated. Use of the gastrostomy tube can be resumed if there is free flow of gastric contents. If there was any difficulty with placement of the gastrostomy tube or if the return is equivocal, its position should be confirmed radiographically. A small amount of water-soluble radiopaque contrast should be administered through the gastrostomy tube and a KUB should be obtained. Normal gastrostomy tube placement will show intraluminal contrast. Any extravasation of contrast is abnormal and requires enteral feedings to be withheld and a General Surgeon to be consulted. In most instances, the patient will require hospitalization for parenteral antibiotics, observation, and bowel rest until the tract heals. Some physicians elect to evaluate all replaced gastrostomy tubes radiographically prior to their use. While doing so is harmless to the patient and causes no complications, this process cannot be routinely recommended, as it is time-consuming and expensive.[29,30]

AFTERCARE

Routine maintenance can resume after successful replacement of the gastrostomy tube. Any factors that contributed to the malfunction should be addressed to prevent a recurrence. The patient and/or their caregivers should be taught the proper care and maintenance of a gastrostomy tube. The patient should follow up with their primary physician in 24 to 48 hours for evaluation, removal of the temporary tube, and placement of a gastrostomy tube. Instruct the patient to immediately return to the Emergency Department if they develop a fever, abdominal pain, nausea, or vomiting.

COMPLICATIONS

A variety of complications may accompany the initial insertion of a gastrostomy tube.[2,6,31] However, replacement at a mature site should be relatively free of problems. Excessive force during replacement can disrupt the tract. A misdirected tube may end in a blind pouch or the peritoneal cavity if the stomach separates from the anterior abdominal wall. Installation of enteral feedings intraperitoneally will cause a chemical peritonitis. This should be suspected if there is poor return from the replaced gastrostomy tube, difficulty installing feedings, or the patient develops pain or fever after the procedure. Peritonitis is preventable if proper positioning is confirmed prior to using the replacement tube.[28]

A replacement gastrostomy tube must be sufficiently secured externally so that the effect of peristalsis does not carry it distally. This is particularly true of balloon-tipped tubes. Once the tube migrates past the pylorus, it can cause bowel obstructions and perforations.[2,6] This can be avoided by carefully securing the replacement gastrostomy tube with an external device or suturing it securely to the skin.

Always advance the Foley catheter into the stomach before carefully and slowly inflating the balloon. Inflation of the balloon within the gastrocutaneous tract can result in hemorrhage, pain, and rupture of the tract. Overinsertion of the catheter can cause the balloon to enter the esophagus, duodenum, or gastroesophageal junction. These structures can rupture when the balloon is inflated. These complications can be avoided by inserting the Foley catheter 8 to 10 cm, slowly inflating the balloon, and not inflating the balloon to its maximal volume.

A mature gastrostomy tract begins to close as soon as the tube is removed. The tract narrows without the presence of the gastrostomy tube to keep it patent. Replace the gastrostomy tube as soon as possible. **Never force a tube through the tract.** This can result in bleeding, gastric perforation, intraperitoneal penetration, pain, and the formation of a false passage. Pass a smaller-size tube if necessary to reestablish the tract and maintain its patency.

An indwelling or replacement gastrostomy tube may result in a gastric outlet obstruction. The patient usually presents with distention of the stomach and vomiting. Immediately and gently, pull back on the gastrostomy tube until it is snug against the abdominal wall. Secure the gastrostomy tube with an external bolster. Observe the patient for resolution of their symptoms and any complications.

The skin exit site may become edematous, erythematous, and tender. A simple cellulitis should be managed with oral antibiotics and local wound care. Failure to resolve with antibiotics alone may suggest the presence of an abscess and further imaging or drainage may be required. A dermatitis can result from leakage of gastric contents around the gastrostomy tube. Ensure that the internal bolster is secured against the anterior abdominal wall. If the leakage persists, replace the gastrostomy tube with a larger one that occludes the tract. Local wound care is all that is necessary once the problem with the gastrostomy tube is corrected. Occasionally, hypersensitivity to the adhesive, cleansing solutions, or the gastrostomy tube itself may develop. The use of different materials and topical corticosteroids will correct this problem. A yeast infection (*Candida albicans*) appears erythematous and moist, with satellite lesions. Topical antifungal creams and local wound care will alleviate the yeast infection. Granulation tissue around the stoma can be eliminated by coagulation with silver nitrate sticks. The patient should follow up with their primary physician in 24 to 48 hours for a reevaluation of all these clinical entities.

SUMMARY

Both surgical and endoscopically placed gastrostomy tubes result in a simple fibrous tract connecting a feeding tube to the stomach. A mature tract can be safely and easily manipulated. Problems with an immature tract should prompt consultation. Techniques for the basic maintenance and repair of gastrostomy tubes are straightforward. Familiarity with the procedures and equipment used to establish gastrostomies will help the Emergency Physician solve common gastrostomy tube problems and intervene in an appropriate and timely manner.

65 Paracentesis

Susan B. Promes, Elizabeth M. Datner, and Sam Hsu

INTRODUCTION

The word *ascites* is derived from the Greek *askos* meaning "bag" or "sac." Ascites, an abnormal accumulation of fluid in the abdominal cavity, has important implications diagnostically, therapeutically, and prognostically. Cirrhosis of the liver, which is usually related to alcoholism, accounts for 75% of cases of ascites; malignancy accounts for an additional 10% to 12%, and cardiac failure for another 5%. The remaining cases have a variety of etiologies.[1] Unfortunately, the physical examination is not very reliable when it comes to detecting ascites, making paracentesis and ultrasound (US) important clinical tools.[2] US-guided paracentesis has two key benefits. It not only facilitates performance of the procedure, but it also identifies patients in whom the procedure is not warranted or could potentially be harmful.[3]

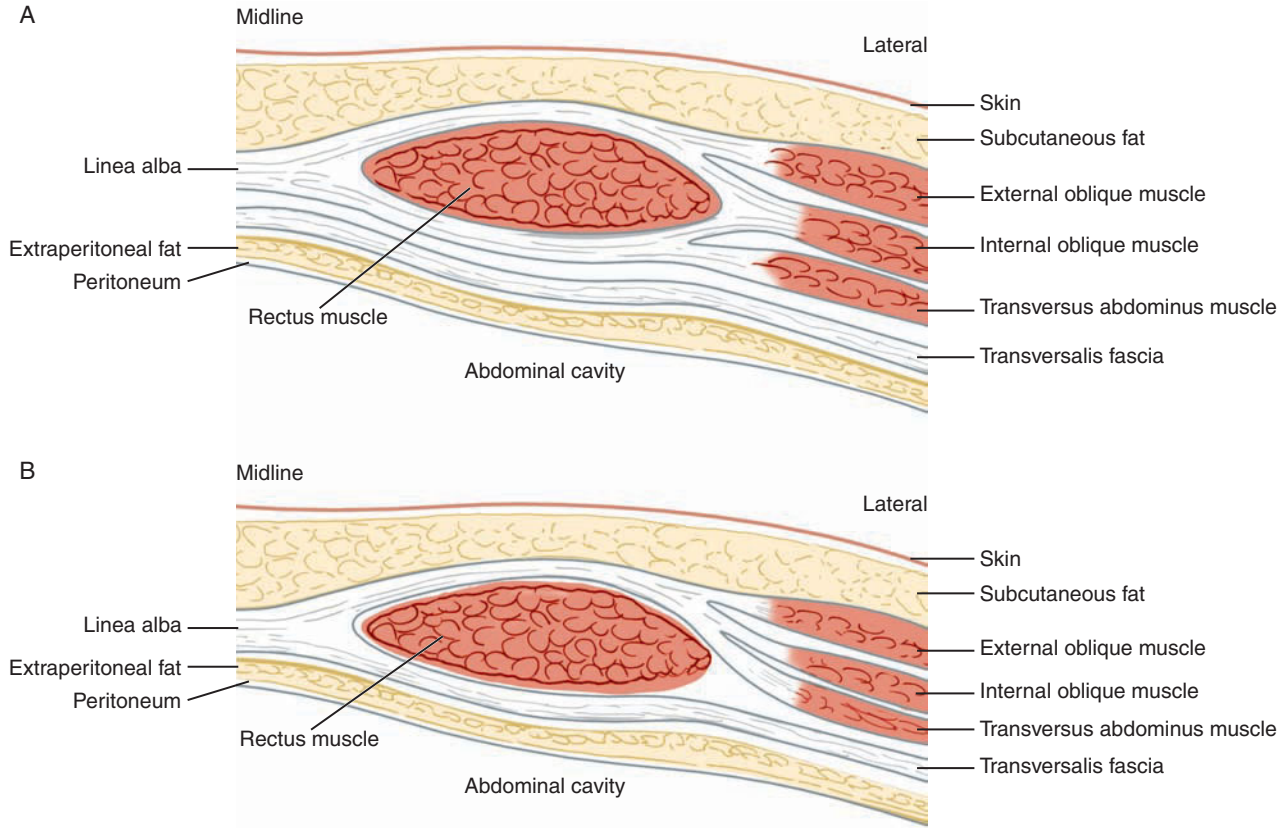


FIGURE 65-1. The layers of the anterior abdominal wall vary above (**A**) and below (**B**) the level of the anterior superior iliac spine.

Peritoneal aspiration of ascitic fluid or paracentesis was first described by Saloman in the early twentieth century.[4] With the introduction of diuretics as well as a fear of procedure-related complications, paracentesis fell out of favor in the 1950s, being replaced by medical management. At that time, large-bore needles were being used and complication rates were significant. Clinical studies published in the late 1980s demonstrated that performing a paracentesis was, in fact, a safe procedure.[5,6] Nowadays, the procedure is commonplace in Emergency Departments.

Paracentesis is an important diagnostic tool for patients with new-onset ascites to determine its etiology and in those patients with long-standing ascites to detect the presence of infection. Spontaneous bacterial peritonitis can be a very subtle disease. Infection occurs in as many as 27% of cirrhosis patients admitted for evaluation of symptoms associated with their ascites.[7] It is well known that some patients with spontaneous bacterial peritonitis are asymptomatic, making peritoneal fluid aspiration, analysis, and cultures imperative.[8] In addition to the diagnostic usefulness of paracentesis, large volumes of ascitic fluid can be removed therapeutically by this procedure in order to improve a patient's respiratory status and comfort level from the pressure of tense ascites. This often occurs in patients with end-stage liver disease as well as in some cases of malignancy. Malignant ascites may occur with carcinoma of the ovary, pancreas, stomach, colon, breast, testes, and a variety of sarcomas and lymphomas.

ANATOMY AND PATHOPHYSIOLOGY

The gross anatomy of the abdomen is well known to the Emergency Physician and is important to review in preparing for a paracentesis. The abdominal cavity is lined by the peritoneum and is protected from the environment by the abdominal wall musculature, fat, and skin. The right and left rectus muscles, which are nourished by the epigastric vessels, meet in the midline at the avascular linea alba. The umbilicus is located along the lower portion of the linea alba. The layers of the anterior abdominal wall structures vary above and below the level of the anterior superior iliac spine (**Figure 65-1**).

The liver sits in the upper right quadrant; when enlarged, it can be palpated in the lower right quadrant. The spleen is normally contained in the upper left quadrant, but when it is enlarged, it can extend into the left lower quadrant (LLQ) of the abdomen. The intestines occupy most of the abdominal cavity and are not rigidly adherent, allowing them to move about in the abdominal cavity. The bladder sits in the pelvis but can enter the abdominal cavity when it is distended with urine.

The abdominal cavity is divided into compartments according to mesenteric attachments. Ascitic fluid can be found anywhere in the peritoneal cavity. The location of the ascitic fluid depends primarily upon the amount of fluid present and the patient's position. Fluid follows the law of gravity. Small amounts of fluid generally accumulate in the cul-de-sac and pericolic gutters. Large amounts of fluid can be found bathing the intestines (**Figure 65-2**). There can also be distinct pockets of fluid in areas of bowel adhesions or scarring. These localized areas of fluid are typically found in those patients who have had previous surgery, trauma, or infection.

Although paracentesis is easily performed blindly, US can provide several benefits. US is diagnostically useful to ensure there is enough fluid to perform a paracentesis. It will identify and help avoid solid organs, masses, and vascular structures. If there are bowel adhesions, US will also identify areas where the bowel is adherent and puncture should not occur. In obese patients, US can measure the



FIGURE 65-2. US of the abdomen demonstrating loops of bowel floating in ascitic fluid (*black*).

soft tissue thickness to the peritoneum, locate the thinnest entry point, and determine the needle length required. US can be used to position the patient so that the maximum amount of fluid collects at the sampling site.

INDICATIONS

A paracentesis can be performed for diagnostic or therapeutic purposes. A paracentesis or "abdominal tap" is warranted in a patient with new-onset ascites to establish the etiology of the fluid. A patient with a history of ascites may need the procedure if they have associated signs and symptoms suggestive of infection such as fever, dyspnea, abdominal pain, encephalopathy, renal impairment, or peripheral leukocytosis.[9] A paracentesis can be performed therapeutically for patients in whom medical management with diuretics has not been successful. It is most commonly performed when an intraperitoneal infection is suspected. Clinical guidelines recommend that patients with ascites admitted to the hospital whether or not they have symptoms of spontaneous bacterial peritonitis should undergo a paracentesis.[9,10] Paracentesis has been used to aid in the diagnosis of ruptured ectopic pregnancy, bowel perforation, and hemoperitoneum due to trauma. More accurate diagnostic procedures should be used rather than a paracentesis for these conditions if they are available.

CONTRAINDICATIONS

There are no absolute contraindications to performing a paracentesis. The relative contraindications include pregnant patients or patients who have a history of abdominal surgery, a current bowel obstruction, a coagulopathy, or thrombocytopenia. Pregnancy is listed because the gravid uterus may fill the space where the procedure is normally performed. If a paracentesis is indicated, it should be performed superior to the uterine fundus. It is important to avoid sites of previous surgical incisions, because adhesions may fix the bowel wall to the abdominal wall, thus increasing the possibility of perforation. Many patients who are subjected to a paracentesis have underlying liver disease and resultant coagulopathies. Some advocate that patients with thrombocytopenia or an abnormal international normalized ratio (INR) should have platelet transfusions or factor replacement prior to performing a paracentesis. This practice is controversial and there are no controlled data to support these contentions.[11] Many, however, would suggest using an infraumbilical midline, also known as a linea alba, approach in coagulopathic patients. This area is free of any vasculature, thus reducing the possibility of bleeding complications. A recent study in which the majority of ascites patients had a paracentesis performed in the LLQ did not demonstrate any bleeding complications.[12] With this in mind, and given that the abdominal wall is thinner and ascitic fluid pools more in the LLQ, this location may be chosen over the infraumbilical approach when US is not being used to guide the procedure.[13]

EQUIPMENT

- Protective eyewear
- Sterile gloves and gown
- Cap and mask
- Povidone iodine or chlorhexidine solution
- Sterile 4 × 4 gauze
- Sterile drape
- Local anesthetic solution with epinephrine
- 25 or 27 gauge needle to anesthetize the skin
- 10 mL syringe for anesthetic
- Choice of needle options: 18 to 22 gauge needle, 3½ in. needle or spinal needle
- Seldinger-type guidewire kit
- Catheter-through-the-needle
- Catheter-over-the-needle—consider Caldwell needle
- Large syringe(s) for fluid collection (20 to 60 mL)
- Intravenous tubing or blood collection tubing if vacuum bottles are being used
- Collection bottles (vacuum) or collection bag
- Adhesive dressing
- Three-way stopcock
- Blood collection tubes for white blood cell (WBC) count, electrolytes, albumin, pH, etc.
- Blood culture bottles (aerobic and anaerobic)
- Sterile specimen container for cytology (optional)
- US machine and probe
- Sterile US gel
- Sterile US probe cover

Commercially available paracentesis kits are available. These contain all the required equipment except the collection bottles. They include the sterile drapes and local anesthetic solution. These are convenient and relatively inexpensive.

A general-purpose curvilinear or phased-array US probe provides the best combination of penetration and field of view into the abdomen. A linear probe can be used for thin, small adults, and children.

PATIENT PREPARATION

Explain the procedure, its risks, and its benefits to the patient and/or their representative. Obtain an informed consent for the procedure. The patient's bladder should be empty. Use an US machine to check for a full bladder or place a Foley catheter to decompress the bladder if the patient is unable to urinate voluntarily. Placement of a nasogastric tube is recommended, although not routine. It prevents an iatrogenic perforation if the stomach is dilated or if a concomitant bowel obstruction is present.

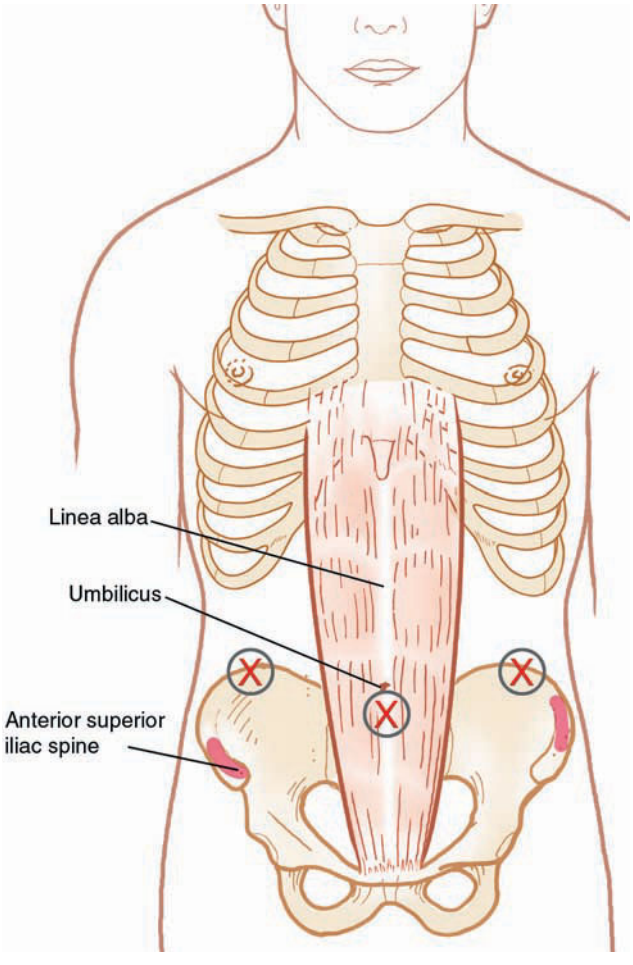


FIGURE 65-3. Needle insertion sites to perform a paracentesis (indicated by a red ⊗). The preferred site is in the midline and 2 cm below the umbilicus. Alternative sites are just medial and 4 to 5 cm above the anterior superior iliac spines.

There are two recommended areas of entry for the paracentesis needle (**Figure 65-3**). The first site is in the midline and 2 cm below the umbilicus. Alternatively, the region 4 to 5 cm superior and just medial to the anterior superior iliac spine in one of the lower quadrants may be used. Some physicians choose the right lower quadrant to avoid the sigmoid colon and spleen. Others choose the LLQ to avoid the cecum and liver. Remember to exercise caution in the region of a scar, prominent veins, caput medusa, or over an area of inflamed or infected skin to minimize complications. US-assisted paracentesis is recommended if an US machine is readily available. Not only can US assist in identifying the ideal fluid pocket but also hopefully avoid a "dry tap".[3]

Place the patient sitting upright for a midline or linea alba approach, lying in the right lateral decubitus position for a right lower quadrant approach, or lying in the left lateral decubitus position for a LLQ approach. Another position one might consider is having the patient assume a hand-knee or "crawling" position. This position, however, is awkward for the Emergency Physician performing the procedure. Remember that the fluid will pool in dependent areas and the bowel will float on top of it—barring any adhesions or masses.

Prepare the patient. Clean the skin around the chosen puncture site of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to delineate a sterile field. Inject 2 to 5 mL of local anesthetic solution subcutaneously and along the needle insertion tract. Allow 3 to 5 minutes for the local anesthetic to take effect.

TECHNIQUES

Z-TRACT TECHNIQUE

A "Z-tract" is used to decrease the possibility of an ascitic fluid leak, especially in patients with tense ascites (**Figure 65-4**). This is the preferred method for inserting the needle. This technique should also be followed when using the other techniques described below. Apply traction on the skin cephalad or caudad to the needle insertion site so that the skin is pulled taut when the needle enters the peritoneum (**Figures 65-4A & B**). The idea is that when the skin tension is released, the skin returns to its normal position and seals off the pathway of the paracentesis needle.

Apply an 18 to 22 gauge, 3½-in needle or spinal needle to a 60 mL syringe. Slowly insert and advance the needle perpendicular to the skin (**Figure 65-4A**) or at 45° to the skin and aimed caudally (**Figure 65-4B**). Apply negative pressure to the syringe as it is being advanced. A loss of resistance should be felt as the needle enters the peritoneal cavity. Stop advancing the needle when ascitic fluid enters the syringe. Continue to aspirate until the syringe is one-half to three-fourths filled with fluid. Depending on the size of syringe consider using a three-way stop cock so syringes can be removed as they are filled.

The omentum, a loop of bowel, peritoneal fat, or other tissue may be occluding the needle tip if ascitic fluid suddenly stops flowing into the syringe. Release the plunger of the syringe. Reattempt to aspirate. If fluid still will not flow, inject 1 to 2 mL of ascitic fluid back into the peritoneal cavity and then reattempt to aspirate. Reposition the needle if ascitic fluid still does not flow into the syringe. **Never reposition the needle while the sharp tip is within the peritoneal cavity. The needle can lacerate the bowel, the omentum, or a blood vessel.** Withdraw the needle to the dermis, reposition it, and then readvance it into the peritoneal cavity. The Caldwell needle appears to be superior to a conventional angiocatheter needle when it comes to problems with fluid return. The Caldwell needle's unique design with fenestrations on the side is believed to allow for continued flow despite occlusion of the needle tip.[14,23]

Note the color and clarity of the ascitic fluid. Aspirate 30 to 50 mL if the procedure is being performed for diagnostic purposes. Withdraw the needle after obtaining the fluid. Immediately place the fluid into the appropriate collection tubes and culture bottles.[15] If the reason for the paracentesis is therapeutic and there is a large collection of fluid that must be drained, hold the needle or catheter securely and remove the syringe. An assistant can place the sample into laboratory containers. Connect the needle or catheter to intravenous tubing. Connect the other end of the intravenous tubing to a suction bottle or bag in order to drain off the desired amount of ascitic fluid. Remove the needle or catheter once the procedure has been completed. Removal results in the formation of the Z-tract, so that ascitic fluid will not leak from the skin (**Figure 65-4C**). Apply a bandage to the skin puncture site. Consider a compression dressing with an occlusive bandage if fluid is oozing from the puncture site.

SELDINGER TECHNIQUE

First described by Seldinger in 1953, this technique allows for the placement of a catheter over a wire (**Figure 65-5**). The wire used must be longer than the catheter. The needle used to insert the wire can be short and of a smaller gauge than the catheter. Materials needed for catheter insertion are commercially available in a prefabricated kit. The Seldinger technique is most commonly used for central venous catheter insertion.

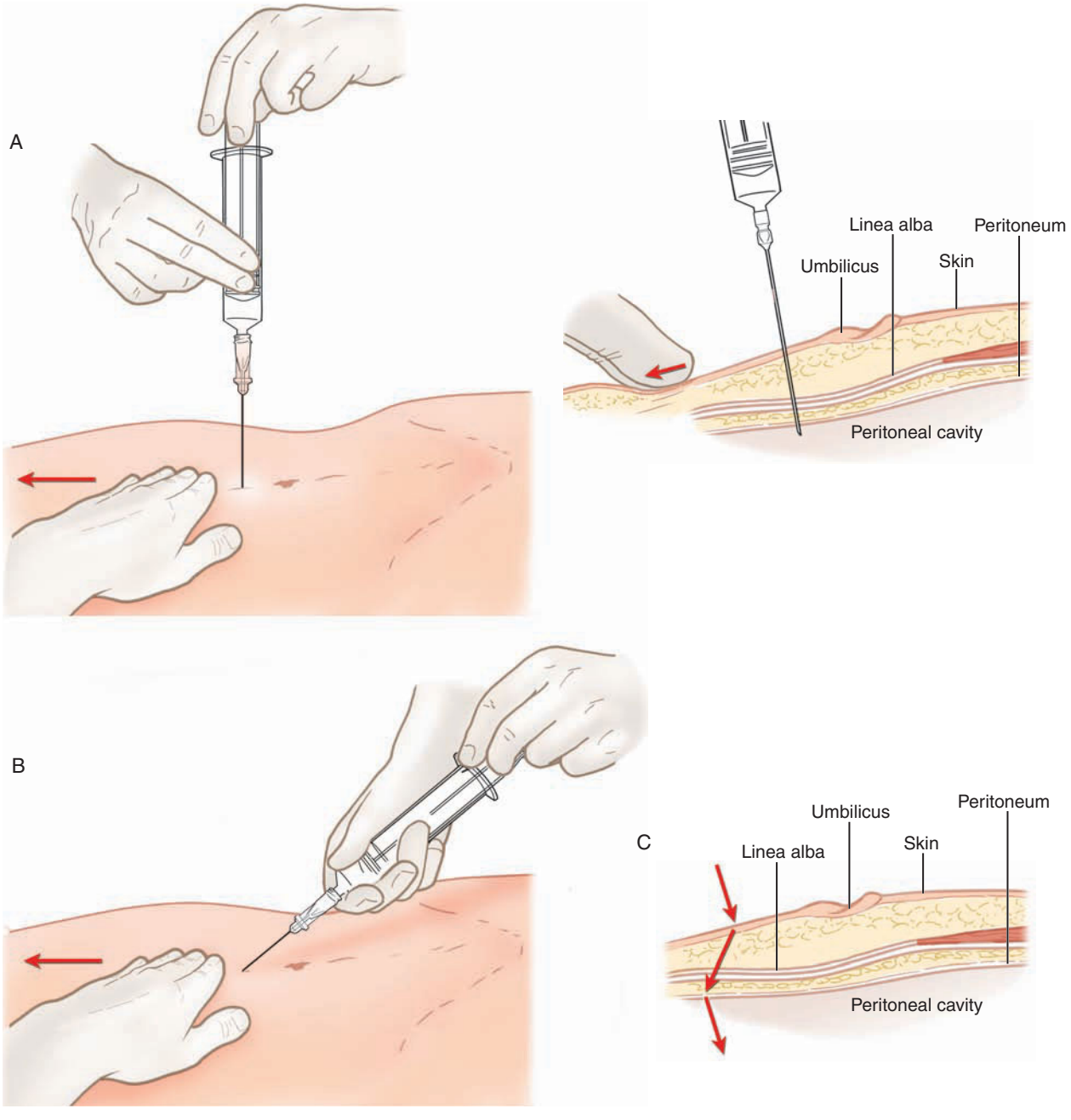


FIGURE 65-4. The Z-tract. **A.** The needle is inserted perpendicular to the skin while the skin is pulled taut. **B.** Alternatively, the needle can be inserted at 45° to the skin and aimed caudally. **C.** The resultant Z-tract (*arrows*).

Choose the puncture site and prepare the patient for the procedure. Insert the thin-walled introducer needle in a Z-tract manner while applying negative pressure to the syringe (**Figure 65-5A**). The introducer needle has a tapered hub on the proximal end to guide the wire into the needle lumen. Avoid using a standard hypodermic needle, as it will not allow for the passage of the guidewire. A flash of fluid in the needle hub signifies that the tip of the needle is within the peritoneal cavity (**Figure 65-5A**). Advance the needle an additional 2 to 3 mm. Hold the needle in place securely and remove the syringe.

Occlude the needle hub with a sterile gloved finger. This will prevent air from entering and ascitic fluid from exiting. Insert the guidewire through the hub of the needle (**Figure 65-5B**). Advance the guidewire to the desired depth, ensuring that it is at least several centimeters beyond the beveled end of the needle. **Always have at least one hand holding the guidewire at all times to prevent it from slipping completely into the peritoneal cavity.** Hold the guidewire securely in place. Remove the needle over the guidewire (**Figure 65-5C**). Make a small nick in the skin adjacent to the guidewire with the #11 scalpel blade included in the kit (**Figure 65-5D**). **Direct the sharp edge of the scalpel blade away from the guidewire to avoid nicking the guidewire.**

Place the dilator through the sheath (or catheter) to form a unit. Advance the dilator and sheath unit over the guidewire (**Figure 65-5E**). Continue to advance the dilator and sheath unit over the guidewire and into the peritoneal cavity (**Figure 65-5F**). A twisting motion may aid in its advancement through the skin and into the peritoneal cavity (**Figure 65-5F**). Advance the unit until the

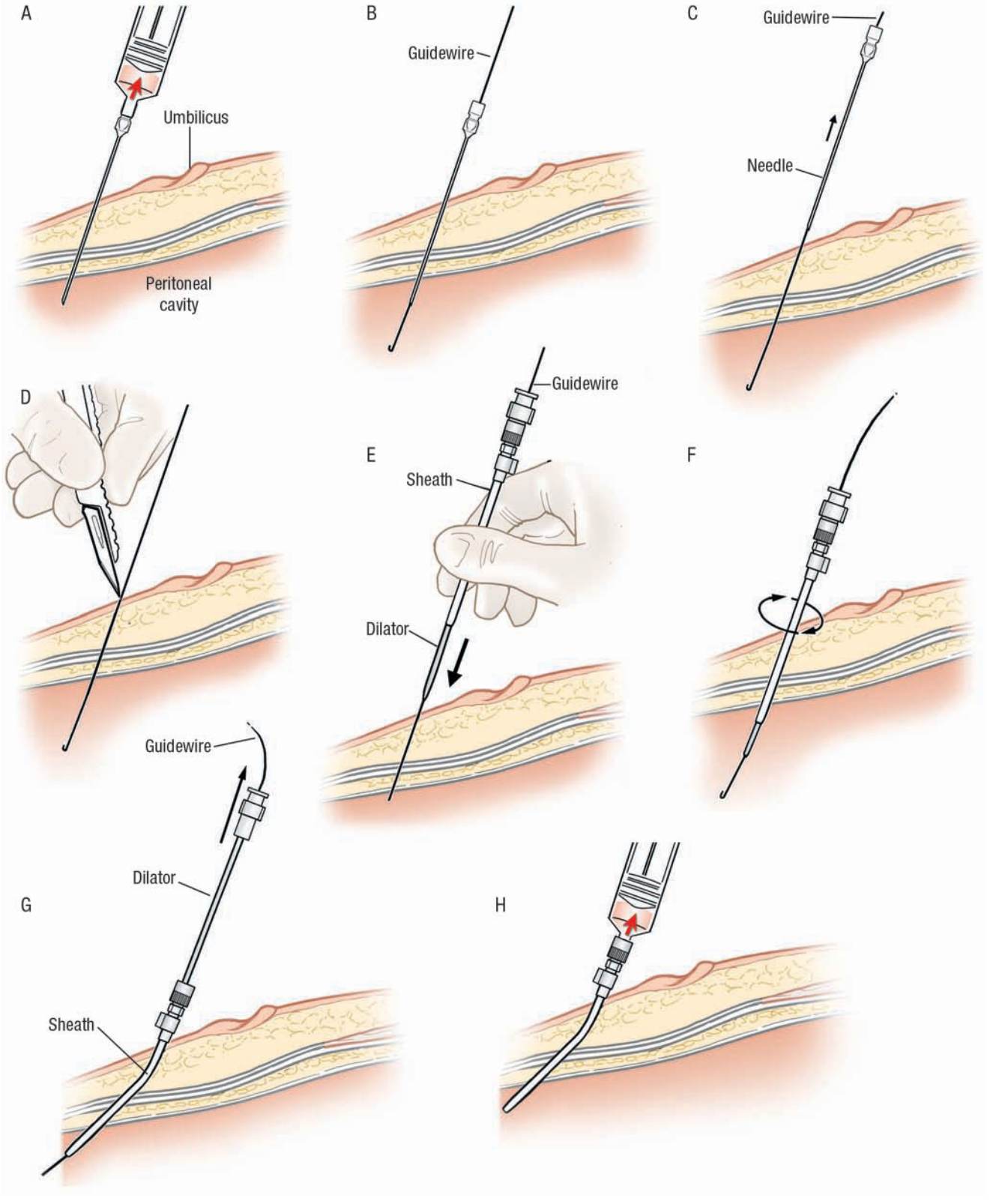


FIGURE 65-5. The Seldinger technique. **A.** The needle is advanced into the peritoneal cavity. **B.** The syringe is removed and a guidewire is inserted through the needle and into the peritoneal cavity. **C.** The needle is removed, leaving the guidewire in place. **D.** An incision is made where the guidewire enters the skin. **E.** The dilator and sheath are advanced as a unit over the guidewire. **F.** The dilator and sheath are advanced into the peritoneal cavity with a twisting motion. **G.** The guidewire and dilator are removed as a unit, leaving the sheath in place. **H.** A syringe is attached to the sheath. The aspiration of ascitic fluid confirms proper intraperitoneal placement of the sheath.

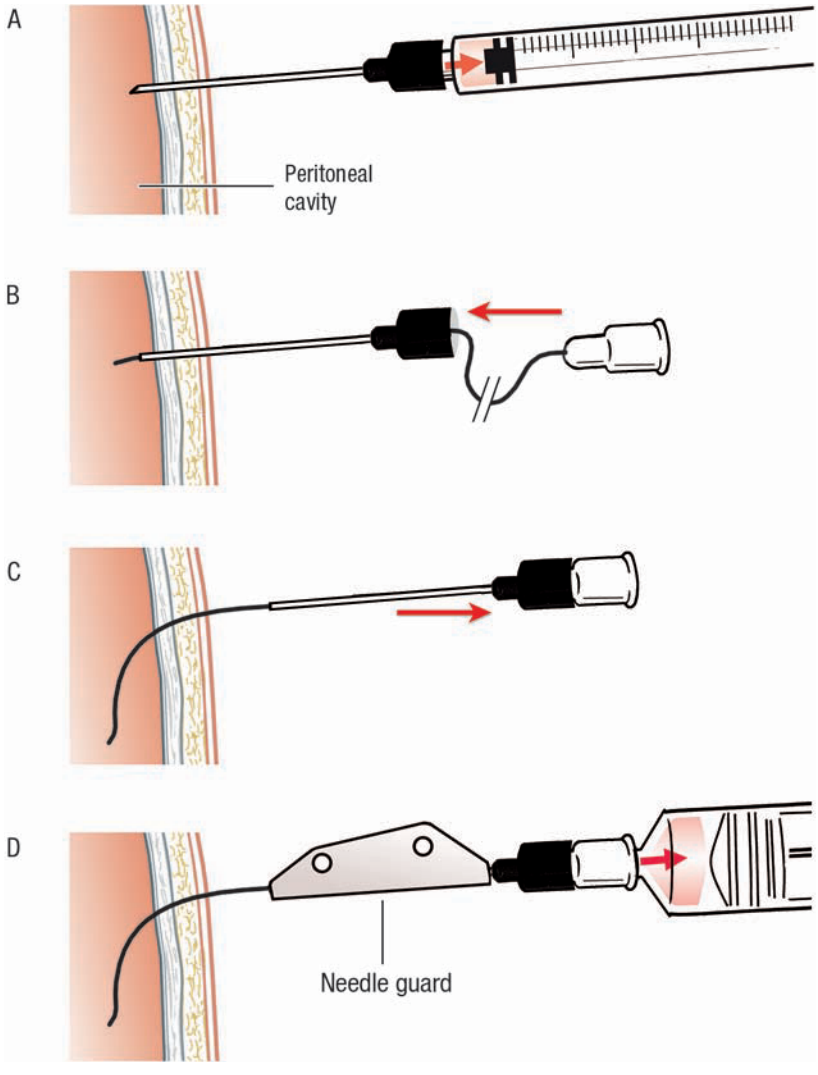


FIGURE 65-6. The catheter-through-the-needle technique. **A.** The needle is advanced into the peritoneal cavity while maintaining negative pressure on the syringe. **B.** The syringe has been removed. The catheter is inserted through the needle. **C.** The needle is withdrawn and the catheter is left within the peritoneal cavity. **D.** A syringe is attached to the catheter and the needle guard applied. The aspiration of ascitic fluid confirms proper intraperitoneal placement of the catheter.

hub of the sheath is against the skin. Hold the hub of the sheath securely. Remove the guidewire and dilator as a unit (**Figure 65-5G**). Attach a syringe to the hub of the sheath (**Figure 65-5H**).

Aspirate fluid from the sheath to confirm intraperitoneal placement. Hold the hub of the sheath securely and remove the syringe. Pass the syringe to an assistant to place the sample into laboratory containers. Connect the hub of the sheath to intravenous tubing. Connect the other end of the intravenous tubing to a suction bottle or bag in order to drain off the desired amount of fluid. An alternative is to attach a three-way stopcock to the distal end of the intravenous tubing. A syringe may then be attached to the stopcock to withdraw laboratory samples or "pump out" the ascitic fluid into a nonsterile container. Remove the sheath once the procedure is completed. Apply a bandage to the skin puncture site. While this technique seems complicated at first glance, it is easy to learn and can be performed in a few minutes by an experienced Emergency Physician.

CATHETER-THROUGH-THE-NEEDLE TECHNIQUE

This system is used most commonly for central venous access. Select a catheter size that is appropriate for the patient and the site of entry. Packaged with each catheter are a needle and a needle guard. The needle will have an inner diameter that is slightly larger than the outer diameter of the catheter. The needle guard has a beveled channel in which the needle can reside. The needle guard hinges closed over the needle to hold it securely and prevent the needle from shearing the catheter.

Choose the puncture site and prepare the patient for the procedure. Place the needle on a tuberculin syringe. Insert the needle through the skin in a Z-tract manner and into the peritoneal cavity while applying negative pressure to the syringe (**Figure 65-6A**). A flash of fluid in the syringe confirms that the tip of the needle is within the peritoneal cavity. Advance the needle an additional 2 to 3 mm to ensure that the tip of the needle is completely within the peritoneal cavity. Securely grasp and hold the needle with the nondominant hand. Remove the syringe with the dominant hand. Immediately place the nondominant thumb over the needle hub to prevent air from entering and fluid from exiting.

Insert the catheter through the hub of the needle (**Figure 65-6B**). Advance the catheter through the needle until the desired length of catheter is within the peritoneal cavity. **If the catheter will not advance, remove the catheter and needle as a unit. Never withdraw the catheter through the needle. The sharp bevel of the needle may cut the catheter as it is being withdrawn and result in a catheter embolism in the peritoneal cavity.**

Withdraw the needle over the catheter (**Figure 65-6C**). **Do not allow the catheter to be withdrawn through the needle.** Continue to withdraw the needle until the tip is completely outside the skin. Apply the needle guard over the needle (**Figure 65-6D**).

Attach a syringe onto the hub of the catheter. Aspirate fluid from the catheter to confirm intraperitoneal placement. Hold the hub of the catheter securely and remove the syringe. Pass the syringe to an assistant to place the sample into laboratory containers. Connect the catheter to intravenous tubing. Connect the other end of the tubing to a suction bottle or bag in order to drain off the desired amount of fluid. An alternative is to attach a three-way stopcock to the distal end of the tubing. A syringe may then be attached to the stopcock to withdraw laboratory samples or "pump out" the ascitic fluid into a nonsterile container. Remove the catheter once the procedure is completed. Apply a bandage to the skin puncture site.

The main disadvantage of this technique is the possibility of the needle tip shearing off the catheter and resulting in a catheter embolism. **This can be prevented by not withdrawing the catheter through the needle and applying the needle guard immediately after the needle is withdrawn from the skin.** Another disadvantage is that the contaminated needle must be handled to some extent, creating a potential risk for needle-stick injuries.

CATHETER-OVER-THE-NEEDLE TECHNIQUE

The catheter-over-the-needle systems are most commonly used for peripheral venous access. The infusion catheter fits closely over a hypodermic needle. The needle and the catheter are advanced as a unit into the peritoneal cavity. They are inexpensive, come in a variety of diameters and lengths, and are widely available. Versions designed to minimize accidental needle-stick injuries are available, and their use is encouraged (**Figure 47-7B**). Placement of these catheters is usually quick and simple. Consider using a Caldwell needle with fenestrations on the side to help minimize problems with the flow of fluid.

Choose the puncture site and prepare the patient for the procedure. Insert the catheter-over-the-needle through the skin in a Z-tract manner and into the peritoneal cavity (**Figure 65-7A**). A flash of fluid in the hub of the needle confirms that the tip of the needle is within the peritoneal cavity. Advance the catheter-over-the-needle an additional few millimeters to ensure that the catheter is within the peritoneal cavity. Hold the hub of the needle securely. Advance the catheter over the needle until its hub is against the skin (**Figure 65-7B**). Withdraw the needle and syringe as a unit. Attach a syringe onto the hub of the catheter (**Figure 65-7C**). Aspirate fluid from the catheter to confirm intraperitoneal placement. Hold the hub of the catheter securely and remove the syringe. Pass the syringe to an assistant to place the sample into laboratory containers. Connect the catheter to intravenous tubing. Connect the other end of the tubing to a suction bottle or bag in order to drain off the desired amount of fluid. An alternative is to attach a three-way stopcock to the distal end of the tubing. A syringe may then be attached to the stopcock to withdraw laboratory samples or "pump out" the ascitic fluid into a nonsterile container. Remove the catheter once the procedure is completed. Apply a bandage to the skin puncture site.

US ASSISTED AND GUIDED PARACENTESIS

The use of US increases the success rates for performing a paracentesis and decreases complications.[22] US may be used to assist or guide the paracentesis. A static technique is used to identify the skin puncture site and ascitic fluid location. The remainder of the procedure is "blind" using one of the above-described techniques. If ascites is not aspirated, the US probe can be placed back on the abdomen to locate the needle and determine if it is off target or not long enough to reach the peritoneal cavity. Occasionally, a dynamic technique is used and the needle inserted using real-time US.

Position the patient. Clean and prep the skin. Scan longitudinally and transversely with the US probe to survey each potential needle entry site (**Figure 65-8**). Ascites appears anechoic (black) and outlines the loops of bowel (**Figure 65-9**). The bowel may be seen

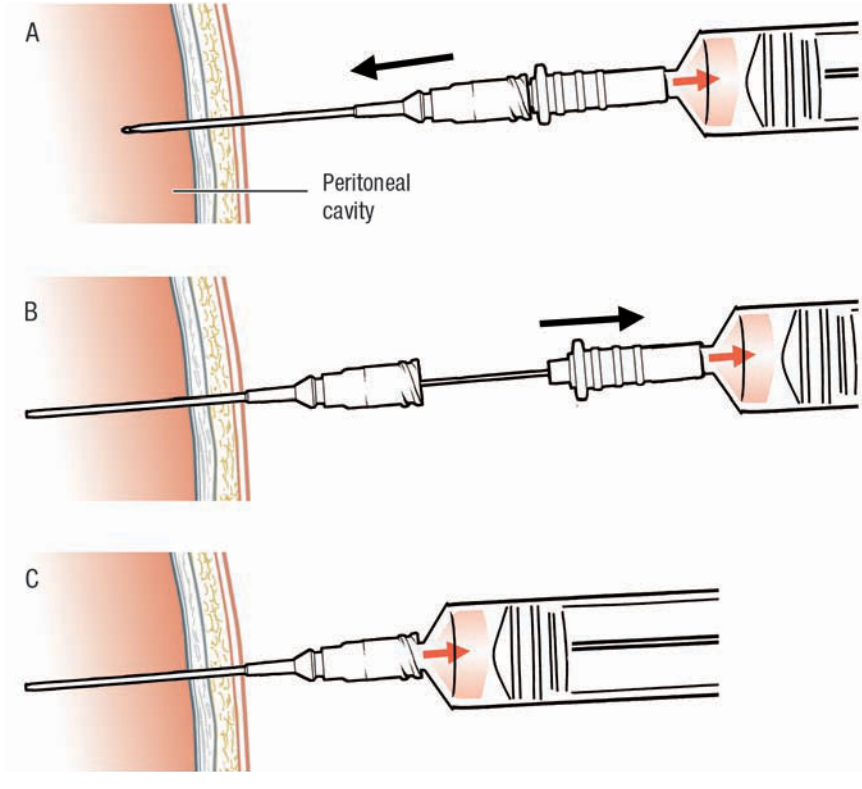


FIGURE 65-7. The catheter-over-the-needle technique. **A.** The catheter-over-the-needle is inserted into the peritoneal cavity while maintaining negative pressure on the syringe. **B.** The needle and syringe are removed. **C.** A syringe is attached to the catheter. The aspiration of ascitic fluid confirms proper intraperitoneal placement of the catheter.



FIGURE 65-8. The patient is positioned and being surveyed for the location of ascitic fluid.

undulating in the ascites as a result of peristalsis. Without ascites, individual loops of bowel cannot be visualized.

Note the amount of fluid and the presence of any structure that might make a particular site undesirable. If no site seems suitable, try repositioning the patient. Note the depth from the skin surface to the fluid. Choose a site with the most fluid at the least depth. Position the US probe so that the target is in the middle of the US view screen. The entry site will now be under the center of the probe. Mark the skin, wipe off the US gel, re-prep the area, and proceed with the procedure. If difficulties are encountered, use the probe to determine the needle's location (**Figure 65-10**).

Do not mistake a cystic fluid collection or the bladder for ascites. Ascites will outline individual bowel loops and appears in many places around the abdomen. Fluid in a cyst or the bladder has

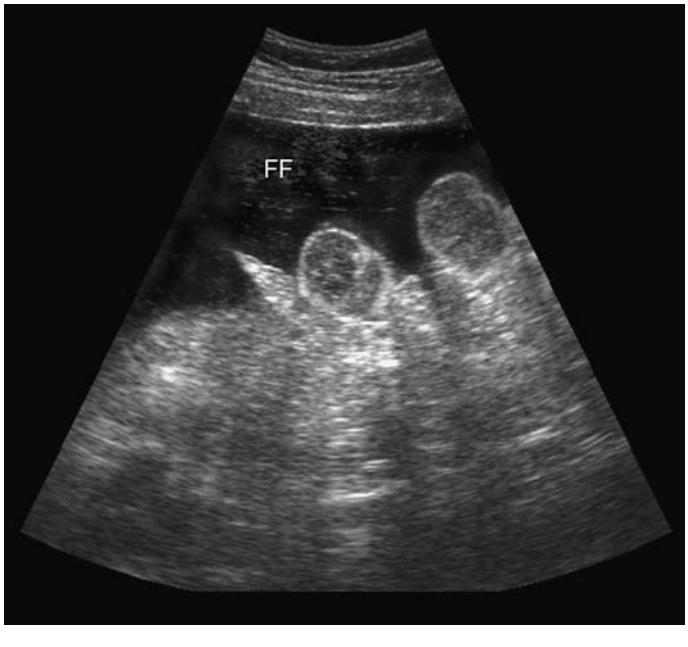


FIGURE 65-9. The presence of anechoic free fluid (FF) allows the individual bowel loops to be discerned.



FIGURE 65-10. The needle (*arrows*) is inserted through the abdominal wall and into the free fluid.

rounded borders and is localized. Loculated ascites will occasionally mimic a cyst but will still outline the bowel.

AFTERCARE

Once the procedure is completed, the puncture site should be bandaged. The site will occasionally ooze fluid in patients with tense ascites. These patients should be directed to change their dressings regularly. Occlusive tape can be helpful in preventing the fluid from leaking onto the patient's clothing and bedding. At times, a simple mattress or figure-of-eight suture is necessary to control the drainage. More recently, Emergency Physicians have used a tissue adhesive such as Dermabond, Indermil, or Histoacryl to help control a fluid leak. The patient may be discharged home if the purpose of the paracentesis was to relieve tense ascites and no signs or symptoms of spontaneous bacterial peritonitis exist and the fluid analysis is unremarkable. The patient should immediately return to the Emergency Department if they develop abdominal pain, nausea, vomiting, abdominal distention, or a fever.

The patient will require hospitalization and intravenous antibiotics if spontaneous bacterial peritonitis is suspected or diagnosed. Empiric antibiotics that cover gram-negative enterics (of which *Escherichia coli* is the most likely) and streptococcal species

(including *Enterococcus*) should be administered in the Emergency Department. A third-generation cephalosporin, such as cefotaxime, covers the most common causative agents in this disorder and should be administered.[9] Ampicillin may be added if *Enterococcus* is suspected. Check previous culture results for antibiotic sensitivities if the patient has a history of spontaneous bacterial peritonitis.

COMPLICATIONS

Complications from abdominal paracentesis are infrequent and rarely serious. However, known complications include shearing of the peritoneal catheter, abdominal wall hematoma, hemoperitoneum, bowel perforation, infection, persistent ascitic fluid leak, and systemic hemodynamic compromise.

Although bleeding is a potential complication of paracentesis, administration of prophylactic blood products such as fresh frozen plasma does not appear to be warranted.[16] Spontaneous hemoperitoneum secondary to mesenteric variceal bleeding has been reported to occur in patients receiving large-volume (i.e., >4000 mL) paracentesis.[17] Patients who developed this complication have had advanced cirrhosis with refractory ascites, previous large-volume paracentesis, and hemorrhagic shock without evidence of gastrointestinal bleeding. Mortality for this complication is exceedingly high. An additional vascular complication, an inferior epigastric artery pseudoaneurysm, has been described as a result of a therapeutic paracentesis.[18]

Perforation of the bowel during paracentesis is rare. Additionally, most of these injuries are self-sealing and develop no further problems. Generalized peritonitis and abdominal wall abscesses have also been reported and are exceedingly rare. Do not move the needle when it is within the peritoneal cavity in order to avoid lacerating the bowel wall.

Ascitic fluid may continue to leak from the site of paracentesis. A simple suture at the site may correct the problem. Patients with persistent leaks should also be evaluated for peritonitis.

Rapid removal of significant amounts of ascitic fluid has been found to cause hemodynamic compromise. Initially, removal of large amounts of ascites causes improvement in circulatory function, likely related to both mechanical (i.e., improved cardiac venous return) and neurohumoral factors. However, total paracentesis in cirrhotic patients may cause delayed (i.e., >12 to 24 hours postprocedure) effective hypovolemia by accentuation of baseline arteriolar vasodilation through neurohumoral mechanisms.[19] The literature suggests that some of the postparacentesis circulatory dysfunction may be avoided by pretreating patients with an intravenous colloid such as albumin.[20] This is not a universally accepted practice.

ASCITIC FLUID ANALYSIS

Normal ascitic fluid should appear clear with a yellow color. Increased turbidity may suggest infection, elevated triglyceride levels, or other particulate matter. Sanguinous fluid is present in patients with malignancy, intraperitoneal bleeding from the intraabdominal organs (spontaneous or iatrogenically introduced), or tuberculous peritonitis.

The specific analytical tests ordered on ascitic fluid should reflect the Emergency Physician's clinical suspicion (**Table 65-1**). Simple analysis of fluid with a cell count and differential, routine cultures, and albumin concentration are all that is necessary in patients with uncomplicated cirrhosis. These initial tests can be supplemented depending upon clinical suspicion. An ascitic fluid pH <7.35 and a blood–ascitic fluid pH gradient ≥0.10 can aid in the diagnosis of spontaneous bacterial peritonitis.[7] Total protein, glucose, LDH, amylase, triglyceride, and bilirubin levels are not helpful except in select circumstances and are not warranted on a routine basis.

TABLE 65-1 Laboratory Tests for Ascitic Fluid

Recommended	Optional	Unusual
Cell count	Total protein	Acid-fast smear and culture
Albumin	Glucose	Cytology
Cultures	LDH	Triglycerides
pH	Amylase	
	Gram's stain	

The serum-ascites albumin gradient is approximately 97% accurate in indicating portal hypertension.[5,21] The gradient is calculated by subtracting the ascitic fluid albumin concentration from the simultaneously measured serum albumin concentration. A gradient of ≥1.1 g/dL suggests portal hypertension as the etiology of the ascites (**Table 65-2**). A gradient of <1.1 g/dL suggests that the patient does not have portal hypertension and that the ascites has some other etiology (**Table 65-2**).

Peritoneal carcinomatosis should be suspected and cytology ordered in those patients with a history of breast cancer, colon cancer, gastric cancer, pancreatic cancer, or the suspicion of undiagnosed malignancy and ascites. Cultures for mycobacteria are approximately 50% sensitive. They should be ordered when the suspicion for tuberculous peritonitis is high, as in patients who have immigrated from endemic areas or have an immunocompromised status.

Patients with uncomplicated ascites secondary to cirrhosis should have an ascitic fluid WBC count < 500 cells/mm^3. The cells should be predominantly lymphocytes and there should be no clinical evidence of peritonitis. If an infection is suspected, a WBC count of >250 cells/mm^3 with greater than 50% polymorphonuclear leukocytes confirms spontaneous bacterial peritonitis. In order to adjust for significant blood in a specimen (RBC > 10,000 cells/mm^3), subtract one neutrophil per 250 RBC.[9] A Gram's stain is usually not helpful other than in the case of spontaneous bowel rupture. Otherwise, the concentration of bacteria is too low to justify utilization of a Gram's stain. All potentially infected ascitic fluid should be cultured by directly inoculating blood culture bottles at the bedside.[15,23]

SUMMARY

Paracentesis is a safe procedure that is common in the practice of Emergency Medicine. There are few relative contraindications to its performance. It is most commonly performed diagnostically to detect spontaneous bacterial peritonitis. It can also be performed therapeutically for symptomatic relief in patients with tense ascites. Complications, although they do occur, are rare.

TABLE 65-2 Classification of Ascites by the Serum to Ascites Albumin Concentration Gradient

High gradient (≥1.1 g/dL)	Low gradient (<1.1 g/dL)
Cirrhosis	Peritoneal carcinomatosis
Alcoholic hepatitis	Tuberculous peritonitis
Cardiac ascites	Pancreatic ascites
Massive liver metastases	Nephrotic syndrome
Fulminant hepatic failure	Serositis in connective tissue diseases
Budd–Chiari syndrome	
Portal vein thrombosis	
Venoocclusive disease	
Fatty liver of pregnancy	
Myxedema	
Mixed ascites	

66 Diagnostic Peritoneal Lavage

Sandeep Johar and Umashankar Lakshmanadoss

INTRODUCTION

The diagnostic peritoneal lavage (DPL) was first described in 1965 by Root who described a method for sampling the peritoneal cavity to determine more rapidly the presence of a hemoperitoneum after trauma.[1] The initial physical examination can be misleading in up to 45% of blunt trauma patients.[2] A DPL can be useful in diagnosing abdominal injury in a timely fashion.[2] It is performed less frequently today due to the use of focused abdominal sonography for trauma (FAST) bedside ultrasound scanning and helical computed tomography (CT). The DPL is the only invasive test of the three and remains the most sensitive test for mesenteric and hollow viscus injuries.[3,4]

Dr. Root's description of the DPL represented an improvement upon the use of paracentesis to identify a hemoperitoneum as described by Salomon in 1906.[5] His initial description of a DPL utilized a trocar placed into the peritoneal cavity to instill fluid. The fluid was visually inspected upon removal and the patient then underwent a laparotomy if it appeared bloody.

DPL has undergone several modifications since its initial description. The trochar technique was abandoned first in favor of the open technique, and later the Seldinger or closed technique.[7,8] A novel method which combines the use of diagnostic laparoscopy and DPL has been termed laparoscopic diagnostic peritoneal lavage (L-DPL).[6] This procedure combines the visual advantages of laparoscopy with the sensitivity and specificity of a DPL for the diagnosis of significant penetrating intraabdominal injury. While the DPL was first described for blunt abdominal trauma, it has found an indication in the patient with penetrating abdominal trauma.[2] Initial attempts to quantify the effluent based on its appearance have been replaced by the red blood cell (RBC) count, the white blood cell (WBC) count, and the measurement of various enzymes.[9–11] The debate still rages in the literature as to which criterion best determines the need for a laparotomy.

ANATOMY AND PATHOPHYSIOLOGY

The gross anatomy of the abdomen is well known to Emergency Physicians and is important to review when preparing for a DPL. The abdominal cavity is lined by the peritoneum and is protected from the environment by the abdominal wall musculature, fat, and skin. The right and left rectus muscles, which are nourished by the epigastric vessels, meet in the midline at the avascular linea alba. The umbilicus is located along the lower portion of the linea alba. The layers of the anterior abdominal wall structures vary above and below the level of the anterior superior iliac spine (**Figure 66-1**).

DPL, unlike a paracentesis, is always performed in the anterior midline of the abdomen (Figure 66-2). The linea alba is an avascular location through which the peritoneal cavity may be entered using either an open technique or a closed Seldinger type technique. This midline location minimizes the number of false-positive lavages that occur due to bleeding from the abdominal wall muscles or blood vessels. This also allows the Surgeon to perform a midline laparotomy, if necessary, through the lavage site and avoid the formation of an avascular skin bridge.

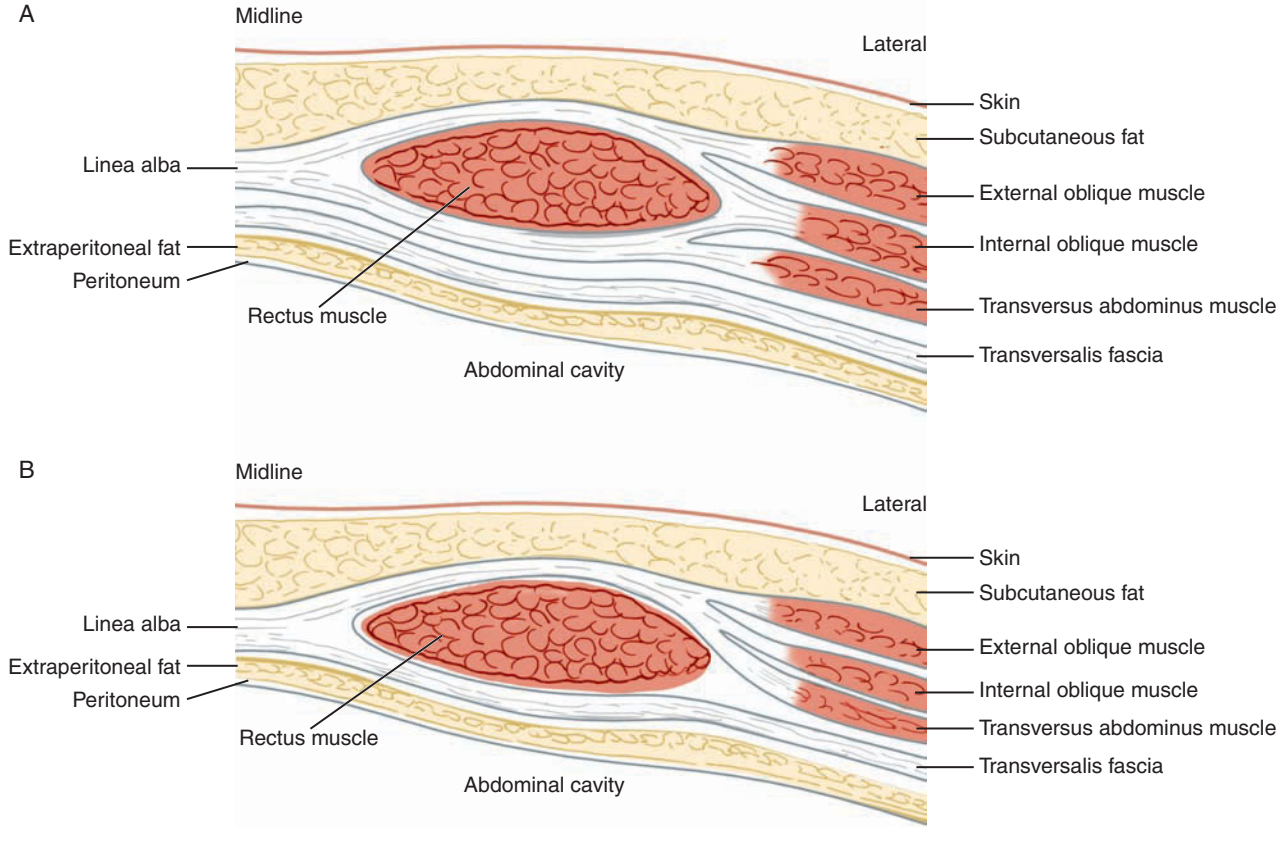


FIGURE 66-1. The layers of the anterior abdominal wall vary above (**A**) and below (**B**) the level of the anterior superior iliac spine.

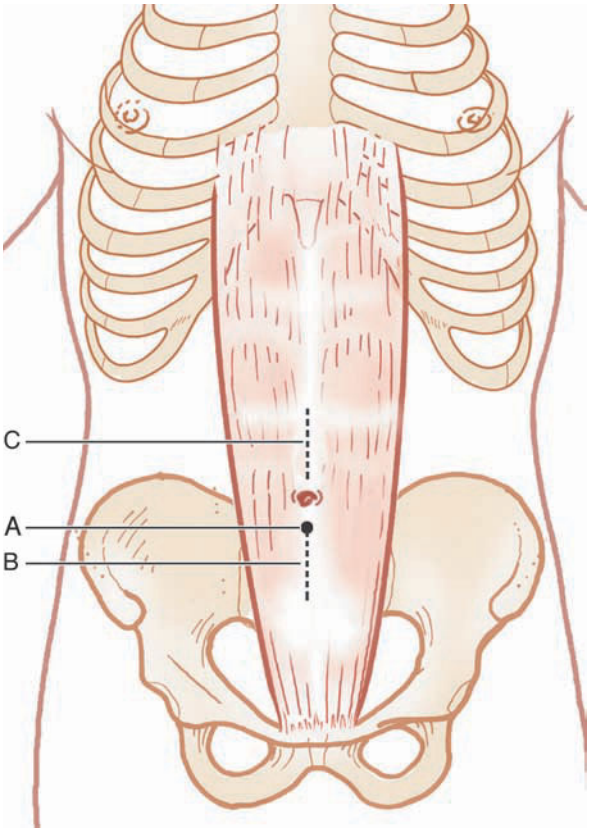


FIGURE 66-2. The preferred sites to perform a DPL. **A.** The midline and approximately 1 to 2 cm below the umbilicus is the location for a closed DPL. **B.** A midline incision beginning 1 to 2 cm below the umbilicus and extending inferiorly for 5 to 6 cm is the location for semi-open and select open DPLs. **C.** A midline incision beginning 2 cm above the umbilicus and extending superiorly for 5 to 6 cm is the location for most open DPLs.

Most DPLs may be safely performed 1 to 2 cm below the umbilicus (**Figures 66-2A & B**). This location allows the DPL catheter to be directed into the pelvis, minimizes the occurrence of inadvertent vascular injury, and increases the likelihood that fluid will be sampled from a dependent portion of the abdomen. It is more difficult to retrieve fluid if the DPL is performed above the umbilicus due to interference from the omentum. All closed and semi-open DPLs, as well as many open DPLs, are performed below the umbilicus.

The resultant retroperitoneal hematoma in patients with a pelvic fracture may extend anteriorly to the level of the linea semilunaris. **Therefore, it is important to perform the DPL in patients with a pelvic fracture using an open technique above the umbilicus (Figure 66-2C).** This will avoid a false-positive DPL and the inadvertent decompression of the hematoma.[12]

Another special situation occurs in the pregnant patient. **The DPL should be performed using an open technique superior to the uterine fundus.**[7] It may be performed below the umbilicus if the patient is in an early stage of pregnancy. The DPL should be performed more cephalad as the pregnancy progresses to minimize the chance of injuring the gravid uterus.

The third situation that may necessitate a change in the location to perform the DPL is in the patient with previous abdominal surgery. These patients must be individualized based upon the location of their scar. The DPL should be performed supraumbilically if the patient has a lower abdominal scar and infraumbilically if the patient has an upper abdominal scar.[1,9] In all cases of previous surgery, the DPL should be performed using an open technique to avoid any adhesions and minimize complications.[13]

INDICATIONS

A DPL is indicated in any patient with suspected abdominal trauma, blunt or penetrating, that does not have an obvious indication for a laparotomy and in whom serial physical examinations are not practical. It can be performed quickly, will reliably exclude significant intraabdominal trauma, and allow the diagnosis and treatment of associated injuries. It does not require transfer of the patient out of the monitored environment of the Emergency Department, as does a CT scan. It likewise does not require sophisticated equipment and extensive training comparable to those required to perform abdominal ultrasonography.

A DPL is especially useful in patients with an unreliable or equivocal abdominal examination and those who will be unavailable for serial physical examinations. The patient with an altered mental status (e.g., alcohol, drugs, head injury, etc.) or abnormal sensation due to a spinal cord injury is considered to have an unreliable physical examination.[7,11,14] Patients may have an equivocal examination due to tenderness from surrounding fractures of the ribs, spine, or pelvis.[11,13] They may also have tenderness over the wound or an area of injury that is difficult to distinguish from peritonitis. The third group of patients who may benefit are those that undergo surgery for another injury, such as a neurosurgical or an orthopedic procedure.[14] These patients are unavailable for serial examinations while in the operating room. Their examination may be altered postoperatively as well due to the analgesics that they receive.

DPL may be useful in the occasional circumstance when the patient presents in shock with other potential sources of hemorrhage, such as intrathoracic or retroperitoneal bleeding. It may confirm or rule out the abdomen as the source of the patient's bleeding and shock.[7] **It is important to remember that an injury confined to the retroperitoneum will not result in a positive DPL.**[15]

CONTRAINDICATIONS

The only absolute contraindication to performing a DPL is if the patient has an obvious indication for a laparotomy. Patients who present following abdominal trauma who are in shock, have peritonitis, pneumoperitoneum on chest radiography, evisceration, blood per orifice, or a retained stabbing implement have obvious indications for a laparotomy.

Several relative contraindications to DPL do exist. These actually represent contraindications to performing the closed technique. Patients with a pelvic fracture may have a large retroperitoneal hematoma that extends anteriorly to the linea semilunares. The DPL may be performed using the open technique above the umbilicus to avoid decompression of the hematoma.[12] Pregnant patients should not have a closed DPL performed because of the risk of injury to the uterus. It is safe, however, to perform an open DPL above the uterine fundus.[7] Patients with evidence of previous abdominal surgery may have adhesions of the viscera to the abdominal wall that make intraabdominal injury more likely to result when a closed DPL is performed.[1,9] An open technique may be performed in a location away from the scar.[13] One must recognize, however, that compartmentalization of the abdomen may have occurred due to intraperitoneal adhesions, thus making it more likely to have a falsely negative DPL result.

The DPL should be performed using the open technique in patients who are unable to have a Foley catheter placed due to urethral injury or stricture. This minimizes the chance of inadvertent injury to the bladder. Morbid obesity is a relative contraindication to closed DPL. This represents a difficulty in technically performing

the DPL when the abdominal wall is thicker than the 2.5 in. long locator needle. It is useful to perform the DPL in these patients using a semi-open technique.[16] Preexisting coagulopathy is also a relative contraindication.

EQUIPMENT

Closed Technique

- Povidone iodine or chlorhexidine solution
- Face mask
- Sterile gloves
- Sterile gown
- 4 × 4 gauze squares
- Local anesthetic solution
- Purple top blood collection tube
- 5 mL syringes
- 18 gauge needles
- 25 gauge needles
- Nasogastric tube
- Foley catheter
- 1 L of IV fluid to infuse, 0.9% NaCl or lactated Ringer solution
- Commercial Peritoneal Lavage Kit (e.g., Arrow AK-0900)

Semi-Open or Open Technique

- All items listed above
- Razor
- #10 scalpel blade on a handle
- Abdominal skin retractors, Weitlaner or skin rakes
- Two tissue forceps
- Two Allis clamps
- Four hemostats
- Needle driver
- Suture for vessel ligation (4-0 Vicryl, 4-0 Dexon, or 4-0 chromic)
- Suture for fascial closure (0 Vicryl, 0 Dexon, 0 Maxon, or 0 Prolene)
- 4-0 nylon suture or skin stapler for skin closure
- Suture scissors

A commercially available, disposable, and single-patient use peritoneal lavage kit is available from numerous manufacturers. The kit includes all the material required to perform a closed DPL except lavage fluid. An example is the Arrow kit (Arrow International, Reading, PA). It contains 10% povidone iodine swabs, gauze squares, a fenestrated drape, IV fluid administration tubing, 1% lidocaine, 5 mL syringes, 22 and 25 gauge needles, an 18 gauge × 2.5 in. introducer needle, an 0.89 mm × 45 cm J-tipped guidewire, an 8 French lavage catheter, and a #11 scalpel blade on a handle.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. This should include the possible complications. Informed consent should be obtained from the patient or from the family if the patient is unable to consent due to age or mental status. **The consent process should not unduly delay the performance of the DPL in an unstable patient.**

Place the patient in the supine position. A distended stomach or bladder may be inadvertently perforated during the procedure.

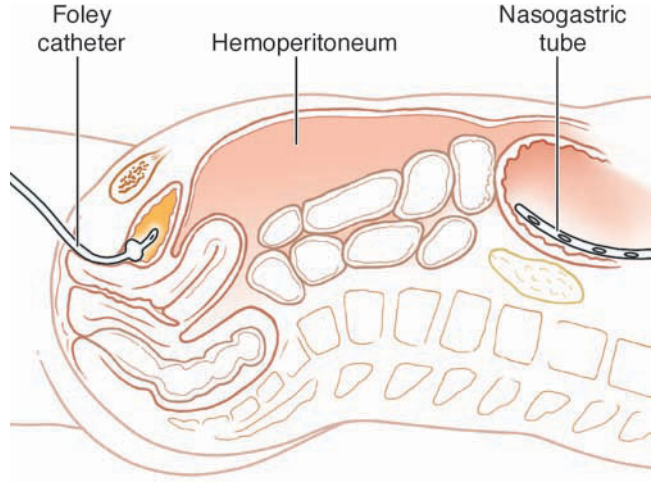


FIGURE 66-3. Midsagittal section through the abdomen and pelvis demonstrating decompression of the stomach with a nasogastric tube and decompression of the bladder with a Foley catheter.

These organs require decompression prior to performing a DPL (**Figure 66-3**). Decompress the stomach using a nasogastric or orogastric tube.[14,17] Refer to Chapter 58 regarding the details of nasogastric tube insertion. Decompress the bladder using a Foley catheter once a urethral injury has been ruled out.[7,8,14,17] Refer to Chapters 142 and 145 regarding the details of urethral catheterization and evaluation of a urethral injury.

Prepare the abdomen.[14] Shave the area surrounding the incision site if an open or semi-open DPL is to be performed. Clean the skin of any dirt, debris, and blood. Apply povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to delineate a sterile field. Each healthcare provider who is involved in the procedure should don a face mask, a sterile gown, and sterile gloves.[14]

TECHNIQUES

A DPL is performed one of three different ways.[18,19] The open technique utilizes a vertical infraumbilical incision and direct visualization of the peritoneal cavity before inserting the catheter. The closed technique relies on percutaneous needle access to the peritoneal cavity, followed by the insertion of a catheter using the Seldinger technique. The semi-open technique follows the same principles of the open technique except that the midline fascia is penetrated with a needle and the catheter is advanced using the Seldinger technique. There is no difference in overall outcomes or rates of injury to visceral contents between the three techniques.[20–24]

PERCUTANEOUS (CLOSED) TECHNIQUE

The closed technique is the preferred method unless contraindications exist (**Figure 66-4**). The closed DPL can be performed in a significantly shorter time than the open technique.[23,24] There is no difference in the amount of fluid retrieved from the abdomen, the diagnostic accuracy, or the complication rate between the closed and open techniques.[23]

The closed DPL is performed in the midline and approximately 1 to 2 cm below the umbilicus (**Figure 66-2A**).[17] Prepare the patient as described previously. Infiltrate the skin, subcutaneous tissue, and fascia with local anesthetic solution. Place the 2.5 in. introducer needle onto a 5 mL syringe. Insert the needle in the midline and 1 to 2 cm below the umbilicus. Advance the needle at a 45° angle and

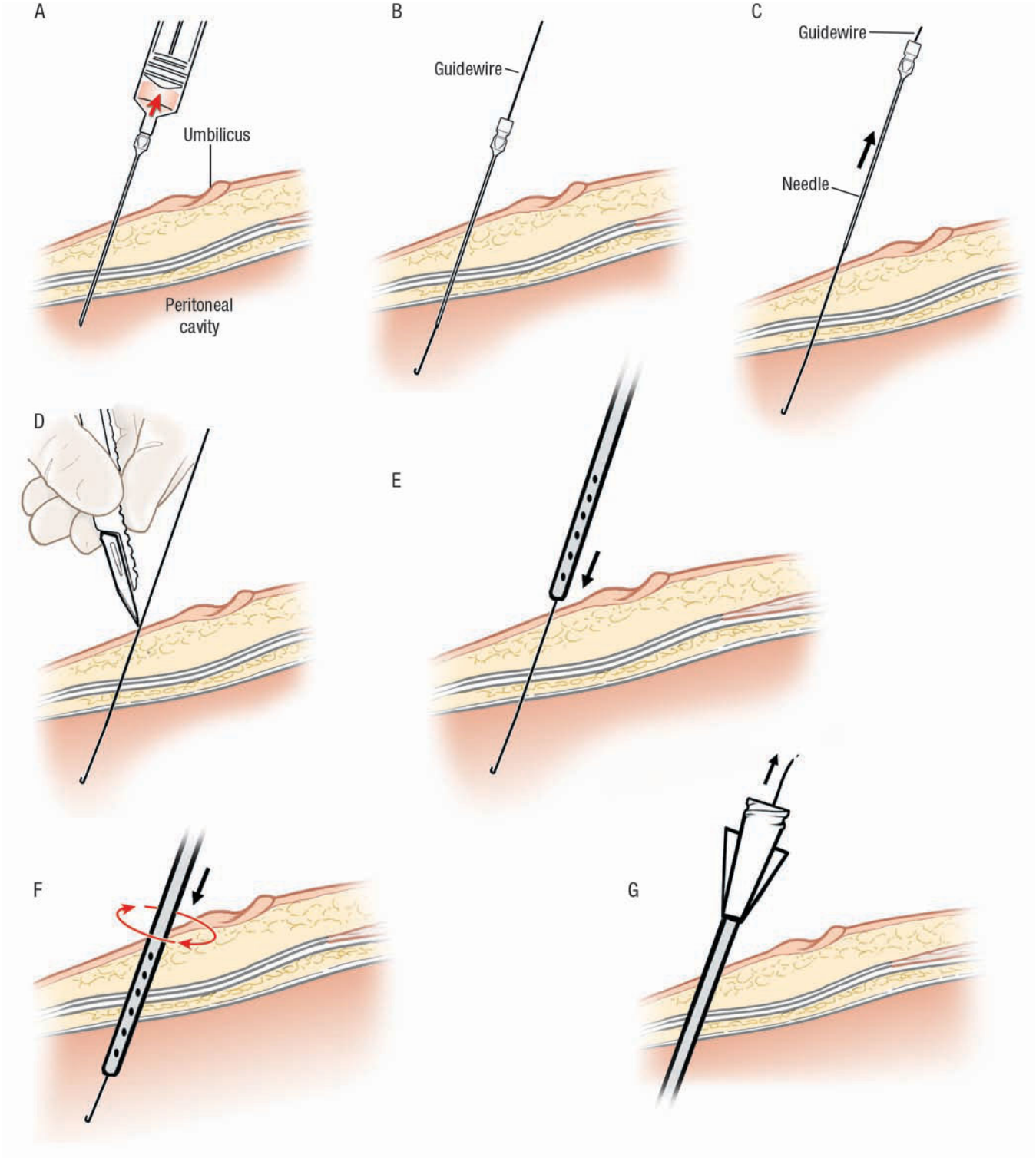


FIGURE 66-4. The percutaneous or closed DPL technique. **A.** The introducer needle is advanced caudally and at a 45° angle to the skin of the abdominal wall while negative pressure is applied to the syringe. **B.** The syringe has been removed and the guidewire is inserted through the introducer needle. **C.** The introducer needle is withdrawn over the guidewire, leaving the guidewire in place. **D.** A small nick is made in the skin and subcutaneous tissue adjacent to the guidewire using a #11 scalpel blade. **E.** The lavage catheter is placed over the guidewire. **F.** The lavage catheter is advanced over the guidewire and into the peritoneal cavity. A twisting motion may aid in the advancement of the catheter. **G.** The guidewire is removed, leaving the lavage catheter in place.

direct it into the pelvis (**Figure 66-4A**). Apply negative pressure to the syringe as it is advanced. Three "pops" are felt as the needle penetrates the skin, fascia, and peritoneum. After the third pop, slowly advance the needle another 2 to 3 mm while maintaining negative pressure on the syringe. A flash of blood will be seen in the syringe if the patient has a massive hemoperitoneum. This is considered a positive tap and concludes the procedure.

Continue the procedure if no blood is aspirated into the syringe. Stabilize the introducer needle with one hand at the level of the abdominal wall and remove the syringe. **Do not allow the**

introducer needle to move as it may lacerate the intraabdominal organs. Insert the guidewire through the introducer needle until only 7 to 10 cm of the guidewire remains outside of the hub of the needle (**Figure 66-4B**). The guidewire should advance through the needle easily with only minimal resistance. **Difficulty in advancing the guidewire or the patient complaining of pain requires removal of the guidewire and introducer needle as a unit. Never withdraw the guidewire through the introducer needle.** The tip of the introducer needle can shear off the guidewire resulting in a piece of the guidewire in the peritoneal cavity and necessitating an operative procedure. Reinsert the introducer needle and restart the procedure.

Stabilize the guidewire and withdraw the introducer needle over the guidewire (**Figure 66-4C**). Make a small incision in the skin and subcutaneous tissue alongside the guidewire with a #11 scalpel blade to facilitate passage of the lavage catheter (**Figure 66-4D**). This incision should be no more than 5 mm in length. It is important not to incise the skin until the operator is sure that the guidewire is within the peritoneal cavity. Making the skin incision prior to inserting the guidewire may result in unnecessary skin incisions if the introducer needle is placed at another location.

Place the lavage catheter over the guidewire (**Figure 66-4E**). Advance the lavage catheter into the peritoneal cavity (**Figure 66-4F**). It may be helpful to twist the catheter as it passes through the fascia to aid in inserting it into the peritoneal cavity. Advance the catheter until its hub is against the abdominal wall in the adult patient. Securely hold the hub of the lavage catheter. Remove the guidewire (**Figure 66-4G**). Attach a 5 to 10 mL syringe to the hub of the lavage catheter. Apply negative pressure to the syringe. Note if any blood is aspirated. The aspiration of blood is not considered to be a positive tap and the procedure should continue.

The presence of gross blood upon entering the peritoneal cavity should be considered an indication for laparotomy. Likewise, blood obtained through the introducer needle is considered a positive peritoneal tap and represents blood throughout the peritoneum. Confusion exists, however, when blood is withdrawn through the lavage catheter (peritoneal aspirate). Because the catheter has been directed into the most dependent portion of the peritoneal cavity, the pelvis, a small amount of blood withdrawn through the catheter may represent the only blood present within the abdomen. This does not indicate that the patient is intrinsically unstable. The patient does not require a laparotomy if the subsequent lavage is negative.[14] Therefore, while the aspiration of blood through the introducer needle (positive tap) does require a trip to the Operating Room, aspiration of blood through the catheter (positive aspirate) means nothing and is not a reason to terminate the procedure.

Continue the procedure. Pass the proximal end of the IV tubing to a nonsterile assistant to insert into a bag of IV fluid (i.e., 0.9% NaCl or Ringer lactate) and prime the tubing. Warmed IV fluid is preferable to room temperature fluid, if available. Attach the distal end of the IV tubing to the lavage catheter (**Figure 66-5A**). Open the clamp on the IV tubing and allow the lavage fluid to flow freely into the peritoneal cavity (**Figure 66-5A**). The lavage catheter may not be within the peritoneal cavity if the lavage fluid does not flow quickly but seems to drip in slowly. Reassess the catheter position. If necessary, remove and reinsert the lavage catheter. Infuse 1 L in the adult patient and 10 to 20 mL/kg (maximum 1 L) in the pediatric patient.[8,13] Stabilize the catheter with one hand during the infusion of the lavage fluid.

After the lavage fluid has been instilled, place the IV bag on the floor to allow the fluid to flow out from the peritoneal cavity (**Figure 66-5B**). There should be a steady rate of flow. Diminution of flow usually results from the omentum blocking the side holes of the lavage catheter. Firm palpation of the patient's abdomen may increase the flow rate if it seems to drop off. The lavage catheter may need to be withdrawn slightly and reinserted. These maneuvers may help to dislodge the omentum. If manipulation of the catheter does not improve flow, a second liter of fluid may be infused (additional 10 mL/kg in children). If this becomes necessary, the threshold for a positive DPL must be halved (i.e., down from 100,000 to

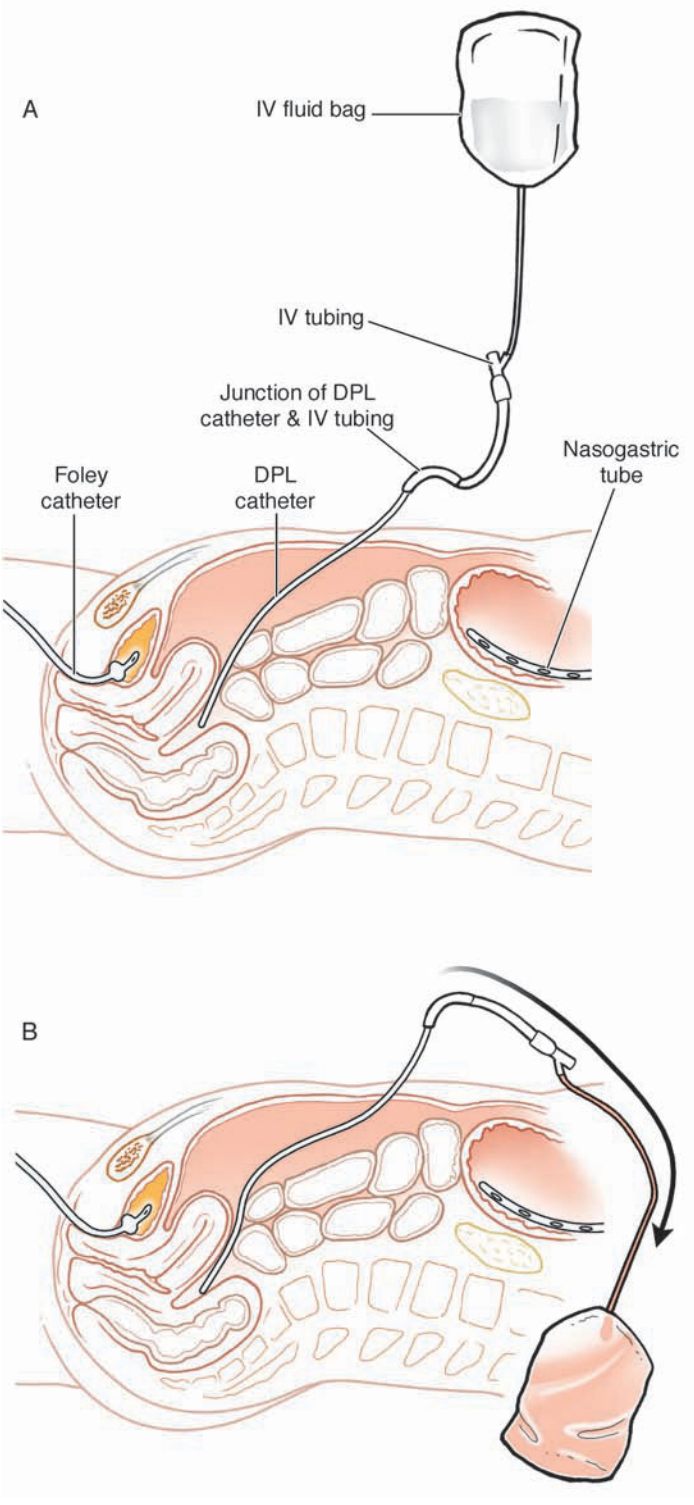


FIGURE 66-5. The instillation and removal of lavage fluid. **A.** The bag of IV fluid is attached to the lavage catheter using IV tubing. The bag of fluid is then suspended and allowed to infuse into the peritoneal cavity. **B.** The IV bag is placed on the floor to allow the lavage fluid to exit the peritoneal cavity and flow back into the bag.

50,000 RBC/mm^3 in blunt trauma); as twice the fluid is infused and results in a halving of the RBC count.

At least 200 to 250 mL of lavage fluid should be returned from the peritoneal cavity to result in a reliable cell count.[24–26] This fluid is referred to as the effluent. Place a new lavage catheter if less than 200 to 250 mL of effluent is obtained after the manipulations described above.[8] Remove the existing lavage catheter while maintaining the sterility of the distal end of the IV tubing. Place a second lavage catheter 1 cm inferior to the site of the first lavage catheter. Reconnect the IV tubing and place the IV bag to gravity drainage to obtain the effluent.

Remove the lavage catheter after obtaining as much effluent as possible from the peritoneal cavity. Place a small gauze dressing over the skin puncture site and remove the drapes. Transfer a small aliquot of the lavage effluent to a purple top blood collection tube. Transport the tube to the laboratory for a cell count. The remainder of the lavage effluent may be discarded or reserved for subsequent testing.

OPEN TECHNIQUE

Prepare the patient as described previously. Infiltrate the skin, subcutaneous tissue, and fascia with a local anesthetic solution in the area where the incision is to be made. Begin the incision 2 cm below the umbilicus and extend it 5 to 6 cm inferiorly in patients who have an upper abdominal scar (**Figure 66-2B**). Begin the incision 2 cm above the umbilicus and extend it 5 to 6 cm superiorly in patients with a pelvic fracture or lower abdominal scar (**Figure 66-2C**). Make the incision in the midline above the uterine fundus in patients who are pregnant.

Incise the skin and subcutaneous tissue longitudinally for a distance of 5 to 6 cm in the midline (**Figure 66-6A**). The incision may need to be longer in an obese patient. Clamp and ligate any small vessels that are bleeding with absorbable suture prior to incising the fascia. This will minimize the incidence of false-positive lavage results. Retract the skin and subcutaneous tissues with a Weitlaner retractor or skin rakes to aid in viewing the fascia (**Figure 66-6B**). The fascial midline may be identified by the interdigitation of its fibers (**Figure 66-6B**). Carefully incise the fascia longitudinally along the length of the previous skin incision (**Figure 66-6C**). Identify the peritoneum. Any preperitoneal fat that is present can be gently moved aside by an assistant using either a forceps or gauze. Grasp and elevate the peritoneum using two Allis clamps (**Figure 66-6D**). **Use extreme care to ensure that no bowel is included in the clamps.**

Make a small (<5 mm) incision in the peritoneum. Insert the lavage catheter through the incision and directed caudally into the pelvis (**Figure 66-6E**).[7] The remainder of the procedure is as described above in the percutaneous (closed) technique. It may be necessary to gently retract the peritoneum upward with the Allis clamps to prevent leakage of the lavage fluid around the catheter.

Remove the lavage catheter and Allis clamps after obtaining as much effluent as possible from the peritoneal cavity. It is not necessary to suture the peritoneum. Close the fascia with # 0 Maxon, Prolene, Vicryl, or Dexon suture in a running fashion. Inspect the edges of the incision for any bleeding blood vessels. Obtain hemostasis of the subcutaneous tissue by ligating small vessels with absorbable suture. Close the skin with interrupted 4-0 nylon sutures or skin staples. Place a gauze dressing over the incision site. Remove the drapes.

SEMI-OPEN TECHNIQUE

This technique is used primarily for patients in whom there is no contraindication to the performance of a closed lavage and their abdominal wall is thicker (>2.5 in.) than the length of the introducer needle. The procedure often begins as a closed technique and is converted to a semi-open technique once it is realized that the introducer needle is not long enough to enter the peritoneal cavity. It is a modification of both the closed and open techniques.[16]

Prepare the patient and begin the procedure as if performing the open technique. Make the midline incision and retract the tissues (**Figures 66-6A & B**). Identify the interdigitations of the fascia in the midline. Place the introducer needle on a 5 mL syringe. Insert the introducer needle through the midline and at a 45° angle directed toward the pelvis (**Figure 66-4A**). Apply negative pressure to the syringe while advancing the needle. A pop will be felt as the introducer needle penetrates the peritoneum. The remainder of the procedure is as described above under the percutaneous or closed technique.

Remove the lavage catheter after obtaining as much lavage fluid as possible from the peritoneal cavity. Inspect the edges of the incision for any bleeding blood vessels. Obtain hemostasis of the subcutaneous tissue by ligating small vessels with absorbable suture. Close the skin using interrupted 4-0 nylon sutures or skin staples. Place a gauze dressing over the skin incision site. Remove the drapes.

LAPAROSCOPIC DPL

The technique of laparoscopic DPL (L-DPL) should be considered in hemodynamically stable patients with penetrating lower thoracic or abdominal stab wounds.[6] It is especially applicable for Trauma Surgeons with only basic experience in laparoscopic techniques. The procedure is used to obtain conclusive evidence of significant intraabdominal injury, confirm peritoneal penetration, control intraabdominal bleeding, and repair lacerations to the diaphragm and abdominal wall. The combination of laparoscopy and DPL adds to the sensitivity and specificity of DPL and avoids under or over sensitivity, which has limited the use of DPL in the hemodynamically stable trauma patients with suspicious or proven peritoneal penetration.

ANALYSIS OF PERITONEAL LAVAGE FLUID

There are several laboratory evaluations that can be performed on the lavage effluent to determine whether the patient requires a laparotomy.[39] Gross evidence of injury exists when there is a positive peritoneal tap (i.e., gross blood obtained either through the introducer needle or noted upon opening the peritoneum during the open DPL), bile stained peritoneal fluid is noted, or enteric contents are seen in the effluent.[9,27] The most commonly used laboratory determination is that of the erythrocyte or RBC count. Other determinations include the leukocyte count and the presence of amylase in the lavage effluent.

Peritoneal lavage was first described as utilizing visual inspection of fluid for the presence of blood.[1,3,9] This has been subsequently shown to be very inaccurate, even when performed by experienced physicians.[28] A much better method of quantification of the presence of blood utilizes the counting of erythrocytes, done either manually or with an automated cell counter.

A positive DPL in an adult classically requires one of the following results: 10 mL of gross blood on initial aspiration, greater than 500/mm^3 RBCs, greater than 100,000/mm^3 WBCs, or the presence of enteric contents or food matter. The RBC count threshold can be adjusted from 100,000 RBC/mm^3 in patients who have sustained blunt trauma or an anterior abdominal stab wound, to a lower 10,000 RBC/mm^3 in patients who may have suffered penetration of the abdominal cavity. Both counts appear to be very sensitive, specific, and accurate at diagnosing either injury or penetration.[29]

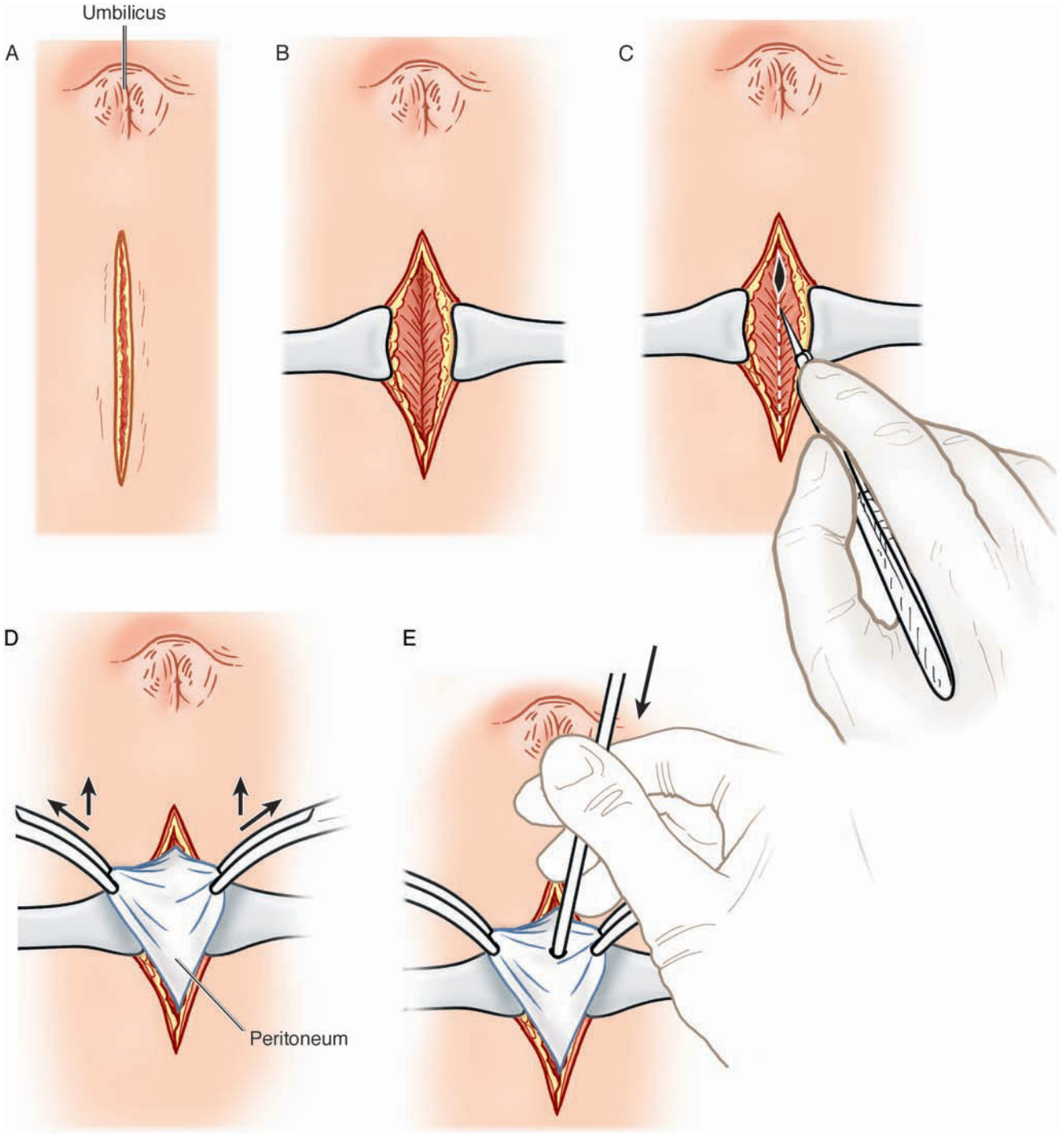


FIGURE 66-6. The open DPL. **A.** An incision is made in the skin and subcutaneous tissues. **B.** The skin and subcutaneous tissues are retracted. Note the interdigitation of the fibers of the fascia in the midline. **C.** An incision is made in the fascia. **D.** The peritoneum is grasped and elevated with Allis clamps. **E.** The lavage catheter is inserted through a small incision (<5 mm) in the peritoneum.

In blunt abdominal trauma, 100,000 RBCs/mm^3 is the most commonly used threshold for a laparotomy.[7,11,27] This corresponds roughly to the presence of 20 mL of blood in the peritoneal cavity. Using the count of 100,000 RBCs/mm^3 to determine the presence of a hemoperitoneum provides a sensitivity of 97%, a specificity of 99.6%, and an accuracy of 99%.[11] The false positives that occur are usually the result of bleeding from the lavage site. False-negative DPLs usually result in RBC counts in the mid-10,000s, which some authors refer to as indeterminate.[7] The injuries that are missed by a count of 100,000 RBCs/mm^3 are injuries to hollow viscera and the diaphragm, organs that may not bleed enough to result in a positive lavage.

Penetrating trauma, on the other hand, has no universally agreed upon threshold for a laparotomy. Documentation of penetration of the peritoneal cavity is felt to be an indication for laparotomy in all gunshot wounds and most stab wounds to the abdomen. Penetration of the peritoneum by a gunshot wound results in a significant intraperitoneal injury in 98% of cases.[30] Therefore, DPL to prove abdominal penetration is useful in cases of potentially tangential gunshot wounds.[15,32] Likewise, penetration into the peritoneal cavity from a

thoracoabdominal wound results, by definition, in a diaphragmatic injury that should be repaired.[17,33] Penetration through the retroperitoneum, from the back or flank, will cause a significant injury in 73% of cases.[15,25] Therefore, DPL is useful in these wounds as well. Penetration of the peritoneal cavity may not bleed enough to result in a 100,000 RBCs/mm^3 count. Most authors believe that a lower RBC count should be used. Unfortunately, there is little consensus as to what that count should be.

The RBC count varies from 1000 to 50,000 RBCs/mm^3 as a threshold for laparotomy in penetrating trauma.[11,15,24,33–35] The higher the count that is used, the more likely there will be a missed injury with an increased false-negative rate.[11,14,17] The lower the count that is used, the more likely that a negative laparotomy will result with an increased false-positive rate.[11,14,17] A threshold of 10,000 RBCs/mm^3 provides the most acceptable balance between false-negative and false-positive results.[17,31,32] This threshold results in a sensitivity of 88% to 99%, a specificity of 97% to 98%, and an accuracy of 95% to 98%.[14,17,32]

A special case of penetrating abdominal trauma exists when there is a stab wound to the anterior abdomen. We know that only two-thirds of these wounds will penetrate the peritoneum, and of those that penetrate, less than 50% will cause an injury that requires repair.[15] Therefore, using a lower threshold for DPL to determine penetration will result in a greater than 50% negative laparotomy rate. For this reason, wounds to the anterior abdomen are lavaged with the standard RBC count of 100,000 RBCs/mm^3 to determine injury, and not penetration, as the threshold for an operation.[36]

Many laboratories will routinely report the WBC count on the lavage effluent. The presence of over 500 WBCs/mm^3 is often quoted as a standard indication for laparotomy.[27] Unfortunately, the presence of an elevated lavage WBC count by itself has poor predictive value in the trauma patient.[25] Most commonly, there is an associated elevation in the RBC count that will trigger a laparotomy. A recently described "cell count ratio" may help to diagnose the presence of a hollow viscus injury by comparing the WBC/RBC ratio in the lavage effluent to the WBC/RBC ratio in the blood.[37] If the lavage ratio is greater than that of blood, there is a high likelihood of hollow viscus injury. This ratio is not universally accepted.

While the quantification of RBCs, and occasionally WBCs in the DPL effluent is the most common test, other laboratory tests may be utilized in indeterminate cases. The most commonly used is the determination of amylase.[2,7,9] Amylase may be elevated in the presence of an injury to the gastrointestinal tract. Unfortunately, the amylase level is neither sensitive nor specific.[10]

AFTERCARE

The patient should be observed in the hospital for up to 24 hours after a negative DPL. The Foley catheter and nasogastric tube may be removed if they are no longer needed for other indications. Reexamine the patient periodically during this observation period for the development of peritonitis that may result from a false-negative lavage or a complication of the lavage procedure itself. The performance of the lavage should not alter the patient's examination; although there may be localized wound tenderness if the lavage was performed using the open or semi-open technique.[1] The patient should receive analgesics as needed after an open or semi-open DPL. Keep the patient NPO during the initial portion of their observation. They can be fed near the end of the 24 hours to insure that they tolerate oral intake prior to discharge.

Discharge instructions to the patients should instruct them to return for the development of a fever, increasing abdominal pain, nausea, vomiting, worsening wound pain, or wound drainage. After undergoing an open or semi-open DPL, the patient should be seen in 7 to 10 days for removal of the skin sutures or staples. No evidence exists supporting the use of prophylactic antibiotics.

COMPLICATIONS

The complication rate for a DPL is relatively low. It varies between 0.6% and 2.3%.[13,38] There is no difference in complication rates between the three techniques.[20–24] The complications may be classified as wound-related or puncture-related.

Wound-related complications occur primarily with open or semi-open lavage techniques. Inadequate hemostasis during performance of the DPL may result in bleeding and a hematoma formation at the wound site.[7,13,38] As with any surgical procedure, there is a risk of wound infection at the lavage site.[7] This infection is usually due to skin flora and may be treated simply by opening the wound and performing twice daily wet-to-dry dressing changes.

Puncture-related complications may occur after any DPL technique. Virtually any organ within the abdominal cavity may be punctured by the introducer needle, the guidewire, or the lavage catheter. Puncture of the bladder and stomach may be avoided by placing a Foley catheter and nasogastric tube, respectively, prior to performing the DPL.[14,17] A punctured bladder is usually noted by obtaining urine during syringe aspiration or by lavage fluid exiting through the Foley catheter. Removing the lavage catheter and continuing Foley catheter drainage for 24 to 48 hours will treat this complication.[9] Puncture of the small bowel, colon, and their mesenteries may also occur.[7,13,14,31,38] Likewise, puncture of blood vessels ranging from mesenteric vessels to iliac vessels has been described.[1] These latter complications will usually result in a positive DPL based on bleeding or return of enteric contents and are repaired at laparotomy.

Some advocate using the abdominal wound to insert the lavage catheter and not making a fresh entry site.[40] This cannot be routinely recommended. This can result in false-positive results from blood in the wound tract, the potential for infection, the wound may be too far away that the catheter cannot reach into the pelvic recesses, and the lavage catheter could track through injured organs.

Occasionally, the lavage fluid may be instilled into the abdominal wall or the retroperitoneum.[1,14] This may result in a false-positive lavage, a false-negative lavage, or more commonly an inadequate lavage fluid return. This complication requires no specific treatment other than recognition. The body will reabsorb the fluid over time.

SUMMARY

The DPL is a well-described procedure for determining the need for a laparotomy after trauma. It has undergone several modifications since its initial description over 45 years ago. The procedure may be performed using a closed, semi-open, or open technique depending upon the patient's history and associated injuries. All three techniques are safe, accurate, and easily performed. Several criteria may indicate a positive result, and knowledge of these criteria is important in the evaluation of the DPL effluent.

Because this is an invasive procedure, it is important that it should be performed after informed consent (if feasible) and using strict aseptic technique. There is a small risk of complications as well as missed injuries necessitating the close observation of the patient with a negative DPL.

The DPL remains one of the most useful tests in the patient with abdominal trauma.[41] Despite advances in imaging technology, the DPL remains the test of choice in the patient with penetrating abdominal trauma and in select patients with blunt abdominal trauma.

67 Anal Fissure Management

Marilyn M. Hallock and Eric F. Reichman

INTRODUCTION

An anal fissure, or fissure-in-ano, is one of the most common anal disorders seen by physicians. It is a linear tear or crack that extends into the anoderm from the mucocutaneous junction to the dentate line (**Figure 67-1**). An anal fissure usually results from the passage of hard stool that traumatizes and tears the anoderm. Frequent bowel movements with diarrhea can cause similar "cracks" that eventually result in fissures. Anal fissures are often seen in infants, but primarily are a condition of young and middle-aged adults.[1–3] It is the most common cause of acute onset painful rectal bleeding in adults and in the first year of life.

A fissure may be acute or chronic, occur at any age, and affect both genders equally. It is the most common cause of rectal bleeding in infants. Fissures are typically a few millimeters long and occur primarily (90%) in the posterior midline. The remaining 10% are found in the anterior area.[4–6] There is a slight gender difference with 1% to 7% of anal fissures found anteriorly in men and up to 12% anteriorly in women.[7] Atypical locations (e.g., lateral) suggest the presence of an underlying disease such as Crohn's disease, anal cancer, previous anal surgery, leukemia, syphilis, tuberculosis, and other infections.

ANATOMY AND PATHOPHYSIOLOGY

The anal canal begins at the level of the anorectal ring and extends distally for 4 cm to the anal verge. The internal anal sphincter and external anal sphincter muscles surround the anal canal. The internal anal sphincter muscle is a continuation of the involuntary layer of circular smooth muscle of the rectum that begins at the anorectal ring. It is contracted at rest so that the lower margin can be palpated 1 to 2 cm below the dentate line in the intersphincteric groove. The internal anal sphincter muscle supplies up to 60% of the resting tone of the anus.[8] The external anal sphincter muscle is an elliptical cylinder of voluntary striated muscle tethered to the coccyx and surrounding the anal canal. Columnar epithelium lines the upper anal canal while the lower anal canal is lined by squamous epithelium. The transitional zone lies between the two different types of mucosa. The anoderm is a thin layer of stratified squamous epithelium around the anus, distal to the dentate or pectinate line, that lacks sweat glands and hair follicles. This area is richly endowed with cutaneous sensory nerve endings.

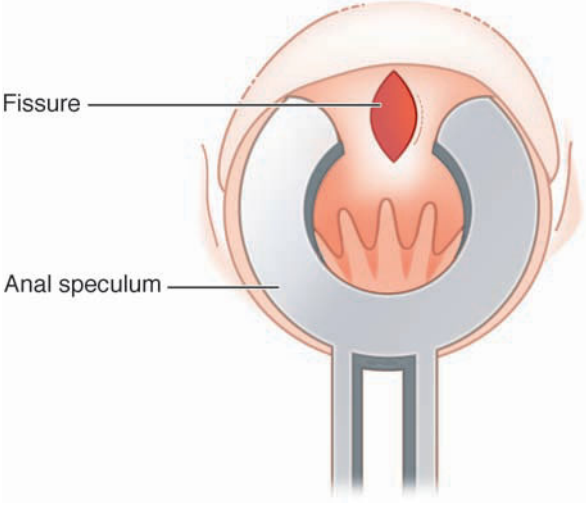


FIGURE 67-1. The anal fissure.

It is hypothesized that anal fissures usually occur in the posterior midline secondary to a decreased vascular supply causing ischemia or a decreased number of external sphincter muscle fibers predisposing the posterior area to a weakness.[9] Constipation or a hard bowel movement causes a tear in the anoderm that causes pain. The tear often results in a vicious cycle of injury by exposing the underlying internal sphincter muscle. This results in spasms of the muscle, which causes severe pain, and results in further separation of the fissure edges and possible further tearing during subsequent stool passage. A delay in wound healing may result, and can ultimately lead to a chronic anal fissure.

Ischemia may contribute to the cycle of injury. The posterior midline, being the primary location for anal fissures, has less than half the blood flow compared to other quadrants in the anal canal.[10,11] Individuals with chronic anal fissures have higher anal pressures than controls or patients with other colorectal disorders due to increased internal anal sphincter tone, which results in blood flow reduction as well.[12,13] These factors lead to the rationale for the use of topical nitroglycerin in treating anal fissures.

A tight anal sphincter is another hypothesis for the etiology of a fissure. Anal manometry in patients with fissures reveals an elevation of the resting anal canal pressures and infrequent spontaneous relaxation of the internal anal sphincter muscle.[13] These high pressures can impede blood flow. The anodermal blood supply passes through the internal anal sphincter muscle and increased resting pressure may result in an ischemic ulcer or fissure.

An acute anal fissure has the appearance of a clean longitudinal tear in the anoderm with minimal inflammation (**Figure 67-1**). A chronic anal fissure is deeper, and exposed internal anal sphincter muscle fibers may be seen at its base. A skin tag or sentinel pile is usually seen externally and a hypertrophied anal papilla may be found at its upper aspect. Patients with a chronic anal fissure may also complain of anal discharge, pruritus, or "a lump." Many people complaining to their physicians of bright red blood per rectum and anal pain think they are suffering from "hemorrhoids." A good history and physical examination can confirm the diagnosis of an anal fissure. These patients will typically describe a sharp, burning, or shearing pain with defecation that lasts for a few moments up to an hour afterward. Some people will complain of a chronic ache that is exacerbated with a bowel movement. The prolonged pain is usually attributed to internal anal sphincter muscle spasm. Bright red blood is usually seen on the stool or toilet paper. Occasionally, a few drops of blood will fall into the toilet bowl.

Patients can usually describe the initial event that triggered the fissure as either an episode of constipation with a hard bowel movement or diarrhea. Most patients with a painful anal fissure will not tolerate a digital rectal examination or anoscopy. A close inspection of the anus can be performed after reassuring the patient and gently pulling the buttocks apart. An anal fissure with a sentinel pile, an abscess, or a thrombosed external hemorrhoid may also be seen. The application of anesthetic jelly may be required to examine the patient with an acute, painful anal fissure. Palpating the anal fissure with a gloved finger or cotton swab will reproduce the patient's pain.

INDICATIONS

Anal fissures are extremely painful and uncomfortable for the patient. They can cause poor job attendance or performance. All anal fissures should be treated when they are identified. Initial therapy is conservative, followed by topical medications and injection

therapy. Surgical treatment is warranted for patients for whom nonoperative therapy fails or who experience severe anal pain.

CONTRAINDICATIONS

A patient with perianal Crohn's disease or ulcerative colitis is a relative contraindication to performing a lateral internal sphincterotomy. Medical management is advocated to initially treat these fissures associated with inflammatory bowel disease followed by the judicious use of an internal sphincterotomy.[14] A patient who has had multiple fistulotomies in the past or a sphincteroplasty should have their anal sphincter evaluated by anal ultrasound or manometry. The patient may have marginal sphincter function and an internal sphincterotomy can render them completely incontinent. A sphincterotomy should be performed only by a Colorectal Surgeon in these difficult patients.

EQUIPMENT

Anal Anesthesia

- Povidone iodine or chlorhexidine solution
- 10 mL syringe
- 27 gauge needle, 2 in. long
- Local anesthetic solution with epinephrine
- 4 × 4 gauze squares
- Sodium bicarbonate solution

Lateral Internal Sphincterotomy

- Anal speculum
- #15 scalpel blade on a handle
- Metzenbaum scissors
- Forceps
- 4-0 chromic gut sutures

Miscellaneous (depending on technique)

- Topical nitroglycerine (0.2% to 2%)
- Topical nifedipine
- Botulinum toxin
- #11 scalpel blade

Dressing

- 4 × 4 gauze squares
- Gelfoam
- 2 in adhesive tape

PATIENT PREPARATION

Explain to the patient and/or their representative the risks, benefits, complications, and the options for treatment. The following discussion applies to the injection or surgical treatment of an anal fissure. Explain the postoperative care if a surgical technique is to be performed. Obtain an informed consent for the procedure. Undress the patient from the waist down. Place the patient prone or in the prone jackknife position (**Figure 67-2**). Tape the buttocks apart and to the procedure table to gain better exposure of the anus (**Figure 67-3**). Clean any dirt and debris from around the anus. Apply povidone iodine or chlorhexidine solution and allow it to dry. Place drapes to delineate a sterile field.

Perform an anal block. Mix 10 mL of local anesthetic solution with epinephrine in a syringe with 1 mL of sodium bicarbonate. This will decrease the burning sensation upon injection of the anesthetic solution. Inject the anesthetic solution into the subcutaneous tissue circumferentially around the anus, under the fissure, and laterally to anesthetize the pudendal nerves. The use of procedural sedation (Chapter 129) is recommended, but not required.

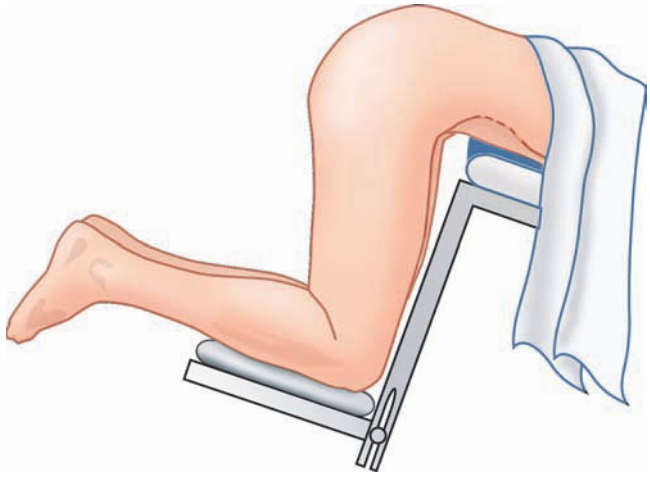


FIGURE 67-2. The prone jackknife position. Note that the lower abdomen is not touching the edge of the table.

TECHNIQUES

Begin the examination with a slow, gentle separation of the buttocks. This usually provides adequate visualization of the clean slit-like, acute anal fissure. The chronic fissure will appear similar to a deep ulcer with skin tags and enlarged anal papillae. Chronic fissures can be confused for external hemorrhoids when accompanied by a sentinel pile, which is a swollen external tag of skin at the base of the fissure. Test for adequate anesthesia. Inspect the lateral areas for an avascular area, usually on the right side between the right posterior and right anterior hemorrhoid complexes. Palpate the intersphincteric groove in the avascular area. It is a palpable depression between the caudal ends of the internal and external anal sphincter muscles.

Anoscopy can be performed for enhanced visualization when necessary. Most patients have too much pain and involuntary

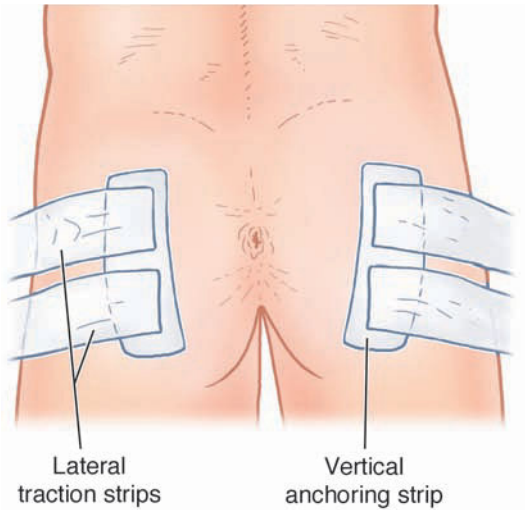


FIGURE 67-3. Taping the buttocks open in the prone patient allows for unobstructed access. The lateral traction strips are taped to the examination table or gurney.

sphincter spasm, which precludes a digital or anoscopic exam. Some require an exam under anesthesia. A proctoscopic exam may assist for ruling out secondary causes.

Atypical appearances of anal fissures, which might be eccentrically located, should prompt alternative diagnoses, such as inflammatory bowel disease, ulcerative colitis, and Crohn's disease. Sexually transmitted infections, such as chlamydia, gonorrhea, herpes, syphilis, and HIV, as well as tuberculosis, anal neoplasms, and sickle cell disease can present with anal fissures. If rectal bleeding is a prominent finding, endoscopy plus sigmoidoscopy or colonoscopy should be performed.

Management of an anal fissure begins conservatively. If unsuccessful, the next steps include topical preparations and injection therapy. A surgical sphincterotomy is the procedure of choice in refractory cases and has a 95% success rate.

FOUR-FINGER ANAL STRETCH

In the past, a four-finger anal stretch technique was performed. This involved putting the index and long fingers of both hands into the patient's anal canal and pulling the anal canal forcibly open. This would often cause an uncontrolled tear in the internal anal sphincter muscle. Although patients had relief of their symptoms, 40% developed a recurrence of the fissure and a significant proportion had some level of incontinence. **This technique is no longer recommended and should never be performed**. It is included only for the sake of completeness.

CONSERVATIVE MANAGEMENT

Most remedies for an anal fissure aim to alleviate internal sphincter hypertonia and anal pain. A trial of conservative treatment is employed for acute fissures and chronic fissures with mild to moderate symptoms. This consists of bulk fiber supplements, a high-fiber diet, increased oral intake of water, sitz baths, and topical anesthetics. The large, soft, bulky stools that result gently dilate the anal sphincter. The topical anesthetics and sitz baths in warm water after bowel movements will cleanse the area, alleviate the anal pain, and relieve internal anal sphincter muscle spasm.[15] Topical anesthetics such as lidocaine gel may be soothing, but are not more effective than fiber and sitz baths alone.[16] Oral pain medications and muscle relaxants such as diazepam may benefit. Suppositories are not recommended because they ascend to the rectal ampulla and do not effectively treat the problem within the anal canal. If an initial trial of conservative therapy for 4 weeks fails, the patient can undergo pharmacological therapy, injection therapy, or operative treatment.

TOPICAL TREATMENT

Nitric oxide has been identified as a chemical messenger mediating relaxation of the internal anal sphincter muscle. Patients treated with 0.2% glyceryl trinitrate ointment to their lower anal canal (near the fissure) twice daily exhibited relief of their anal pain, reduced maximal anal resting pressure, and increased anodermal blood flow as measured by laser Doppler flowmetry.[17] Topical nitroglycerin increases blood flow to the site, which is thought to result in less internal anal sphincter pressure, less pain, and a resultant improvement in healing rates in acute and chronic anal fissures.[18,19] After 8 weeks, 68% of patients treated with glyceryl trinitrate had healed their fissures. Some studies have shown no significant difference in healing rates when compared to placebo.[20] However, up to 75% of patients will have an adverse reaction, mainly a headache unresponsive to mild pain relievers or develop a tolerance to the nitrate.[21] Up to 33% of patients will have a recurrence of an anal fissure after the initial anal fissure has healed with nitroglycerin treatment.[22] Oral nifedipine, topical nifedipine 0.2% gel, oral diltiazem, topical diltiazem, and bethanechol have also been studied for the treatment of anal fissures.[23–29,36,37] They were all found to be comparable to topical nitroglycerin and with fewer side effects.[23–29,36,37]

Side effects such as a headache, primarily, may occur 10 minutes after application of topical nitroglycerin and typically lasts less than 30 minutes. Orthostatic hypotension has also been described in patients. Patients taking medications for erectile dysfunction (i.e., Cialis, Levitra, or Viagra) should not receive nitroglycerin-containing medications within 24 hours of their use due to the potential for life-threatening hypotension. After 24 hours, a lower concentration of nitroglycerin (e.g., 0.2% glyceryl trinitrate) is recommended compared to standard 2% ointments.

Topical nifedipine gel in a concentration of 0.2% used every 12 hours for 3 weeks has been successfully used to decrease anal sphincter pressures and help heal fissures.[30] No systemic side effects or significant anorectal bleeding was observed in 141 patients treated with topical nifedipine.[30]

BOTULINUM TOXIN

Botulinum toxin is another pharmacological approach to the treatment of a chronic anal fissure. Botulinum toxin inhibits the release of acetylcholine from nerve endings and has been shown to be a beneficial treatment for chronic anal fissures.[31] Injection close to each side of the fissure improves healing rates.[31] Inject 20 units of botulinum toxin A (Botox, Allergan, Irvine, CA) or 0.4 mL (50 U/mL) into the internal anal sphincter muscle on either side of the fissure using a 27 gauge needle. This can alleviate anal pain, decrease anal sphincter pressure, and promote healing.[32] Unfortunately, this can result in some form of temporary incontinence.[31,32]

LATERAL INTERNAL SPHINCTEROTOMY

The mainstay of operative therapy is a lateral internal sphincterotomy. This technique is curative in 95% of patients. Unfortunately, approximately 15% of patients will be left with some form of minor incontinence. The technique divides the internal anal sphincter muscle between the dentate line and the anal verge. A meta-analysis of 2727 patients undergoing operative techniques for anal fissures revealed no significant difference between open versus closed lateral internal sphincterotomy for persistence of fissure or incontinence.[33] However, significant differences were found when anal stretch was compared to all forms of sphincterotomy.

CLOSED LATERAL INTERNAL SPHINCTEROTOMY

The closed lateral internal sphincterotomy technique is preferred by some physicians (**Figure 67-4**). Its advantage is that a smaller wound is created. Unfortunately, this is a blind procedure and can result in injury to the patient and the physician.

Prepare the patient as described previously. Place a well-lubricated anal speculum into the anal canal. Open the speculum to provide a slight stretch to the anal sphincter muscles. Expose and view the left or right posterolateral quadrant of the anal canal. Place a gloved finger into the anal canal and palpate the internal aspect of the internal anal sphincter muscle. **Perform the remainder of this procedure while carefully palpating the course of the scalpel blade with the gloved finger in the anus.**

Insert a #11 scalpel blade horizontally through the skin and into the intersphincteric groove (**Figure 67-4A**). Advance the scalpel blade into the plane between the internal and external anal sphincter muscles and up to the level of the dentate line (**Figure 67-4A**). Direct the scalpel blade medially by turning it 90° (**Figure 67-4B**). Slowly divide the full thickness of the internal anal sphincter muscle while

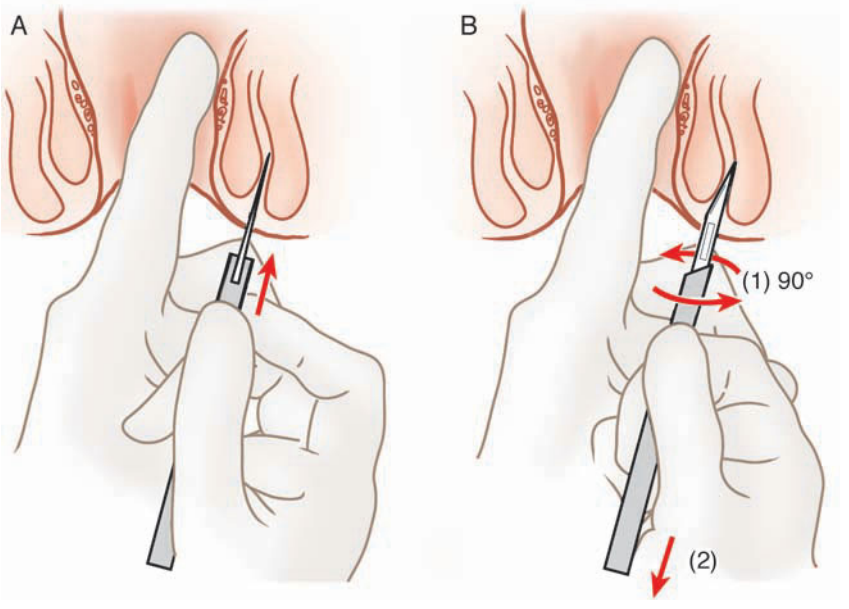


FIGURE 67-4. The closed lateral internal sphincterotomy. **A.** The #11 scalpel blade is inserted horizontally between the internal and external anal sphincter muscles. **B.** The scalpel blade is turned 90° (1) then withdrawn (2) to transect the internal anal sphincter muscle.

withdrawing the scalpel blade. **Do not cut the anoderm.** Withdraw the scalpel from the anal canal. Remove the anal speculum. Close the incision site with 1 or 2 size 4-0 chromic gut interrupted sutures. Pack the anal canal with 4 × 4 gauze squares for 10 to 15 minutes to aid hemostasis and prevent the formation of a hematoma.

OPEN LATERAL INTERNAL SPHINCTEROTOMY

The open technique provides a clear exposure to the anatomy of the region. This is especially important for those less experienced with the procedure. It avoids the potential for injury to the physician when compared to the closed technique.

Prepare the patient as described previously. Place a well-lubricated anal speculum into the anal canal. Open the speculum to provide a slight stretch to the anal sphincters and view the fissure (**Figure 67-5A**). Rotate the speculum 90° to expose and view the left or right posterolateral quadrant of the anal canal (**Figure 67-5B**). Place a gloved finger into the anal canal and palpate the internal aspect of the internal anal sphincter muscle.

Make a 1 cm longitudinal incision through the skin and subcutaneous tissue, between the dentate line and the anal verge (**Figure 67-5B**). This will center the edge of the internal anal sphincter muscle in the middle of the incision. Slide a scissors submucosally along the white internal anal sphincter muscle until the tips are at the level of the fissure, but not beyond the dentate line. Spread the arms of the scissors once to open the jaws of the scissors. Repeat this process on the other (deep) side of the internal sphincter muscle. Grasp and elevate the internal anal sphincter muscle with a forceps. Use a scissors to make a cut in the internal sphincter muscle the same length as the length of the anal fissure (**Figure 67-5C**).[34] **Do not completely transect the internal anal sphincter muscle. Preserve at least one-third of the proximal internal sphincter**

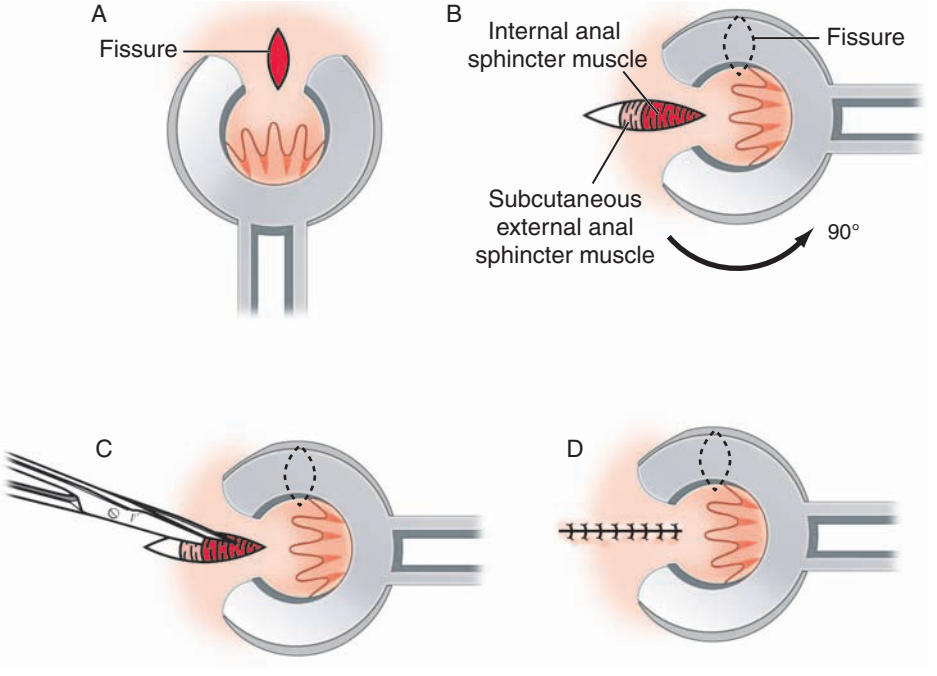


FIGURE 67-5. The open lateral internal sphincterotomy. **A.** The anoscope is inserted so that the anal fissure is visible. **B.** The anoscope has been rotated 90°. An incision has been made through the anoderm and subcutaneous tissue to expose the underlying anal sphincter muscles. **C.** The internal anal sphincter muscle is partially transected with a scissors. **D.** Closure of the incision.

muscle intact.[34] Pack the anal canal with 4 × 4 gauze squares to apply pressure to the area for 10 to 15 minutes to aid in hemostasis and to prevent the formation of a hematoma. Suture the incision closed with size 4-0 interrupted chromic gut (**Figure 67-5D**). Place a small piece of Gelfoam over the wound. Remove the anal speculum. Dress the incision site with 4 × 4 gauze squares.

AFTERCARE

Instruct the patient to remove the dressing in 12 to 24 hours or before a bowel movement. Warm sitz baths four times a day will keep the area clean and alleviate any pain. Prescribe a high-fiber diet with oral stool softener supplements to keep the stools soft and bulky. Oral analgesics such as acetaminophen or nonsteroidal anti-inflammatory medications with supplementary narcotic analgesics will often ease the immediate and postoperative pain. The patient should follow up in 1 to 2 weeks for reevaluation. The patient should immediately return to the Emergency Department if a fever, severe pain, or bleeding from the incision site develops.

COMPLICATIONS

Many complications have been associated with a lateral sphincterotomy. Itching, burning, bleeding, delayed wound healing, and constipation are minor problems. The patient may complain of mucus drainage or fecal soiling during the healing phase. Bulking agents or a high-fiber diet may help decrease the drainage. Recurrent fissures occur in about 8% of patients, 66% of which heal with conservative treatment. Up to 45% of patients may experience some degree of incontinence, but only 3% of patients may have their life affected.[35] A fecal impaction, abscess, or hemorrhage can become significant. Enemas are useful for the constipated patient. An abscess should be incised and drained, preferably in the Operating Room for adequate anesthesia to completely explore the wound and debride any necrotic tissue. A subcutaneous fistula can develop if the anoderm is violated during the sphincterotomy and not recognized. This is easily taken care of by doing a fistulotomy of this superficial skin bridge. The physician may be injured while performing the closed technique. This technique should be reserved for those with experience and a patient that is sedated to decrease the chances of injury.

SUMMARY

Anal pain with bleeding due to an anal fissure is initially treated conservatively with a high-fiber diet, stool softeners, and warm sitz baths. Most patients will respond to these measures. A few will fail conservative therapy and need pharmacological or operative therapy. The goal of all the different regimens is to decrease anal pain, reduce anal sphincter spasm, and heal the fissure.

68 External Hemorrhoid Management

Charles Orsay and Eric F. Reichman

INTRODUCTION

The primary disease process affecting external hemorrhoids is thrombosis. The mainstay of treatment is excision. **It is important to remember that the excision is to alleviate or palliate the pain.** The natural history of an untreated thrombosed external hemorrhoid is to rupture and spontaneously evacuate the clot or to resorb the clot over time. Therefore, treatment should give the maximum amount of pain relief with the least chance of complications. To make this decision it will be important to obtain a good history of the length of the pain, how severe it is, and whether there has been improvement. It is important to perform a physical examination to rule out prolapsed grade IV internal hemorrhoids, perianal abscesses, and other perianal masses.

ANATOMY AND PATHOPHYSIOLOGY

External hemorrhoids fall into three main groups: left lateral, right anterior, and right posterior (**Figure 68-1**). They are covered with anoderm and visible on the outside of the anal canal. They are composed of a venous plexus mixed with connective tissue. They drain into the middle and inferior rectal veins that terminate into the internal iliac and femoral veins, respectively. External hemorrhoids do not prolapse like internal hemorrhoids. They engorge and thrombose. It will not benefit the patient to try to reduce an external hemorrhoid since their normal location is mostly outside the anal canal and reduction will not remove the clot. External hemorrhoids are never covered with mucosa. The overlying skin may appear to look shiny, swollen, gangrenous, or like an orange peel mimicking the look of mucosa.

It is important to differentiate internal versus external hemorrhoids. Internal hemorrhoids originate above the dentate line, lack sensation, and are covered with mucosa. Prolapsed internal hemorrhoids are painless unless they become gangrenous, infected, strangulated, or thrombosed. External hemorrhoids originate below the dentate line, have sensory innervation, and are covered with squamous epithelium that matches the surrounding skin.

The patient usually complains of a history of the sudden onset of pain and swelling. The exact cause of thrombosed external hemorrhoids is unknown. It is probably related more to straining with lifting, jogging, or bicycling than chronic constipation. This explains why this problem occurs more often than internal hemorrhoidal disease in a younger age group.

External hemorrhoids can be diagnosed when a patient complains of a sudden onset of pain and swelling, usually with no

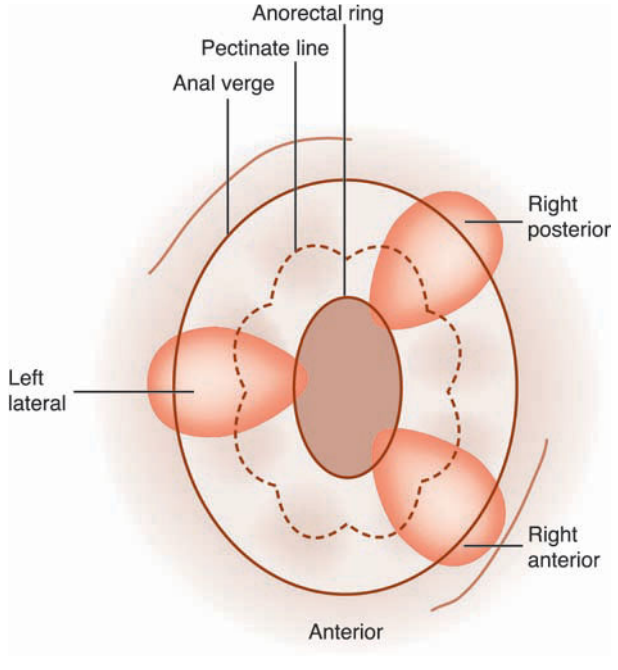


FIGURE 68-1. The position of the three main groups of external hemorrhoids.

bleeding. The physical examination will reveal a tensely swollen area covered with anoderm. The swelling will be visible by gently spreading the buttocks and inspecting the area near the anal canal. They have a bluish coloration, especially in patients with little skin pigmentation, and almost no redness. The swelling is abrupt, like placing a marble under a sheet and tucking in the edges. This differentiates the appearance of a thrombosed external hemorrhoid from the appearance of an abscess that would have erythema and gently sloping sides from edema.

INDICATIONS

The primary indication for the excision of a thrombosed external hemorrhoid is pain. The excision should occur as soon as possible from the onset of pain and usually not after the fourth day.[1] The pain should become tolerable in the normal course of events after the fourth day. The clot is already being absorbed at this time and the chance of having problems with bleeding increases and medical management is indicated. Improving pain suggests that medical management is the more appropriate method of care as thrombosed external hemorrhoids will spontaneously resolve in a few weeks with no complications. Medical management includes fiber supplements, sitz baths, stool softeners, topical corticosteroids (i.e., Proctofoam HC or Anusol HC), and over the counter hemorrhoidal agents (e.g., Preparation H). There is, however, a small subgroup of patients who do not seem to improve with medical management and will require excision, even late in the course of the disease. Surgical excision has a lower frequency of recurrence and a longer time interval to recurrence than conservative treatment.[2] The thrombosis to be excised should involve one or at most two hemorrhoids.

CONTRAINDICATIONS

There are several contraindications to the Emergency Department incision and drainage of a thrombosed external hemorrhoid. Grade IV internal hemorrhoids with thrombosed external hemorrhoids, circumferential hemorrhoids, or very large thrombosed external hemorrhoids should be managed by a Surgeon in the Operating Room using electrocautery or suture ligation to control hemorrhage. Patients taking anticoagulants require meticulous care and possible reversal of the coagulopathy. An allergy to local anesthetic agents will require a trip to the Operating Room to excise the hemorrhoid. Painless masses are never thrombosed external hemorrhoids and require evaluation by a Surgeon. Draining external hemorrhoids should be followed up in 24 hours by a Surgeon. Patients who are unable to cooperate with the procedure may require procedural sedation or general anesthesia. A Surgeon should manage patients who have thrombosed external hemorrhoids and also have inflammatory bowel disease, anorectal fissures, perianal infections, portal hypertension, rectal prolapse, anorectal tumors or who are immunocompromised. Patients with external hemorrhoids that are not thrombosed usually require no treatment for their external hemorrhoids. They may need appropriate referral for their anal pain.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Local anesthetic solution with epinephrine
- 5 mL syringe
- 25 gauge needle
- 18 gauge needle
- #11 scalpel blade on a handle
- 4 × 4 gauze squares
- 2-0 absorbable sutures (Vicryl, Dexon, chromic gut, or plain gut)
- 3-0 absorbable sutures (Vicryl, Dexon, chromic gut, or plain gut)
- Small dissecting scissors
- Small grasping forceps
- 2 in. adhesive tape
- Tincture of benzoin
- Silver nitrate applicator sticks
- Moisture-resistant drapes
- Posthemorrhoidectomy pack or 18 gauge Foley catheter

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedures to the patient and/or their representative. It is also important to explain to the patient what to expect after the procedure. Obtain an informed consent for the procedure.

It is crucial to position the patient so that the anus is clearly visible and the Emergency Physician can work with both hands. Place the patient in the prone or prone jackknife position with their hips flexed (**Figure 68-2**). Tape the buttocks to the procedure table (**Figure 68-3**). Apply tincture of benzoin to the buttocks and allow it to dry. Place strips of 2 inch adhesive tape on the left and right cheeks of the buttocks and perpendicular to the anus. Apply lateral and slightly cranial traction with adhesive tape to get the proper exposure. Attach the distal ends of the tape to the procedure table or stretcher to maintain exposure during the procedure. This positioning works best in the Operating Room when the patient is under anesthesia and unlikely to move. Explain to the patient that they must relax and refrain from squeezing their buttocks shut. If the patient is poorly positioned and there is difficulty with hemorrhage in the middle of the procedure, it is very difficult to stop and reposition the patient to place a suture for control. Apply drapes to protect the patient and clothing from spills. Clean the anus and surrounding area of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry.

The patient usually is in significant pain. The injection of local anesthetic solution can be excruciating. Consider the use of ice packs to the area for 5 to 10 minutes before injection, intravenous analgesics, sedatives, or procedural sedation. This will be greatly appreciated by the patient.

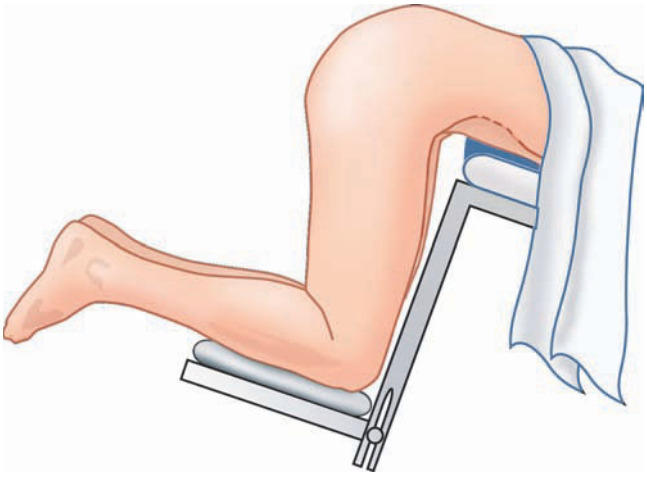


FIGURE 68-2. The prone jackknife position. Note that the lower abdomen is not touching the edge of the table.

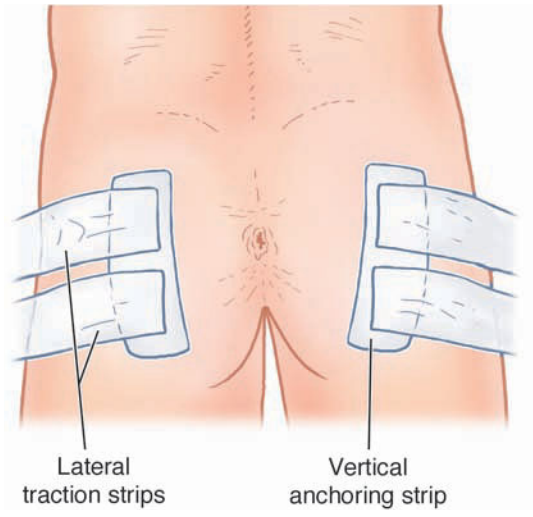


FIGURE 68-3. Taping the buttocks open in the prone patient allows for unobstructed access. The lateral traction strips are taped to the examination table or gurney.

TECHNIQUE

Determine the area of the incision. **The best pain relief will be achieved if the thrombosis is excised rather than incised.** If the hemorrhoid is very large, one-third or greater of the anal circumference, it is best to excise the middle third of the hemorrhoid leaving as much anoderm as possible to prevent the wound healing with a stricture. Excision can be achieved with two radial incisions starting near the center of the anus and enclosing an ellipse of skin that will be removed with the thrombosis (**Figure 68-4A**).

Inject local anesthetic solution containing epinephrine starting laterally and injecting medially to and beyond the thrombosed hemorrhoid (**Figure 68-4B**).[1] The injection should include both lines of the planned incision and, if possible, the area medial to the thrombosis. The local anesthetic agent should also cross the midline anteriorly and posteriorly to include nerve fibers crossing over from the opposite side of the anus. Allow 5 minutes for the local anesthetic to take effect. The degree of local anesthesia can be checked by pinprick or by pinching the thrombosed hemorrhoid with forceps.

Make the incisions with a #11 scalpel blade when satisfactory local anesthesia has been achieved. Dissect the ellipse of skin and the underlying clot from lateral to medial with a scissors (**Figure 68-4C**). **Do not cut the anal sphincter at the base of the wound (Figure 68-4D). It is important to remove the entire clot since the purpose of the excision is only to palliate the patient's pain.** Small clots in or between the sphincter muscles may still cause considerable pain. These can be grasped with a fine forceps and removed.

Examine the wound carefully for hemostasis. Localized areas of bleeding can often be controlled with the application of silver nitrate to cauterize the wound. It is the author's personal belief that there is less discomfort if silver nitrate is used for hemostasis than if one is forced to use suture ligature. However, if there is continued bleeding, a 3-0 absorbable suture can be used in a figure-of-eight formation over the area of bleeding. Plain catgut is preferred because the suture will dissolve very quickly. A suture that remains in place for several weeks in this area can sometimes be very uncomfortable for the patient. Dress the wound with 3 or 4 gauze squares folded in half and one piece of tape across the buttocks to hold the dressing in place.

AFTERCARE

The patient should leave the dressing in place until the next day or the next bowel movement. It is best to remove the dressing in a sitz bath and replace it with dry 4 × 4 gauze placed between the buttocks to collect any moisture. Frequently, tape is not necessary. Encourage the patient to take three or four sitz baths per day and after every bowel movement. The water should be warm, not hot, and the bath

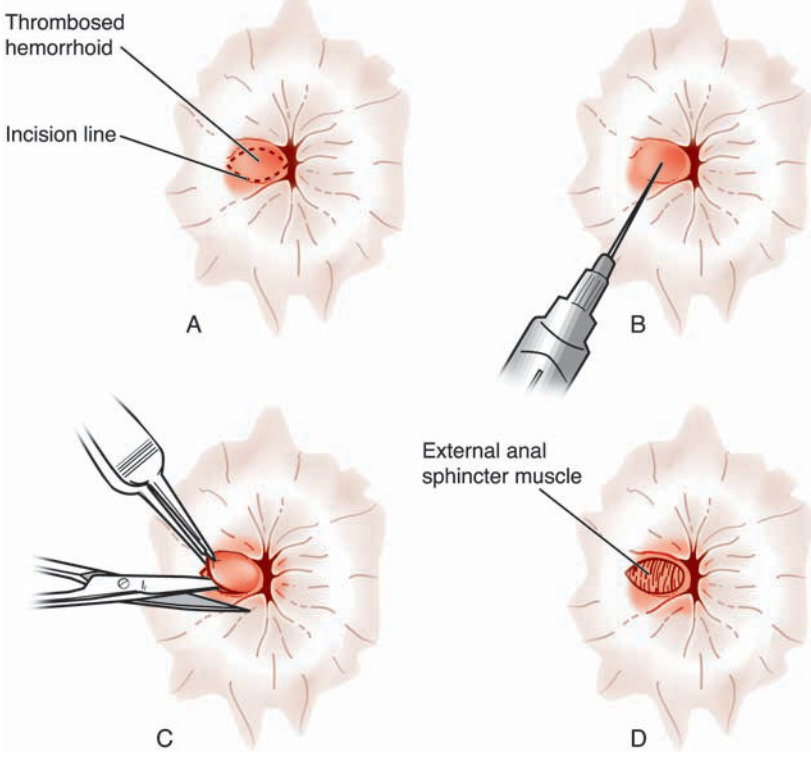


FIGURE 68-4. Excision of the thrombosed external hemorrhoid. **A.** The dotted line represents the incision lines to remove the skin and underlying thrombosis. **B.** Injection of local anesthetic solution. **C.** The skin incision has already been performed. The skin and underlying thrombosis are dissected free with a scissors. **D.** The ellipse of skin and the underlying thrombosis have been removed. The fibers of the underlying external anal sphincter muscle are visible.

should be for 20 minutes each time. The sitz bath serves two functions. It keeps the wound clean and helps relax the internal anal sphincter muscle spasm, which helps relieve the pain. An alternative to wiping after bowel movements and sitz baths is to shower. The shower will gently wash away any material and not hurt like wiping. The sitz baths and dressing changes should continue until the wound is healed.

Fiber supplements and stool softeners should be continued for at least 6 weeks. Prescribe one tablespoon of psyllium products (e.g., Metamucil) with water twice a day to soften and bulk the stool. The goal is to achieve an atraumatic stool that gently dilates the anus as it passes. If the patient is unable to tolerate psyllium, 100 mg of docusate orally once or twice a day can be used to soften the stool but will not provide the bulk.

The patient should feel much less pain after the thrombosed hemorrhoid is excised. The remaining pain can frequently be controlled with the sitz baths. Some form of oral analgesia is required. Acetaminophen or ibuprofen is usually adequate. The use of codeine or opiates has a pronounced constipating effect that could result in painful bowel movements. Do not prescribe narcotic analgesics for more than 24 hours. The patient should return to the Emergency Department if the pain is not improved, if bleeding continues, or if they develop a fever. The wound must be watched for infection, which fortunately is very rare.

COMPLICATIONS

The rate of complications for excision of thrombosed external hemorrhoids is not well reported.[1–6] Reported complication rates for more major anal surgery show that bleeding occurs in 1.5% to 4.0% of patients and infection occurs in 2% of patients.[1–3] Considering the persistent fecal contamination at the anus, this is a very low rate of infection. We can estimate that the complication rate for the excision of a thrombosed external hemorrhoid would be even less.

Any posthemorrhoidectomy bleeding that is minimal can be managed by the application of local pressure. Moderate to severe bleeding will require the insertion of a commercially available posthemorrhoidectomy pack.[7] This is an accordion-like pack that is inserted through the anoscope and into the anal canal. Pulling the two strings of the pack accordions the pack down into the anal canal to tamponade the bleeding. A Foley catheter may be substituted if the packs are not available. These patients require intravenous analgesics, intravenous sedation, and hospitalization.

The treatment for a patient with an infection in the perianal area who has not had surgery is to open the abscess and place the patient on sitz baths. Infection is very unlikely since the wound is already open from the excision procedure and the patient is taking sitz baths. Broad-spectrum antibiotics for aerobic and anaerobic bacteria should be given to any patient with a postprocedural infection and the wound examined under general anesthesia to rule out any underlying pathology.

Long-term theoretical complications include stricture and incontinence. These are exceedingly rare and can be prevented by not removing too much anoderm and not injuring the underlying external anal sphincter muscle.

The use of a linear incision should be avoided. The stretched skin will close and create a pocket in which a hematoma or abscess can form. Removal of clots through a linear incision (rather than an elliptical incision) is often difficult, inadequate, and may lead to a higher incidence of recurrence.

SUMMARY

External hemorrhoids may thrombose and cause the patient considerable pain. The natural history of this disease is for the clot to drain or resorb without significant long-term morbidity. Excision of the thrombosed external hemorrhoid will provide considerable relief if the patient presents acutely. It is important to achieve good hemostasis and not damage the underlying external anal sphincter muscle or remove too much anoderm to avoid problems with continence or stricture formation. Fiber supplements and sitz baths should be prescribed rather than surgical excision if the patient presents later in the course of the disease.

69 Prolapsed Rectum Reduction

Jamil D. Bayram and Eric F. Reichman

INTRODUCTION

Rectal prolapse is an uncommon condition. It was first described in the Bible (2 Chronicles 21). "You yourself will be very ill with a lingering disease of the bowels, until the disease causes your bowels to come out. … After all this, the Lord afflicted Jehoram with an incurable disease of the bowels. In the course of time, at the end of the second year, his bowels came out because of the disease, and he died in great pain." The pathophysiology of a rectal prolapse has been evolving since 1543 when Vesalius described the detailed anatomy of the anorectum. Today, three types of rectal prolapse are recognized and they represent three stages of a continuum.[1]

Rectal prolapse usually affects people at the extremes of age. It is most common in the very young and the elderly. The condition usually manifests itself in children within the first 4 years of life, with the highest incidence occurring in the first year.[2] The gender incidence in children is equal but slightly weighted toward males.[1] The peak incidence in the elderly is approximately between 60 and 70 years of age. It affects primarily elderly women, with a 6:1 ratio of females to males.[3]

ANATOMY AND PATHOPHYSIOLOGY

A rectal prolapse is classified into one of three stages (**Figure 69-1**). An internal prolapse is the prolapse of the upper rectum and sigmoid colon into the rectal ampulla (**Figure 69-1A**). It is also known as a hidden or occult prolapse. This type of prolapse does not emerge through the anus. Mucosal prolapse is more common in children. It results from the loose attachment of the mucosa to the submucosal layers and an associated weakness of the anal sphincter. A mucosal prolapse is diagnosed by the presence of radial folds and the absence of muscular wall.[3]

If the condition progresses, it leads to the protrusion of part or all layers of the rectum through the anal orifice. If only the mucosa is prolapsed, it is classified as an incomplete prolapse (**Figures 69-1B & C**). Synonyms include mucosal prolapse and partial prolapse. A complete rectal prolapse occurs when all bowel layers, including the muscular wall, are involved (**Figures 69-1D & E**). This condition is also known as a procidentia. The complete rectal prolapse is more common in the elderly. It results from generalized weakening of the pelvic floor and anal sphincter muscles. A complete rectal prolapse is characterized by the presence of concentric folds. A double thickness muscular wall will be felt upon palpation.[4]

Numerous risk factors are associated with a rectal prolapse.[4–11] These include malnutrition, chronic constipation, excessive straining, and diarrheal disorders such as amoebiasis, giardiasis, and other parasitic infections. Rectal prolapse in children is often idiopathic. However, there is an association with paraplegia, meningomyelocele,

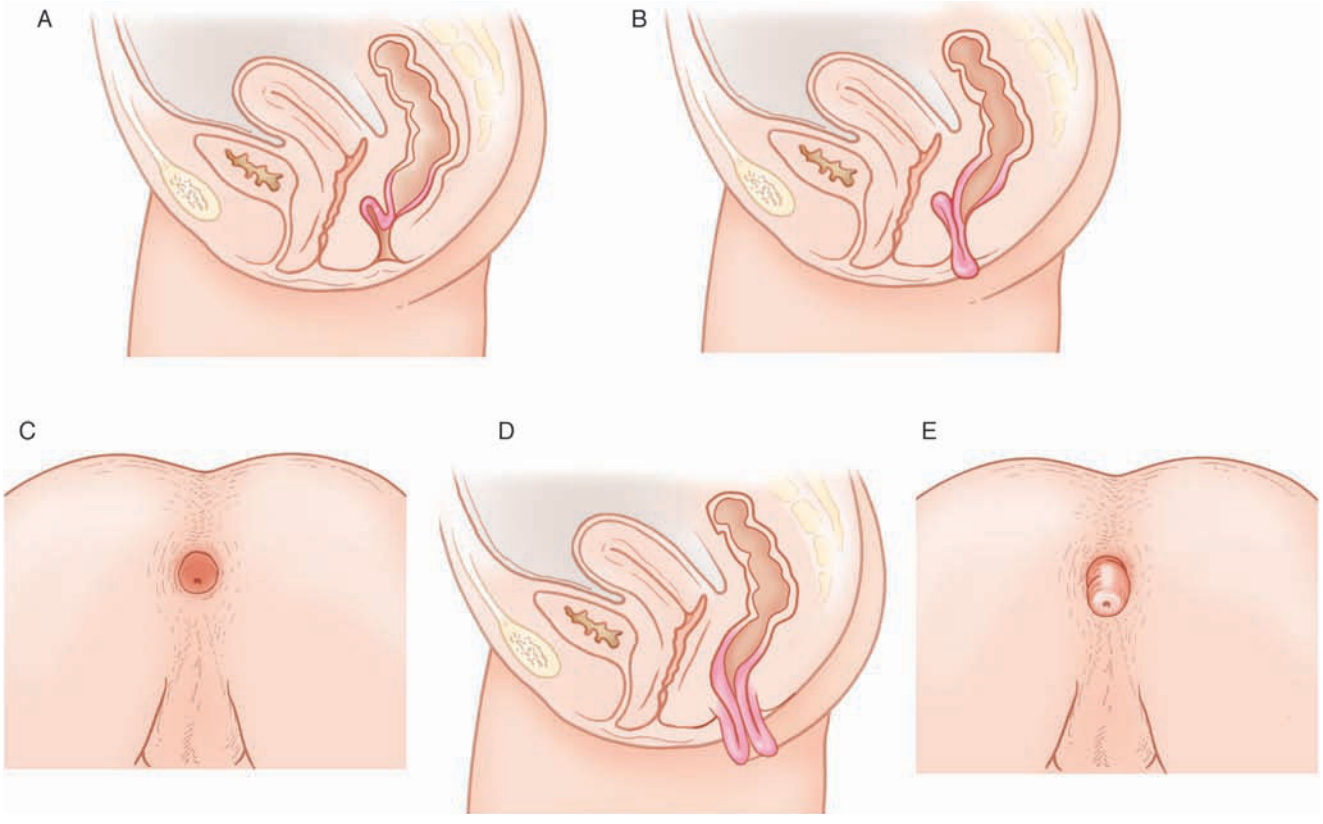


FIGURE 69-1. Types of rectal prolapse. **A.** Midsagittal view of the internal, hidden, or occult prolapse. **B.** Midsagittal view of the incomplete, mucosal, or partial prolapse. **C.** Posterior view of the incomplete, mucosal, or partial prolapse. **D.** Midsagittal view of the complete prolapse or procidentia. **E.** Posterior view of the complete prolapse or procidentia.

and pinworms. Anatomic variations such as a vertical course of the rectum, flat sacrum and coccyx, and lack of levator ani support can also result in a rectal prolapse. Children placed on adult toilet seats for prolonged periods of time may develop a rectal prolapse. One of the most serious risk factors for a rectal prolapse in children is cystic fibrosis.[6] Patients with cystic fibrosis have an 18% incidence of rectal prolapse. Children with no apparent cause for a rectal prolapse should be considered for a sweat chloride test. In the elderly, rectal prolapse is associated with collagen vascular diseases, malignancy, pelvic floor weakness, mental retardation, organic brain syndrome, stroke, chronic psychiatric conditions, and chronic neurologic conditions (e.g., tabes dorsalis, cauda equina, and multiple sclerosis).[5,11] It is important to note that patients with rectal prolapse often present with no apparent causes. The physician should maintain a high index of suspicion for the risk factors mentioned above.

The diagnosis can be difficult in the early stages when the prolapse remains in the upper canal (i.e., internal or hidden prolapse). The patient may complain of anorectal pain, back pain, discomfort during defecation, difficulty initiating a bowel movement, feeling of incomplete evacuation, tenesmus, pelvic fullness or pain, bloody discharge, or mucoid discharge. At this stage, asking the patient to strain may provoke the prolapse.

The diagnosis becomes easier in a partial or complete prolapse because it protrudes through the anus (**Figures 69-1C & E**). These patients may complain of an anal mass when they sit, stand, or walk.[1,5] It is usually the parent who notes the anal mass during defecation in the pediatric patient. The Emergency Physician should consider the mass described by the parents to be a rectal prolapse if the physical examination is negative.[2] Spontaneous reduction will often occur in this age group. It might be noted as an incidental finding on physical examination.

The differential diagnosis of a rectal prolapse includes anal warts, hemorrhoids, intussusception, prolapsed rectal polyp, or a prolapsed rectal tumor. **Mistaking an intussusception for a rectal prolapse may result in significant morbidity and mortality. Differentiating features of an intussusception include the ability to pass the finger between the prolapsed bowel and the anal sphincter (Figure 69-2). This is in contrast to patients with a rectal prolapse in which the protruding mucosa is continuous with the perianal skin and the examiner's finger will not pass that junction (Figure 69-1D).**[1,2,7] Patients with an intussusception usually appear ill whereas those

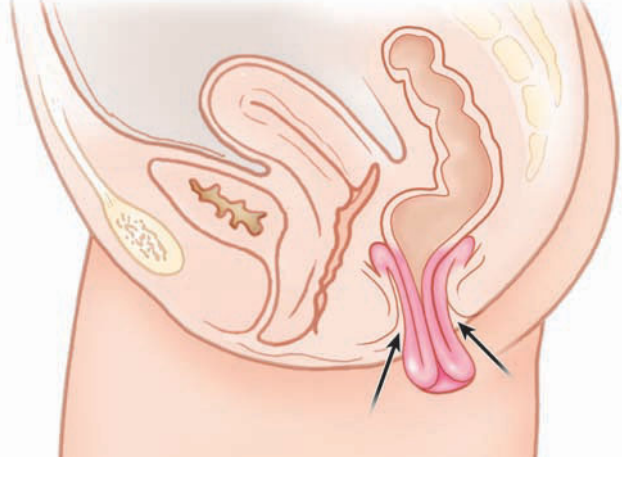


FIGURE 69-2. An intussusception. Note the junction where the finger can be passed (*arrows*).

with a rectal prolapse appear well.[2] Prolapsing hemorrhoids are more often seen in adolescents and adults, are usually purple in color, have deep grooves between the areas of prolapsing tissue, and lack radial or concentric folds. A prolapsed polyp or tumor is plum-colored, does not involve the entire anal circumference, is movable, and is usually palpable as a small growth on a stalk.[2,8]

INDICATIONS

Reduction should be attempted on all patients with a visible rectal prolapse as soon as possible to avoid vascular compromise of the bowel. It is easier to reduce before edema occurs from prolonged prolapse. Early reduction may avoid complications and stretch damage to the pelvic floor ligaments, the pelvic floor muscles, and the anal sphincter muscles.

CONTRAINDICATIONS

There are few absolute contraindications to the reduction of a rectal prolapse. Gangrene, necrosis, or ulceration of the mucosa are signs of vascular compromise or ischemia and require an emergent consultation by a General Surgeon or Colorectal Surgeon. **Do not reduce ischemic tissue as it may precipitate peritonitis or cause a perforation of the rectum. If the Surgeon's arrival is delayed, prompt gentle reduction should be attempted only after discussions with the Surgeon. Do not reduce an intussusception.** Consult a Surgeon for further evaluation and management of an intussusception.

EQUIPMENT

- Gloves
- Water-soluble lubricant
- 4 × 4 gauze squares
- 2 in. wide adhesive tape
- Benzoin spray or swabs
- Sedatives as necessary

PATIENT PREPARATION

Explain the reduction procedure to the patient and/or their representative. Reduction is most likely successful in a relaxed and nonstraining patient. Sedation may sometimes be required in adults. Sedation is more often needed in pediatric patients. Children tend to be more anxious, crying, fighting, or straining; all of which will increase the intraabdominal pressure and make reduction more difficult. The sedation may be administered intramuscularly, intravenously, orally, or subcutaneously.

Position the patient.[8,9] Place the child in the prone knee-chest position on the parent's lap or on the examination table (**Figure 69-3**). Place the adult patient in the prone position on an examination table. Large buttocks or tense buttocks may interfere with the reduction of a prolapsed rectum. In these cases, apply benzoin to the buttocks and allow it to dry. Tape the buttocks open for better access (**Figure 69-4**). Alternatively, in both age groups, the patient can be placed in the lateral decubitus position.

TECHNIQUE

Position the patient. Liberally apply water-soluble lubricant onto the prolapsed rectum. Apply gauze squares onto the prolapsed tissue at the 3 o'clock and 9 o'clock positions (**Figure 69-5**). The bowel wall is quite slippery after lubrication and the gauze will improve the grip on the mucosa. Place both thumbs near the bowel lumen with the hands stabilized on the buttocks (**Figure 69-5A**). Apply steady, gentle



FIGURE 69-3. The prone knee-chest position for children.

thumb pressure to gently roll the prolapsed rectum back through the anus. Alternatively, the index and the middle fingers can be used to reduce the prolapsed rectum (**Figure 69-5B**). **Regardless of the method used, constant and steady pressure must be applied to the prolapse.** The reduction often requires patience as it may take up to 15 minutes to reduce a prolapsed rectum.

The rectum will become edematous, and swelling will be noted, if the rectal mucosa has been prolapsed for a prolonged period of time. Wrap a gauze square around the prolapsed rectum and apply gentle manual compression for 3 to 5 minutes before attempting the reduction. If the first effort is unsuccessful without sedation, a second attempt at reduction after administering sedation is appropriate. If the prolapse rectum will not reduce (i.e., incarcerated), consult a General Surgeon or Colorectal Surgeon for reduction under general anesthesia and possible surgical repair.

ALTERNATIVE TECHNIQUES

A novel method to help reduce a prolapsed rectum uses simple table sugar.[12] The longer the rectum is prolapsed, it becomes more edematous and the more difficult to reduce. Apply a liberal amount of sugar onto the prolapsed rectum and cover it with several layers of gauze. Allow the patient to relax for 15 to 30 minutes. The hyperosmotic sugar draws fluid out from the edematous prolapsed rectum. Gently wipe off the sugar with saline or water moistened gauze. Attempt manual reduction as described above.

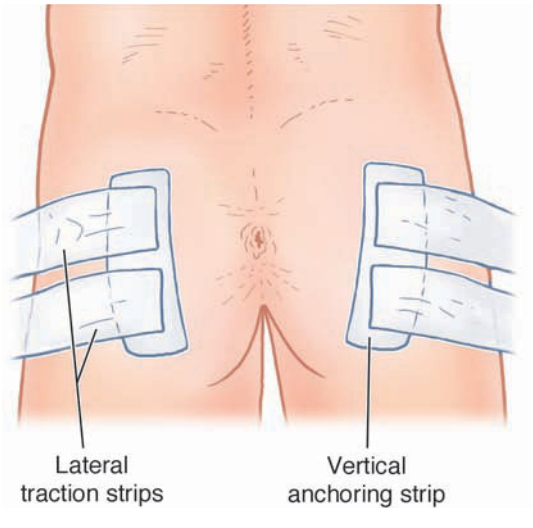


FIGURE 69-4. Taping the buttocks open in the prone patient allows for unobstructed access. The lateral traction strips are taped to the gurney or examination table.

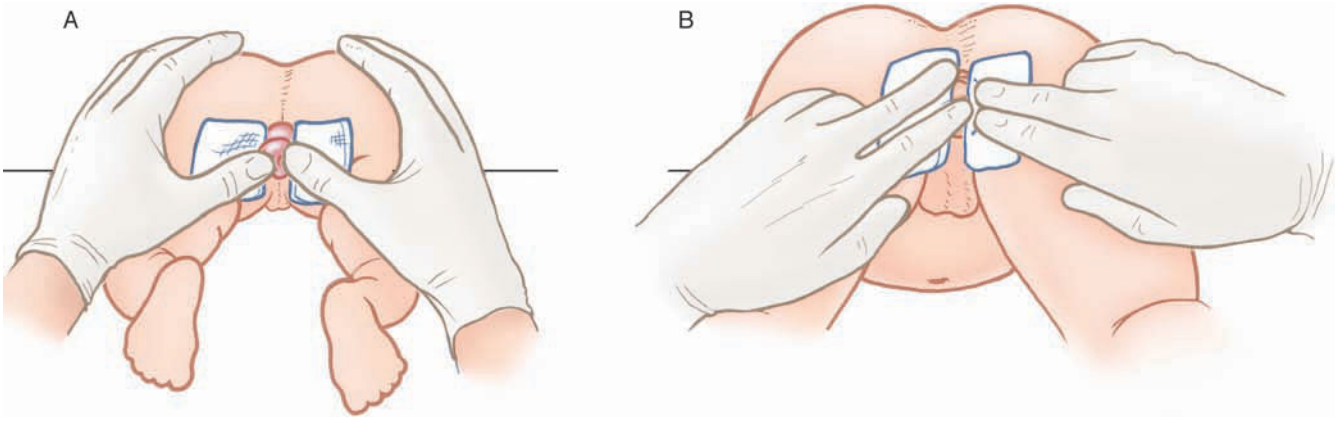


FIGURE 69-5. Rectal prolapse reduction techniques. **A.** Thumb method. **B.** Finger method.

ASSESSMENT

Perform a digital rectal examination to ensure that the reduction is complete.[8] If not, apply pressure with the examination finger to completely reduce the prolapse.

AFTERCARE

The application of a bulky pressure dressing will prevent an acute recurrence of the prolapse. Apply petrolatum gauze over the anus. Apply several gauze squares over the petrolatum gauze and into the gluteal cleft. Tape the buttocks together. **The patient and the family must be informed that reduction might be temporary and the prolapse could recur.** Training cooperative parents to reduce the prolapse is warranted in cases of recurrent rectal prolapse in the pediatric age group. Be sure to send them home with gauze squares, gloves, and lubricant.

The underlying cause of the rectal prolapse should be treated. A prophylactic regimen of laxatives and stool softeners should be started if the patient is constipated. Instruct the patient on proper eating habits including fruits, vegetables, and roughage. In cases of diarrhea, treatment should target the underlying causes. Seating children on a child's potty-chair or on an adult toilet seat with a small hole may prevent future episodes of rectal prolapse. Discourage excessive squatting and straining.[3]

All patients who have undergone successful reduction should be referred to a Colorectal Surgeon for further evaluation. Children should be followed up to rule out serious etiologies such as cystic fibrosis. As the child grows, the supporting tissue around the rectum develops. Therefore, rectal prolapse in this age group is usually self-limited and surgery is rarely required. Adults should be referred for proctosigmoidoscopy to rule out a tumor. Conservative management in the elderly is rarely successful and most patients eventually require surgical repair. Early referral can avoid complications and stretch damage to the pelvic floor ligaments, pelvic floor muscles, and the anal sphincter muscles.

COMPLICATIONS

The complications of the procedure are often minimal. The reduction itself may lead to minimal mucosal bleeding that is self-limited. The patients may experience a slight discomfort in the anus for up to 24 hours after the reduction. This can be managed with oral acetaminophen or nonsteroidal anti-inflammatory drugs.

The inability to reduce a rectal prolapse is an indication for surgical consultation in the Emergency Department. An incarcerated rectal prolapse can lead to vascular compromise. Signs of vascular compromise include mucosal gangrene, necrosis, and ulceration. These patients require admission to the hospital with an emergent surgical consultation, even if the reduction is felt to be successful, due to the risk of reducing ischemic bowel that could perforate. Very rarely, the rupture of an incarcerated rectal prolapse with small bowel herniation through the tear has been reported during attempted reduction.[10] Fecal and urinary incontinence may also occur as a result of a long-standing prolapse. This is due to the entrapment and stretching of the pudendal or perineal nerve resulting in neurovascular dysfunction and not a complication of the reduction procedure.

SUMMARY

Rectal prolapse is an uncommon condition affecting the very young and the elderly. Reduction can usually be performed in the Emergency Department. It is important to differentiate a prolapsed rectum from an intussusception and from external hemorrhoids. The reduction procedure is quick and simple. The application of constant, firm, and gentle pressure to the rectum in a relaxed and nonstraining patient will reduce most rectal prolapses. All patients with a prolapsed rectum should be referred for further evaluation to rule out underlying pathologic causes for the prolapse.

70 Anoscopy

Charles Orsay and Eric F. Reichman

INTRODUCTION

Examination of the anal canal is important to evaluate several common patient complaints relating to the anus including itching, pain, and bleeding. While it is possible to examine parts of this area with flexible instruments or a rigid rectosigmoidoscope, the only method that will give a consistent clear view of the anal canal is anoscopy.[1] To properly perform this examination, it is necessary to thoroughly understand the anatomy, be aware of the possible causes of the symptoms you are evaluating, use the appropriate equipment, and position the patient correctly.

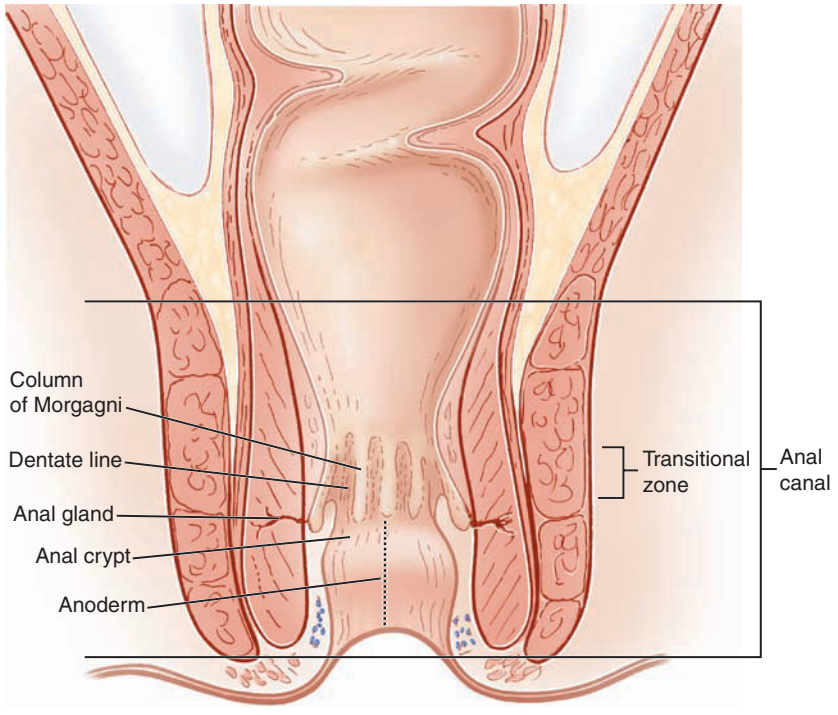


FIGURE 70-1. The topical anatomy of the anal canal.

ANATOMY AND PATHOPHYSIOLOGY

It is necessary to understand the anatomy of the anal canal in order to evaluate the patient's signs and symptoms properly. The anatomy can be divided into topical anatomy and major supporting structures.[2] The topical anatomy is depicted in **Figure 70-1**.

Perineal skin covers the perineum, is fully innervated, and includes both hair follicles and apocrine glands. It can be grossly distinguished from the anoderm surrounding the anal canal by the visible hair. The anoderm is specialized squamous epithelium that lines the majority of the anal canal. It is fully innervated but does not have apocrine glands or hair follicles. This epithelium is very thin, elastic, and if destroyed by surgery or infection may relate to stricture formation during healing.

Looking into the anal canal, the anoderm can be seen to end in an irregular line called the dentate line. This is a demarcation of anoderm to transition zone mucosa. Proximal to the dentate line there is no longer cutaneous sensation. This allows minor therapeutic procedures like banding or suture ligation to be done without an anesthetic agent. It is also the reason that internal hemorrhoids do not routinely cause pain. The transition zone continues proximally for a variable length of 6 to 12 mm before it becomes the rectal mucosa. The junction of the transitional zone with the rectal mucosa is not visible to the naked eye. The rectal mucosa decreases in diameter in the area of the transitional zone. The mucosa appears to be bunched together in columns called the Columns of Morgagni at the level of the dentate line. Crypts are formed between the columns as the transitional zone becomes the dentate line. Under the anoderm in the crypts are multiple anal glands. Blockage of the anal glands by foreign material leads to infection. Blockage or primary infection of the glands causes the majority of abscesses that arise around the anus. The crypts also are areas to look for foreign bodies such as fish or chicken bones.

External hemorrhoids are located in the left-lateral, right-posterior, and right-anterior portions of the distal anal canal and are covered with anoderm. Their normal position is outside the anal canal and they can be examined by gently spreading the buttocks. The internal hemorrhoids also are located at the left-lateral, right-posterior, and right-anterior positions. They are normally located in the distal rectum and are covered with transitional epithelium and rectal mucosa. They can best be examined with an anoscope if they are not prolapsed. It is possible to see them with a retroflexed sigmoidoscope or colonoscope, but the increased air pressure tends to flatten them out giving a false impression as to their size.

The anoscope is used to examine the closed portion of the anal canal. It dilates the anal sphincter and allows one to examine the underlying canal through an opening cut out from the side of the anoscope called a fenestration. It is important to understand the anatomy and functions of the anal sphincter musculature to properly perform this examination (**Figure 70-2**). Immediately below the anoderm is the internal anal sphincter muscle. It is circumferential and consists of a thickening and rounding of the continuation of circular smooth muscle from the rectum. This muscle is not under conscious control. The first response of the internal anal sphincter muscle to a rectal examination or anoscopy is contraction. It is necessary to pause and use slow gentle dilatation to prevent patient discomfort and complete the examination. The axis of the anal canal will normally follow an imaginary line drawn from the anus to the umbilicus. Surrounding the internal anal sphincter muscle is the external anal sphincter muscle. This is comprised of three external sphincters of striated muscle that are more loop-like than circumferential. Deep to these muscles and at the top of the anal canal is the puborectalis muscle. This forms a sling, pulling the anus anterior. It is connected to both the anal sphincters and the levator ani group of muscles. The puborectalis muscle can be felt as funnel-shaped during the digital rectal examination.

INDICATIONS

Anoscopy is indicated for the evaluation of most anal symptoms.[1–6] There are numerous common complaints and conditions where an anoscope, in conjunction with visualization and a digital rectal examination, would be used for evaluation or therapy.[3–5] Anoscopy can be used diagnostically to evaluate rectal bleeding, anal pain, pain with defecation, perirectal infections, fistulas, foreign bodies,

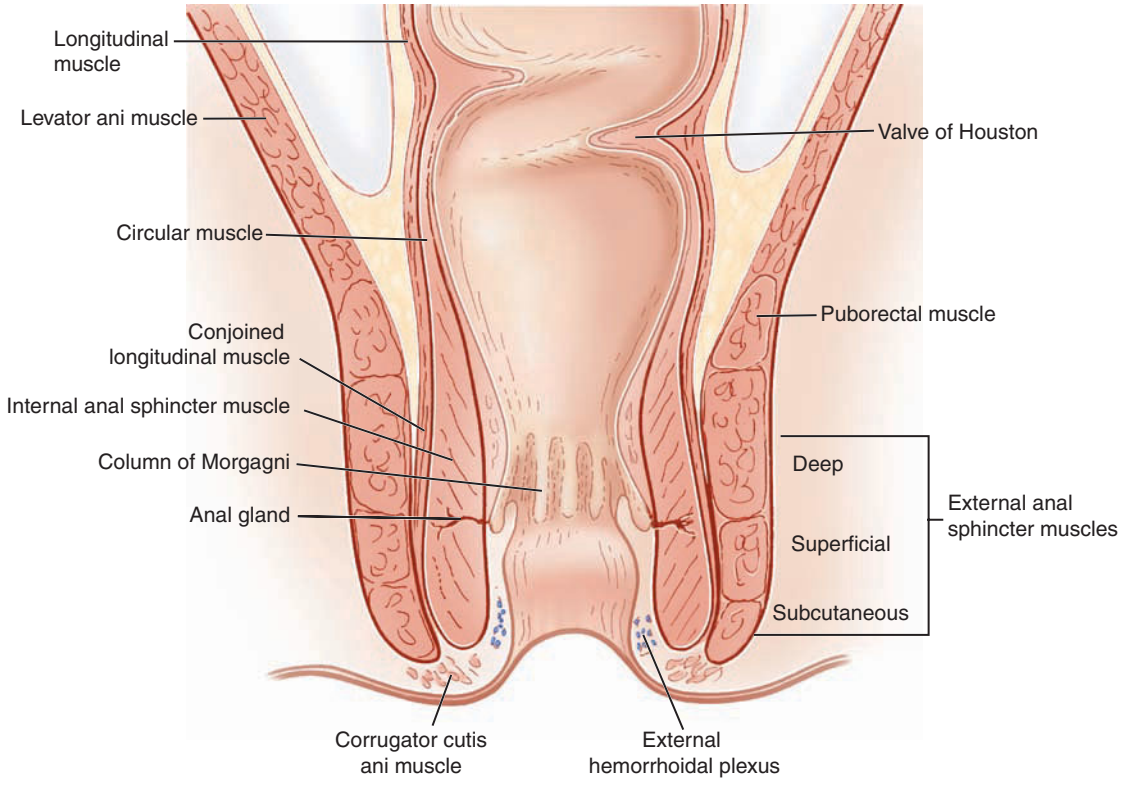


FIGURE 70-2. The major supporting structures of the anal canal.

internal hemorrhoids, anal masses, and abnormal digital rectal examinations. Anoscopy can be used therapeutically to open the anus and allow the application of medications, procedures to be performed, or for observation in the management of anal fissures, intraanal condylomata, and hemorrhoids.

CONTRAINDICATIONS

Most contraindications to anoscopy are relative. The amount of discomfort a patient will undergo relates to their tolerance. Minor discomfort associated with topical skin excoriations can be treated with 2% lidocaine jelly used as a lubricant and the examination can then continue. Moderate pain can be managed with the application of procedural sedation. Severe pain associated with anal fissures or anal abscesses is best managed in the Operating Room under general anesthesia.

Strictures can occur from postsurgical changes, inflammatory bowel disease, chronic diarrhea, and other disease processes. Anoscopy should not be performed if the patient has anal strictures, a partially imperforate anus, or a completely imperforate anus. The physician should determine if the anoscope will pass through the anus during the visual examination and the digital rectal examination. **Never insert the anoscope if resistance is encountered. The anoscope should not be used to dilate the anus.**

Anoscopy is contraindicated if any recent surgical procedure has been performed on the anus. The possible exception is for that of the physician who performed the surgical procedure.

EQUIPMENT

- Water-soluble lubricant
- Lidocaine jelly, can be used as lubricant for patients with pain
- Anoscope or Vernon-David rectal speculum
- Drapes
- Examination table, preferably a proctoscopy table
- Nonsterile examination gloves
- 4 × 4 gauze squares
- Large cotton-tipped applicators
- 4-0 chromic gut suture
- Suction, optional
- Bright directional light source
- Tincture of benzoin
- 2 in. adhesive tape

There are many different types of anoscopes available. The type of instrument chosen is largely the preference of the examining physician. The Vernon-David type anoscope is often preferred as it has a wide fenestration and a diameter that is not too large for most patients while allowing the best view. The Ives anoscope may be used if a larger diameter instrument is required. Some of the metal reusable and plastic disposable anoscopes allow for the attachment of a fiberoptic light source. Unfortunately, many of these anoscopes do not allow the same view as a Vernon-David anoscope. **Some physicians use a glass test tube as a substitute for an anoscope. This is to be discouraged as the test tube can break and cause serious complications.**

The anoscope is a two-piece device (**Figure 70-3**). It ranges from 7 to 25 cm in length. It can be manufactured from clear plastic, opaque plastic, or metal. The anoscope may have a handle that allows the operator to control its movements. The proximal end is funnel-like and tapers into the cylindrical shaft that is approximately 2.5 cm in diameter. The distal end of the anoscope is tapered on one side and known as the fenestration. The fenestration allows the mucosa to be viewed within the anoscope. It is also where procedures are

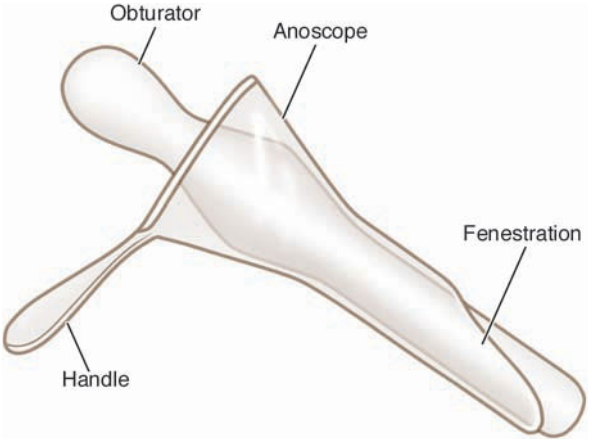


FIGURE 70-3. An example of an anoscope.

performed through the anoscope. Some anoscopes have a site proximally to attach a light source. The obturator is smooth tipped, fits within the anoscope, and occludes the anoscope. Its rounded, distal end protrudes from the anoscope. The obturator is used each time the anoscope is inserted to prevent trauma to the anal mucosa. It is removed after the anoscope is inserted to allow viewing through the anoscope.

PATIENT PREPARATION

The area being examined is within the anal canal and requires no special preparation to view correctly. The patient should be given an opportunity to voluntarily evacuate their bowels prior to the examination. It is necessary to have the patient remove their clothes from the waist down and provide protective barriers to protect the patient, the patient's clothing, and the surrounding area from spills. It is usually wise to avoid enema preparations, as liquid stool is much more difficult to contain than solid stool.

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. Explain to the patient what to expect. Discuss the order of examination, the importance of relaxing, the reason for multiple insertions and withdrawals of the anoscope, and what you are looking for or expect to find.

Anoscopy can be performed with the patient in one of many positions. The position that allows the best observation in most patients is the knee-chest or prone position (**Figure 70-4**). This allows the buttocks to be to either side and places the anus at the proper angle.

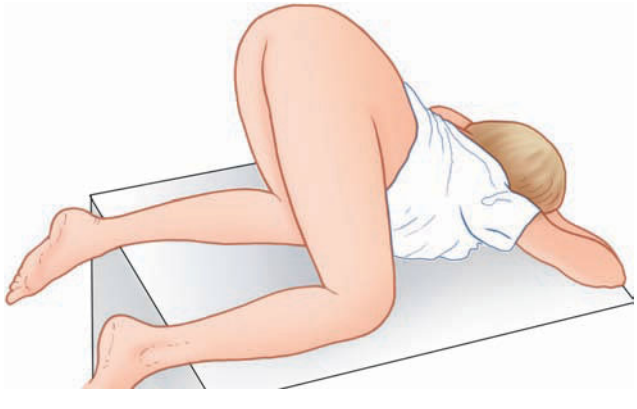


FIGURE 70-4. The knee-chest position.

Examination of the anus in this position is easiest on a proctoscopy table, but can also be performed on an examination table. The lateral decubitus position with the knees drawn up and the buttocks protruding partly off the table is acceptable for limited diagnostic examinations. Large buttocks may prevent the examination. Apply tincture of benzoin to the buttocks and allow it to dry. Apply 2 in. adhesive tape to the buttocks and tape them to the examination table to spread the buttocks apart (**Figure 68-3**). Place a Mayo stand or bedside examination table next to the patient's buttocks.

Carefully inspect the entire perineum and anal verge. Many types of pathology such as fissures, fistulas, hemorrhoids, condylomata, and dermatologic conditions can be seen at this time. **A digital rectal examination with a well-lubricated gloved finger prior to anoscopy is mandatory.** The digital rectal examination has many advantages. It allows one to find pathology that is better palpated than viewed. It gives the examiner the size and angle of the anal canal. It will allow the examiner to identify if the patient has tenderness that would preclude anoscopy. Any strictures will be identified, allowing the examiner to prevent the anoscope from advancing through these strictures and lacerating the tissues. It may identify pathology, so that the examiner can focus the anoscopy in a specific area. It prelubricates the anal canal, making insertion of the anoscope easier. Lidocaine jelly can be used as a lubricant and as an anesthetic if the patient has pain from excoriation. The use of intravenous analgesics, intravenous sedatives, procedural sedation, or general anesthesia may be occasionally required if the patient has significant pain.

TECHNIQUE

The technique of anoscopy is rather simple.[6] Look closely at the anoscope and be sure it is intact and correctly assembled. Liberally lubricate the obturator and anoscope. Ensure that the obturator is easily removed and replaced from within the anoscope. Grasp the anoscope with the dominant hand, with the obturator secured in place by the thumb of that hand (**Figure 70-5A**).

Use the nondominant hand to spread the anus (**Figure 70-5A**). Place the obturator at the center of the anus. Slowly insert the anoscope, giving time for the internal anal sphincter muscle to relax. Direct the tip of the obturator toward the patient's umbilicus (**Figure 70-5A**). Insert the anoscope to its fullest depth to start the examination with the area of fenestration pointed toward the area you wish to view first (**Figures 70-5B & C**). Slowly remove the obturator and place it on a Mayo stand or a bedside table where it can easily be retrieved. Adjust the directional light for the best illumination.

The usual starting place for the examination is the posterior midline (**Figures 70-5B & C**). Slowly withdraw the anoscope under direct observation to evaluate the entire depth of the anal canal exposed by the fenestration. Remove any fecal material with a cotton-tipped applicator. Note the appearance of the dentate line, the mucosa, and the anoderm. Note the presence and location of any blood, hemorrhoids, masses, mucus, purulence, or other abnormalities. If the anoscope does not fully dilate the columns of mucosa, a cotton-tipped applicator can be used to gently move the mucosa to view between the columns. Continue to withdraw the anoscope as the mucosa is viewed.

Replace the obturator when the anoscope is fully removed from the patient. Rotate the anoscope 30° to 40° and reinsert it into the anal canal. It often takes four or five repeated insertions to evaluate the entire circumference of the anal canal. Some physicians prefer to replace the obturator and rotate the anoscope while it is still within the anal canal. This method is discouraged as it may pinch the tissue of the anus between the obturator and the viewing tube and does not allow the examiner to see the entire depth of the anal canal.

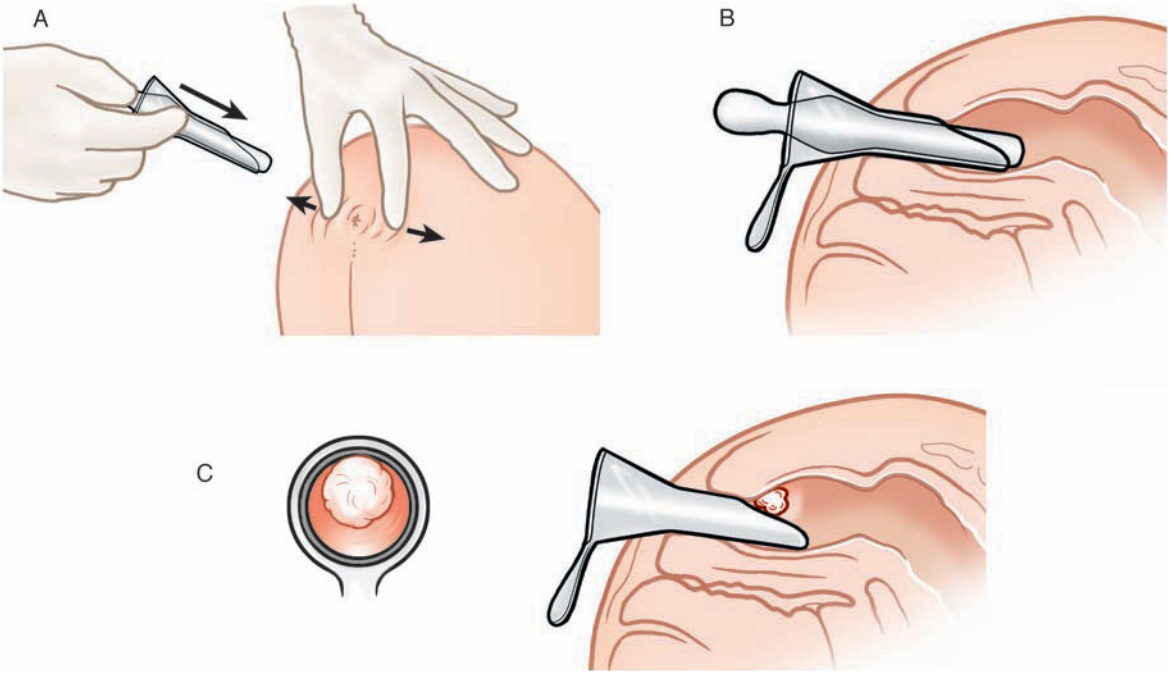


FIGURE 70-5. Placement of the anoscope. **A.** The nondominant hand is used to spread the anus. The anoscope is inserted at an angle and aimed toward the umbilicus. Note that the dominant thumb is used to secure the obturator within the anoscope. The anoscope is completely inserted with the fenestration pointed toward the posterior midline (**B**) or the area of interest (**C**).

It is helpful to ask the patient to bear down when examining the left-lateral, right-posterior, and right-anterior sections of the anal canal when evaluating the internal hemorrhoids. It is often possible to reproduce the prolapsing of internal hemorrhoids to evaluate the grade of the hemorrhoids. Bearing down is particularly important if bleeding is the symptom. It is possible to identify the area of bleeding.

ANOSCOPY IN CHILDREN

Anoscopy may be performed in children for the same indications as an adult. An anoscope of 8 to 10 cm in length and 1 cm in diameter is appropriate for a neonate and young infant. An anoscope of over 12 cm in length and 1.5 cm in diameter is appropriate for an older infant and child. An adult anoscope is appropriate for an older child and adolescent. Position the young child supine with their buttocks at the edge of the examination table. Have an assistant grasp, abduct, and flex the child's thighs so they touch the abdomen without compressing the abdominal wall. The remainder of the procedure is as described above.

COMPLICATIONS

Examination of the anal canal with an anoscope should have minimal or no complications. It is possible to cause abrasions or lacerate the very thin anoderm. This is normally avoidable with adequate lubrication, the use of the obturator when inserting the anoscope, and gentle technique. Minimal bleeding from mucosal irritation is common and self-limited. Dislodgement of a clot may result in hemorrhoidal bleeding that can be controlled with direct pressure, packing the anal canal with gauze squares, or a 4-0 chromic gut figure-of-eight suture. The most common complication is pain. This is avoidable by allowing enough time for the anus to relax while gently inserting the anoscope. The presence of an anal fissure may preclude the examination. The use of a topical anesthetic will usually allow the examination to proceed.

SUMMARY

Anoscopy is a commonly performed procedure in the Emergency Department. The anal canal is a cylindrical structure surrounded by sensitive anoderm and contracting anal sphincter muscles. The best way to examine this area is with a side-viewing fenestrated anoscope. Anoscopy allows direct viewing of the anal canal to best evaluate anal and perianal complaints. Anoscopy will give the most information with minimal discomfort when properly performed. Always perform a digital rectal examination prior to anoscopy.

71 Rigid Rectosigmoidoscopy

Charles Orsay and Eric F. Reichman

INTRODUCTION

Rigid rectosigmoidoscopy has largely been replaced by the flexible sigmoidoscope for routine elective screening and diagnostic workups. The rigid rectosigmoidoscope is superior to the flexible sigmoidoscope in measuring distances accurately, examining an unprepared patient, and when trying to work within the bowel lumen, for example when removing foreign bodies. The larger lumen of the rigid rectosigmoidoscope allows for a larger biopsy of lesions where pathology is in question. The cost associated with this examination is less than that for flexible sigmoidoscopy. The rigid rectosigmoidoscope can be purchased in a disposable model that performs well. It is important for a physician who evaluates and treats problems related to the colon, rectum, and anus to be familiar with rigid rectosigmoidoscopy.

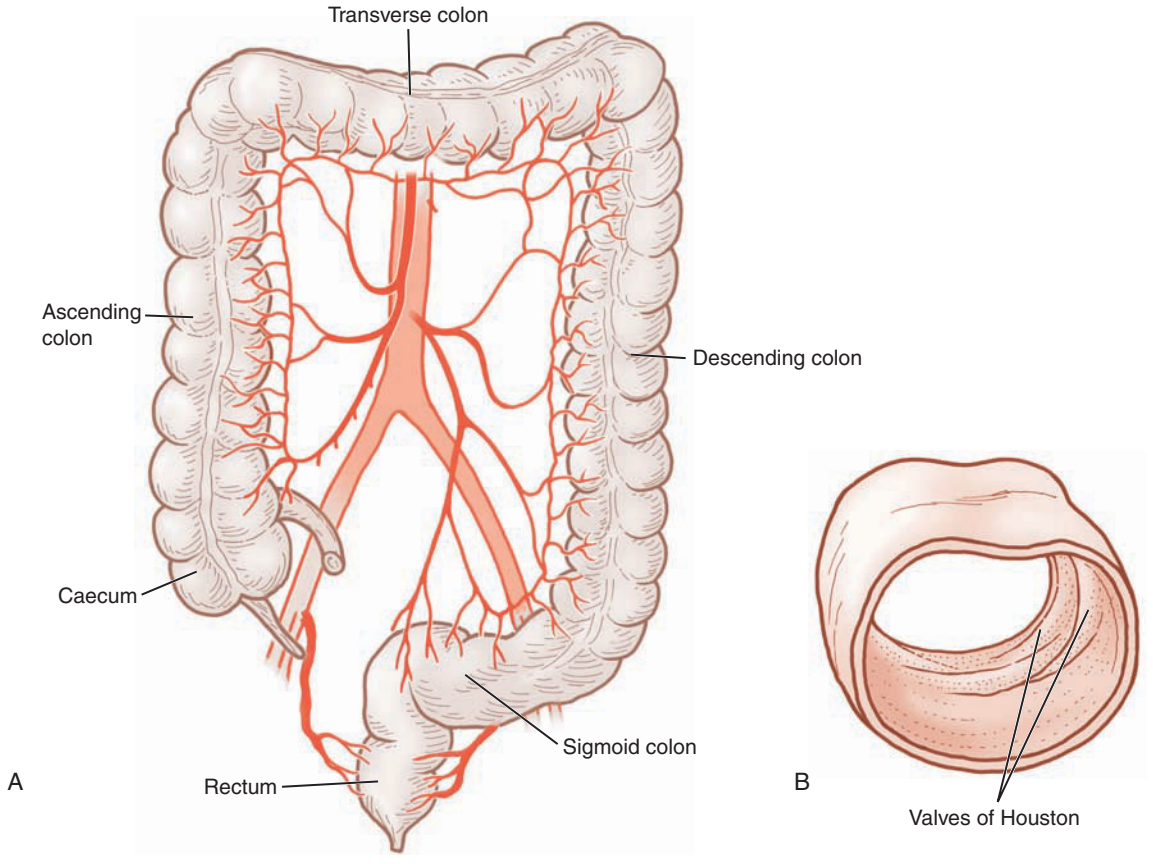


FIGURE 71-1. Anatomy of the colon. **A.** The gross anatomy. **B.** Cross-section through the colon demonstrating the valves of Houston.

ANATOMY AND PATHOPHYSIOLOGY

The significant anatomy of the anal canal that is necessary to understand and to perform rigid rectosigmoidoscopy is covered in Chapter 70 describing the anatomy for anoscopy (**Figures 70-1 & 70-2**). The gross anatomy of the colon is reviewed in **Figure 71-1A**. It is important to be aware of the large folds that impinge on the lumen of the colon called the valves of Houston (**Figure 71-1B**). These folds must be gently flattened to advance the rigid rectosigmoidoscope and clearly see the proximal side of the valve when looking for pathology. It is also necessary to understand the three-dimensional path followed by the distal colon, rectum, and anus. The direction to follow will be toward the patient's umbilicus for 3 to 5 cm initially. The anus then turns posteriorly as it becomes the rectum and follows the curve of the sacrum. The rectosigmoid junction is reached at 10 to 15 cm, at which point the lumen sharply angulates anteriorly and to the left. Because the scope is rigid and straight, it is necessary to angle the tip of the rigid rectosigmoidoscope toward the lumen of the bowel and then gently flatten the haustra or move the patient's colon so that the lumen is in a straight line.

INDICATIONS

Many of the indications for rigid rectosigmoidoscopy are the same as those for performing flexible sigmoidoscopy. The rigid scope is more useful when the bowel is not properly prepared, if a bigger biopsy is needed, or if a larger instrument needs to be passed to the last 25 cm. The following is a list of such indications.

The rigid rectosigmoidoscope may be used to evaluate the rectum and sigmoid colon in the office or the Emergency Department. Rectal bleeding can be evaluated in the unprepared patient. It is particularly helpful to determine if stool is mixed with blood when evaluating hematochezia and determining if colonoscopy is indicated. Foreign bodies in the rectum or sigmoid colon can be removed. The rigid rectosigmoidoscope will allow a much larger biopsy and grasping forceps to assist in removing foreign bodies. Traumatic injuries can be assessed. Since the rectum is seldom prepared in the evaluation of a traumatic injury and flexible instruments are unable to clear solid or thick stool, the rigid rectosigmoidoscope is superior in this instance. A sigmoid volvulus can be decompressed using the rigid rectosigmoidoscope to pass a tube to splint the volvulus. It is much easier to suction out a large volume of obstructed material in the colon and leave a large tube with the rigid rectosigmoidoscope. It can be used for surveillance of colon or rectal cancer after a subtotal colectomy. It can be used to accurately measure the distance to rectal lesions from the anus prior to surgery.

CONTRAINDICATIONS

There are no absolute contraindications to rigid rectosigmoidoscopy.[1] Relative contraindications include severe anal pain that may require general anesthesia, recent surgical anastomosis in the distal 25 cm of the colon and rectum, severe stenosis of the anus or rectum, and peritonitis. This procedure should not be performed by anyone unfamiliar with the equipment and technique as significant complications can occur.

EQUIPMENT

- Phosphate soda enemas
- Rigid rectosigmoidoscope with obturator, air insufflator, eyepiece, and light source

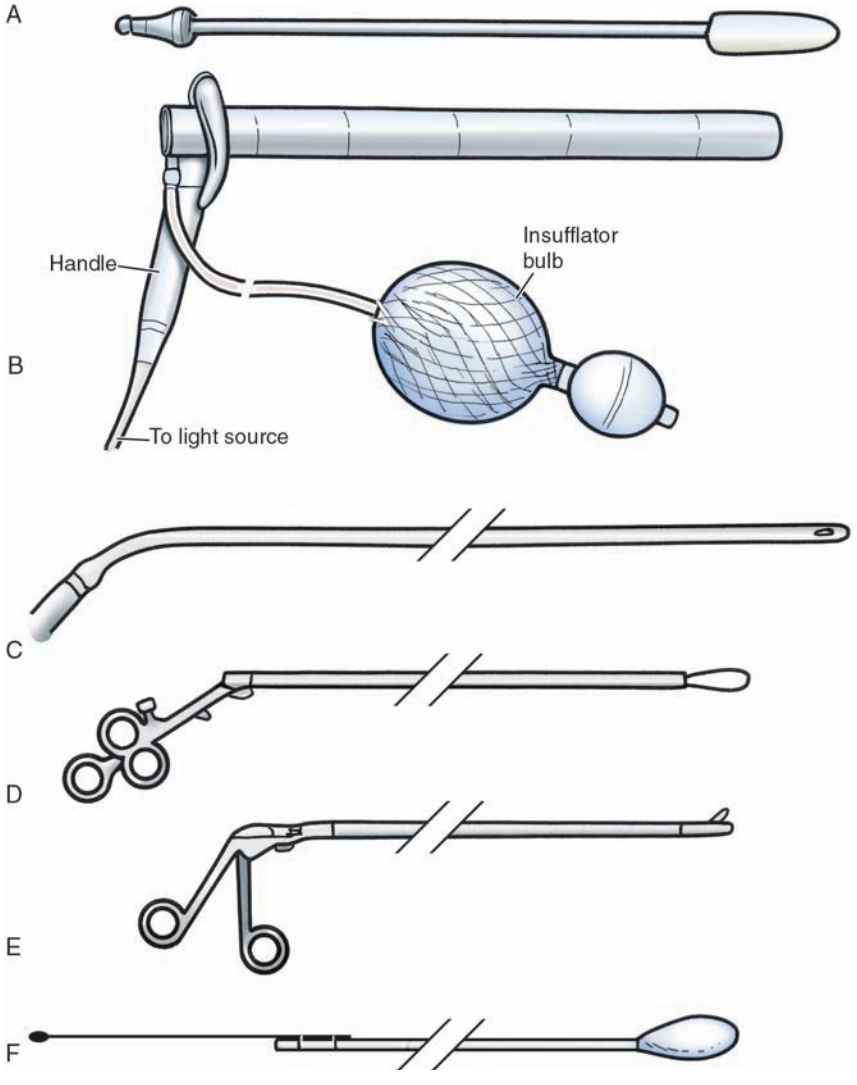


FIGURE 71-2. The instruments required to perform rigid rectosigmoidoscopy. **A.** Obturator. **B.** Rigid rectosigmoidoscope. **C.** Suction catheter. **D.** Polypectomy snare. **E.** Biopsy forceps. **F.** Cotton-tipped applicator with silver nitrate matchstick taped to the opposite side.

- Suction catheter
- Suction machine or wall suction
- Biopsy forceps
- Long cotton-tipped applicator with a silver nitrate applicator on the opposite end
- Proctoscopy table or examination table
- Protective drape with exam fenestration
- 4 × 4 gauze squares
- Water-soluble lubricant
- Exam gloves
- Impermeable gown
- Instrument stand
- Anoscope, should be available to examine the anal canal if indicated

The rigid rectosigmoidoscope and other required instruments are available in preassembled sterile trays. The tray usually contains the rigid scope, an obturator, a suction catheter, polypectomy snare, and biopsy forceps (**Figure 71-2**). These trays are available from the Operating Room, hospital central supply, or the surgical clinics. The trays may contain disposable single-use instruments or multiuse instruments depending upon the institution. The remainder of the equipment must be gathered from around the Emergency Department.

The rigid rectosigmoidoscope is a simple instrument (**Figures 71-2A & B**). The shaft is approximately 30 to 40 cm in length and has 1 cm increments marked on the outside. Attached to the proximal end are an eyepiece, a handle, and an inflation port. The eyepiece swings to open and close over the proximal shaft of the scope. The handle is used to direct and move the scope. Inside the handle is a fiberoptic light source that transmits into the shaft. The insufflator bulb and tubing attach to the inflation port. These are used to insufflate air through the scope and into the colon. The obturator fits within the shaft of the scope. The distal end of the obturator is smooth, occludes the shaft of the scope, and projects 1 to 2 cm distal to the scope.

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. It is also important to explain to the patient what to expect. Discuss the order of examination, the importance of relaxing, the reason for multiple insertions and withdrawals of the rigid rectosigmoidoscope, and what you expect to find. It is important to explain the reason for insufflating air and how this may produce discomfort. Explain that the procedure should not require procedural sedation and that the patient

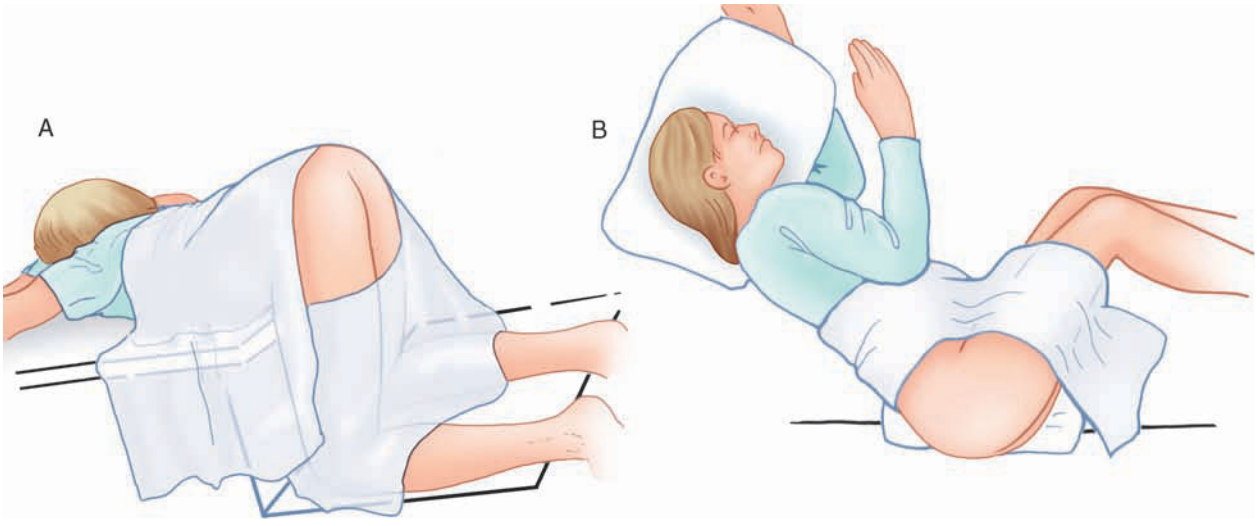


FIGURE 71-3. Patient positioning. **A.** The prone jackknife position on a proctoscopy table. **B.** The left lateral decubitus position on an examination table with the buttocks extended over the edge of the table. Note that the drape is placed so that the buttocks are completely exposed.

should inform the physician of any discomfort. Assure the patient that the complaint of pain will at least temporarily stop the examination. Perforations are unlikely with a relaxed, cooperative patient. Obtain a signed informed consent for this procedure.

While it is possible to perform a rigid rectosigmoidoscopy with this instrument on an unprepared rectum, more information about the mucosa will be obtained if the bowel has been prepared. Two 4 ounce phosphate soda enemas given at 2 and 1 hours before the examination will give an adequate preparation in most patients. The use of high-volume PEG preparations, saline, or mannitol should be reserved for colonoscopy. There is no need to clean the entire colon. The preparations used for colonoscopy are expensive, involve too much preparation, and cause patient discomfort for the extent of this examination. The judicious use of intravenous sedation may be required in some patients who are anxious.

It is important to check the equipment prior to its insertion into the patient. Open the tray and place the instruments and supplies on the Mayo stand. The eyepiece on the proximal end of the scope should open easily, close easily, and seal against the rigid rectosigmoidoscope. Open the eyepiece and insert the obturator completely within the rigid sigmoidoscope. The handle, including the light source, must be firmly attached. Turn on the light source. The light must be seen coming from the end of the scope. The bulb of the insufflator must pump air into the rigid rectosigmoidoscope and should reinflate after the bulb is released. Liberally lubricate the distal 5 cm of the rigid rectosigmoidoscope and the obturator. Reinsert the obturator into the rigid rectosigmoidoscope.

Disrobe the patient from the waist down. Place the patient in the prone jackknife position on a proctoscopy table if one is available (**Figure 71-3A**). If the patient is unable to get in this position, or only a routine examination table or stretcher is available, place the patient in the left lateral decubitus or Sims position (**Figure 71-3B**). The Emergency Physician should be prepared with an impermeable gown and one glove on the left hand and two on the right hand (if right handed). If possible, it is helpful to have someone assist with the remainder of this procedure. Place the fenestrated drape over the patient so that the buttocks are completely exposed (**Figure 71-3**). Place a Mayo stand or bedside procedure table within reach of the patient's buttocks.

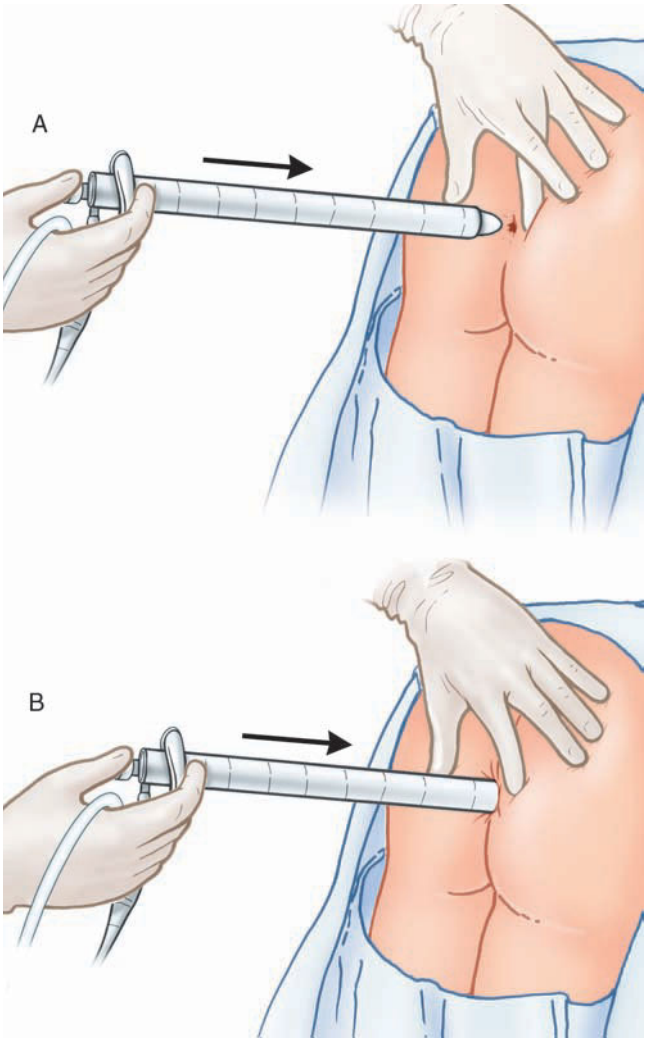


FIGURE 71-4. Insertion of the rigid rectosigmoidoscope. **A.** The left (nondominant) hand is placed on the buttocks and used to spread the buttocks. **B.** The right (dominant) hand is used to insert and advance the scope while the thumb keeps the obturator properly seated.

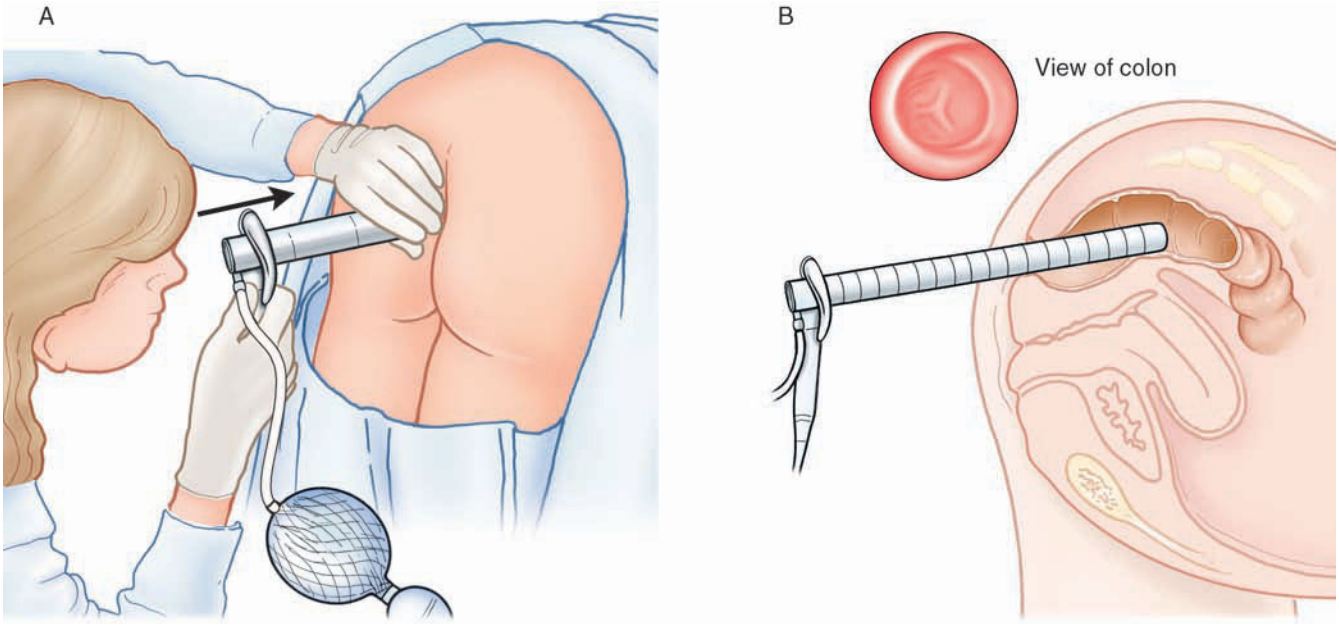


FIGURE 71-5. Advancement of the rigid rectosigmoidoscope. **A.** The nondominant hand stabilizes the scope while the dominant hand advances it under direct visualization. **B.** The rectum begins as the anal canal turns posteriorly toward the sacrum.

As in anoscopy, it is important to carefully inspect the entire perineum and anal verge prior to the examination. Many types of pathology such as fissures, fistulas, hemorrhoids, condylomata, and dermatologic conditions may be seen at this time.

Digital rectal examination prior to the procedure with a well-lubricated, gloved finger is mandatory. It gives the following advantages. It allows the examiner to find pathology that is better palpated than viewed. It gives the examiner the size and angle of the anal canal. It will allow the examiner to identify if the patient has tenderness that would preclude the examination. It may identify pathology so that the examiner can focus in a specific area. It prelubricates the anal canal, making insertion of the rigid rectosigmoidoscope easier. If the patient has pain from excoriation, 2% lidocaine jelly can be used as a lubricant and will provide some local anesthesia. This examination is usually performed with the right hand. Remove the extra glove from the dominant hand before picking up the rigid sigmoidoscope. This prevents the contaminated glove from holding the scope near the Physician's face.

TECHNIQUE

Stand to the left side of or directly behind the patient. Place the left, or nondominant, hand on the patient's buttocks (**Figure 71-4A**). Grasp the handle of the rigid rectosigmoidoscope with the right, or dominant, hand. Place the right thumb on the obturator to keep it properly seated (**Figure 71-4B**). Spread the buttocks with the left hand (**Figure 71-4**). Gently and slowly insert the rigid rectosigmoidoscope into the anus and aimed toward the patient's umbilicus. Advance it to the 5 cm mark.

Support the rigid rectosigmoidoscope at the anus with the left hand (**Figure 71-5A**). This is necessary so that if the patient moves, the instrument will move with the patient. Remove the obturator and place it on the Mayo stand. Close the eyepiece and insufflate air into the rectum.

One must control the insertion and direction of the rigid rectosigmoidoscope with the right hand while stabilizing it with the left hand (Figure 71-5A). Continue to slowly advance the rigid rectosigmoidoscope under direct viewing while simultaneously insufflating air to distend the walls of the colon (**Figure 71-5A**). The anal canal is approximately 4 to 5 cm in length (**Figure 71-6**). The rectum will be seen to turn somewhat posteriorly and follow the hollow of the sacrum (**Figure 71-5B**). Moving the right hand and the rigid rectosigmoidoscope anteriorly will direct the tip posteriorly (**Figure 71-6B**). Use the left hand as a fulcrum to help maneuver

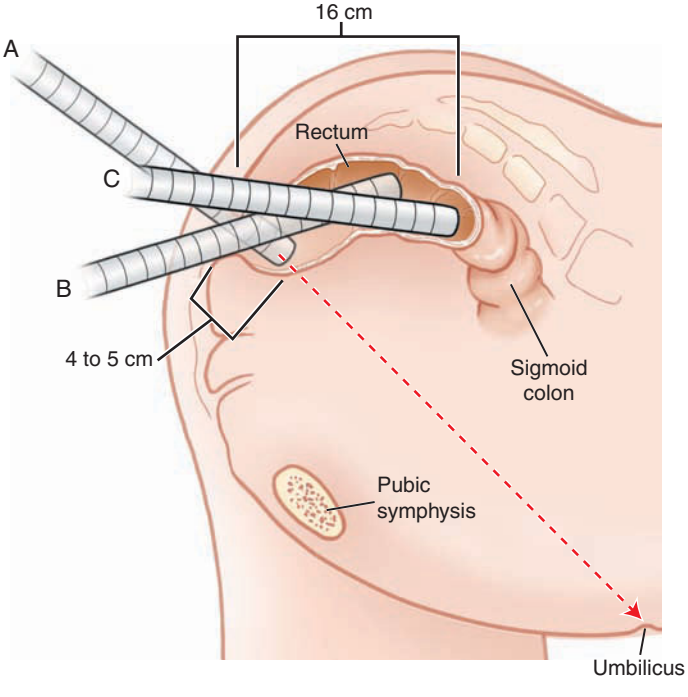


FIGURE 71-6. Insertion and advancement of the rigid rectosigmoidoscope. **A.** The scope is inserted and aimed toward the umbilicus. **B.** Moving the handle anteriorly will direct the tip of the scope posteriorly. **C.** The rectosigmoid junction is located approximately 16 cm from the anus, where the rectal lumen turns anteriorly and to the right.

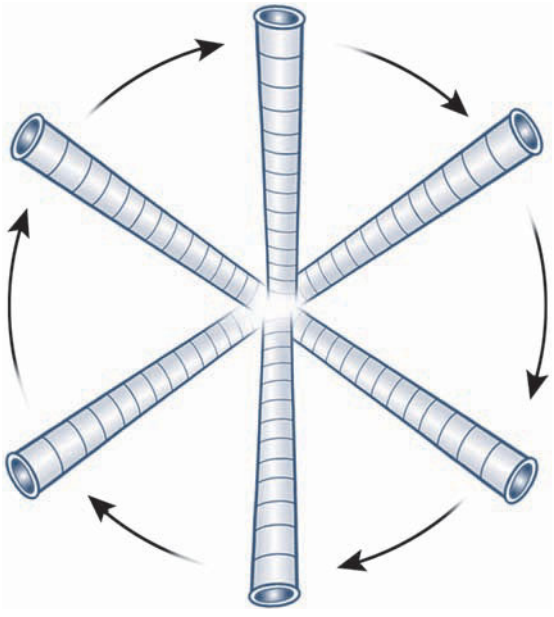


FIGURE 71-7. The rigid rectosigmoidoscope is rotated in a circular motion while simultaneously withdrawing the scope and visualizing the mucosa.

the distal tip of the rigid rectosigmoidoscope to follow the lumen of the rectum (**Figure 71-6**). The sigmoid colon can also be identified by the presence of transverse folds that are lacking in the rectum. The rectosigmoid junction is approximately 16 cm from the anus and can be seen when the lumen turns anteriorly and to the right (**Figure 71-6C**). It is necessary to use the rigid rectosigmoidoscope to gently straighten the colon while completely inserting the instrument to a depth of 25 cm. **It is important to view the bowel lumen at all times. Never advance the instrument blindly as this may cause a perforation.**

Maintain communication with the patient, inform them of what is happening, and elicit the status of their comfort. Open the eyepiece if it becomes clouded with moisture and wipe it with dry gauze so the view is kept clear. Do not keep your face near the eyepiece when opening the eyepiece. The insufflated air may forcefully expel stool and secretions. The bowel must be reinflated when the eyepiece is reclosed.

After the rigid rectosigmoidoscope is advanced to 25 cm, or as far as the patient will allow, slowly remove it with a circular motion (**Figure 71-7**). View the mucosa while removing the rigid rectosigmoidoscope in a circular motion. This flattens out the haustra and valves of Houston so that the entire mucosal surface can be viewed. Attempt to keep at least 50% of the colonic lumen in view at all times. Open the eyepiece just prior to completely removing the rigid rectosigmoidoscope to release as much of the insufflated air as possible. This will make the patient more comfortable.

The viewing window, which seals in the air, must be opened if it is necessary to biopsy or to grasp something. This will result in the collapse of the rectum and loss of view. It is important to place the tip of the rigid rectosigmoidoscope over the area in question so it will stay in the examiner's view. The obturator should be reinserted if it is necessary to reinsert or readvance the rigid rectosigmoidoscope.

ASSESSMENT

Completely and carefully inspect the colonic mucosa. Note the presence, location (i.e., anterior, posterior, left, and right), and the depth of any bleeding, diverticulum, fistulas, hemorrhoids, lesions, masses, mucosal irregularities, and/or polyps. Document any findings in the medical record.

AFTERCARE

The patient may be discharged home after the procedure if there are no complications and there is no other reason to admit them to the hospital. They may experience mild discomfort, flatus, and spotting of blood in the stool for several hours. Instruct the patient to immediately return to the Emergency Department if they develop a fever, abdominal pain, nausea, vomiting, bright red blood per rectum, or if they have any concerns. Follow-up should be arranged with a Family Practitioner, Internist, Gastroenterologist, or Surgeon depending upon the findings of the examination.

COMPLICATIONS

The primary complication of rigid rectosigmoidoscopy is perforation of the rectum or sigmoid colon. Air insufflation may cause an existing perforation, such as may be associated with diverticulitis, to burst, and is the reason one should not perform this examination if the patient has existing peritonitis. Perforation can occur with forceful insertion of the instrument without viewing the colonic lumen or if the patient moves suddenly and the scope is not supported with the left hand. Perforation may also occur with instrumentation in related procedures, such as a biopsy. Perforation should be almost nonexistent if one supports the scope well, views the colonic lumen while advancing the scope, and listens to the patient about complaints of pain.

Minor complications may occur. Trauma to the mucosa from the rigid rectosigmoidoscope or instrumentation in related procedures, such as a biopsy, can result in minor bleeding that is usually self-limited. Brisk bleeding can be controlled by the judicious use of a silver nitrate matchstick. Bacteremia may occur in up to 10% of patients. Antibiotic prophylaxis for endocarditis should be administered, if indicated, prior to the procedure. Mild abdominal discomfort and flatus can last a few hours.

SUMMARY

Rigid rectosigmoidoscopy is inexpensive, easy to perform, and useful in bowels with poor preparation or where a wider access is needed. These characteristics make the instrument useful in many indications. With proper training and understanding of the anatomy, this examination is well tolerated by the patient and will be useful to diagnose and treat many colonic and rectal problems.

72 Rectal Foreign Body Extraction

Charles Orsay and Eric F. Reichman

INTRODUCTION

Foreign bodies within the rectum are the result of an ingestion from above or are placed into the anus from below.[1] Fortunately, the majority of items ingested from above that pass the pylorus and ileocecal valve also pass the anal sphincter. The most frequent types of items found in the anus from above are undigested fish or chicken bones. Foreign bodies that are placed into the rectum from the anus are placed iatrogenically (e.g., enema tips and thermometers), inserted by the patient in an attempt to remove impacted stool, inserted by

the patient or their partner as a form of anorectal auto-eroticism, forcibly placed in the anus during a rape, or placed in the rectum to smuggle objects across a border illegally.

The items placed into the rectum from the anus seem to be limitless and represent all the shapes and sizes imaginable.[2] This makes their removal more difficult. **It is important to attempt to identify the characteristics of the foreign body in order to devise the safest way of removal.** As an example, consider the typical electric lightbulb. The glue that attaches the metal base to the glass loosens with moisture and time. Pulling off the metal base exposes a thin, sharp glass edge. The glass globe is very thin and breaks very easily. If the glass breaks, it may take a long time to remove the fragments and cause considerable damage to the surrounding rectal mucosa or the examining finger. **The idea is to remove the foreign body without causing further damage to the rectum or the anal sphincter muscle.** The more knowledge the Emergency Physician has about the foreign body and how it was inserted, the more likely it is that it will be removed safely.

ANATOMY AND PATHOPHYSIOLOGY

The significant anatomy of the anal canal is discussed in Chapter 70, describing the anatomy for anoscopy. Important anatomic considerations in removing rectal foreign bodies include the axis of the lumen of the anus. The anus is pointed toward the patient's umbilicus, while the curve of the sacrum forms a posterior arc. If the length of the foreign body is longer than the curve of the sacrum, such as a long vibrator or dildo, the sacral promontory causes the distal end of the foreign body to be directed toward the tip of the sacrum or coccyx. When the object is being removed by bringing the distal end anteriorly, the middle portion may push anteriorly (i.e., into the prostate, uterus, or bladder) and cause considerable discomfort.

The important physiologic considerations include the anal sphincter muscles, edema, and the creation of a vacuum. The anal sphincter is a complex group of muscles. The external anal sphincter muscle is made up of voluntary muscle fibers. The internal anal sphincter muscle is made of smooth muscle fibers. The reflex response to dilatation of the rectum is contraction of the external anal sphincter muscle. The normal tone of the anal sphincter comes from the internal anal sphincter, which can go into spasm with manipulation.

Therefore, it is very important to try to remove foreign bodies with slow and steady traction. Maintain constant pressure and wait for the sphincter muscle to fatigue. The technique is not too dissimilar to the methods used to relocate a shoulder. The slow and constant traction will also help with the edema that forms around rectal foreign bodies that have remained in the rectum for a prolonged period of time.

Finally, it is important to consider the formation of a vacuum, which may result from pulling a large, smooth foreign body such as a bottle or lightbulb. It is sometimes necessary to place one or more soft catheters above the foreign body so that air may get around the object as it is removed. This will prevent the formation of a vacuum and allow the foreign body to be removed. Large Foley catheters with the balloon inflated can be used for air insertion to prevent the vacuum and traction to bring the object further down into the rectum.

INDICATIONS

The indication to remove a foreign body from the rectum is the identification of a foreign body in the rectum. The majority of patients with this problem have already tried to pass the item with a bowel movement. They may also have already tried oral laxatives. It is impossible to estimate the number of rectal foreign bodies that are removed at home. It is estimated that very few objects inserted through the anus will pass spontaneously. Waiting is detrimental for the vast majority of items. Sharp foreign bodies may already have begun to perforate the rectum. Large foreign bodies will continue to cause irritation and edema, making removal more difficult with the passage of time.

CONTRAINDICATIONS

There are a few absolute contraindications to removing a rectal foreign body in the Emergency Department. However, the removal of a rectal foreign body that has not perforated is not an emergency. **Time taken to plan the removal and obtain adequate anesthesia and relaxation of the anal sphincter muscles is well spent, especially if the object is difficult to retrieve.** The patient's general condition must be taken into account. Patients with peritonitis require operative removal and exploration. The time taken to remove the object is wasted and identification of the perforation is easier in the Operating Room with the item in place. Patients with lower abdominal pain and fever may have a perforation below the peritoneum that can be confirmed with a water-soluble contrast enema. Foreign bodies that are large, irregularly shaped, or have sharp edges should be extracted in the Operating Room. In patients who have been assaulted, a complete assessment of all the patient's injuries is mandatory. It usually is better to leave the object in place to help identify all the possible associated injuries that may have occurred. The foreign body should be removed in the Operating Room if it is not palpable, not visible upon dilating the anus, or removal of the object may cause injury to the patient. Packets containing illicit drugs should be extracted with a rigid rectosigmoidoscope or in the Operating Room. Rupture of the packets can result in significant morbidity and mortality.

EQUIPMENT

- Local anesthetic solution with epinephrine (1% lidocaine or 0.5% bupivacaine)
- 25 gauge needle, 2 in. long
- 10 mL syringe
- Povidone iodine or chlorhexidine solution
- Anoscope
- Ring forceps
- Tenaculum
- Park retractor
- Hill-Ferguson retractor
- Large spoons
- Foley catheters
- Endotracheal tubes
- Endoscopic snare
- Rigid rectosigmoidoscope
- Vacuum extractor (optional)

PATIENT PREPARATION

The patient must undergo a complete history and physical examination. It is important to ascertain the overall health of the patient in case it is necessary to go to the Operating Room to extract the foreign body. **Attempt to identify patients with rectal perforations as they need to go to the Operating Room quickly.** Biplane plain radiographs with an upright are useful to determine the number, shape, and location of the foreign bodies as well as the

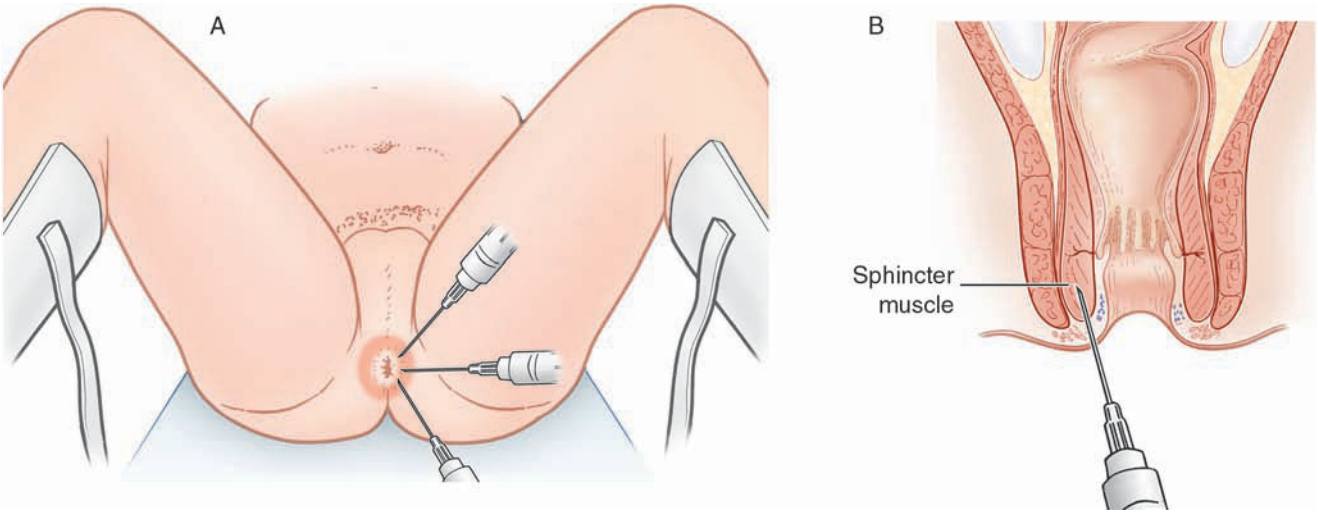


FIGURE 72-1. Anesthesia of the anal region. **A.** Local anesthetic solution is infiltrated subcutaneously and circumferentially around the anus. **B.** Injection of local anesthetic solution into the anal sphincter muscles.

presence of free air under the diaphragm. It is necessary to look at both the anteroposterior view as well as the lateral view to completely appreciate the object in three dimensions.[1] It is important to inform the patient in advance that while 90% of the objects can be removed from below, some may require general anesthesia or even an operation and a temporary colostomy. Explain the local anesthesia and the extraction procedures to the patient and/or their representative. Obtain an informed consent for the extraction of the foreign body.

Ascertain the type and number of objects in the rectum. It is possible to remove one foreign body and miss others that the Emergency Physician was not aware were present. Unfortunately, it is common to find that the patient is unsure of this part of the history; this is why plain radiographs can be so helpful. It is also important to identify the technique of insertion. Patients with objects that were inserted forcefully should undergo a trauma-oriented workup, and sexual abuse must be considered. Determine the length of time since insertion. Edema formation will be significant if the object has been present more than 24 hours. This will make it more likely that an anesthetic will be needed or that it will be necessary to use catheters to break the vacuum that forms during extraction.

The parts of the physical examination that are most helpful are the abdominal and rectal examinations. The abdominal examination should focus on the presence or absence of tenderness, peritonitis, and the palpation of a mass. Many objects are long enough to be palpated in the left lower quadrant. It may be useful to apply pressure on the lower portion of the abdomen to help remove the object. The rectal examination should include a careful external examination looking for evidence of trauma. The digital portion of the examination should roughly quantify the sphincter tone and squeeze pressure.

The remainder of the examination should consist of careful palpation of the foreign body to determine its location, texture, and mobility and to identify possible areas to grasp. Examples would include the open end of a bottle or the narrow end of a lightbulb. Determining if the object is hard, soft rubber, or plastic will help determine which tool would be best suited to grasp the object. **One exception to performing the digital rectal examination would be determining, on radiographs or by history, whether the object is sharp (such as a knife blade) or consists of broken glass. It is recommended to postpone the digital rectal examination, especially in prisoners and psychiatric patients, until a radiograph rules out a sharp foreign body.** If the examiner is not able to palpate the foreign body, a rigid rectosigmoidoscope should be used to identify and remove the object. The technique of rigid rectosigmoidoscopy is described in Chapter 71.

ANESTHESIA

The second general consideration is to have a relaxed anal sphincter. The use of intravenous or procedural sedation will relax the patient and relieve any discomfort associated with the procedure. It may be necessary to inject the anus with local anesthetic solution if the patient experiences pain or if slow steady traction will not overcome the tone of the anal sphincter.[3,4] Anesthesia of the sphincter muscles will provide for patient comfort and allow dilation of the sphincter muscles. Place the patient in the lithotomy position (**Figure 72-1A**). Wipe away any dirt, debris, and fecal material from the perianal skin and surrounding area. Apply povidone iodine or chlorhexidine solution and allow it to dry. Inject local anesthetic solution subcutaneously and circumferentially around the anus (**Figure 72-1A**). Inject 1 to 1.5 mL of local anesthetic solution into the anal sphincter muscles at the 12, 3, 6, and 9 o'clock positions (**Figure 72-1B**).

An alternative is a pudendal nerve block. Determine if the ischial spines are palpable through the rectum. Insert the needle through the skin and toward the ischial spine. Use the finger inside the rectum to palpate and guide the needle to the ischial spine. Inject 3 to 5 mL of local anesthetic solution just medial to the ischial spine. Repeat this procedure on the other side. The main disadvantage of the pudendal nerve block is that it is a blind procedure and has the potential for a needle stick. If these are not successful, it will be necessary to take the patient to the Operating Room for regional or general anesthesia.

The patient may remain in the lithotomy position for the extraction of the foreign body (**Figure 72-2A**). Other positions include the modified Lloyd Davies position (**Figure 72-2B**) and the Sims position (**Figure 72-2C**). The choice of positions is physician dependent and limited by patient comfort.

TECHNIQUES

It is important to understand that since the types of foreign bodies found in the rectum are so variable, it is impossible to give exact instructions on how to remove them. There are some general

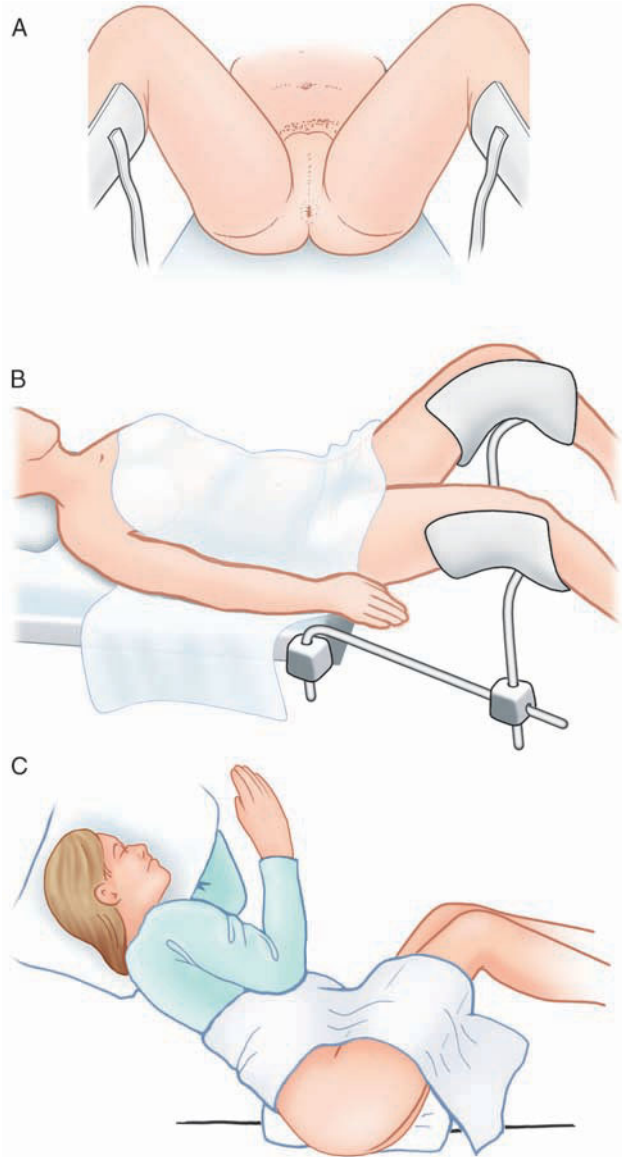


FIGURE 72-2. Patient positioning for removal of rectal foreign bodies. **A.** Lithotomy position. **B.** Modified Lloyd Davies position. **C.** Sims or lateral decubitus position.

considerations to remember. The first is to visualize the foreign body. Gentle suprapubic pressure will often push the foreign body into the distal rectum. The distal end of the foreign body may get caught along the curve of the sacrum. Place a finger in the rectum to redirect the orientation of the foreign body. The second consideration is to grasp the object. Sometimes an object is low-lying and may be grasped with gloved fingers. The object can then be removed by gentle continuous traction. Low-lying objects may be soft enough to be grasped with an instrument. **It is necessary to do this under direct vision so that the rectum will not be damaged in the attempt to grasp the foreign body.** Hard, low-lying objects made of metal or plastic may be grasped with a tenaculum.

Insert two well-lubricated fingers into the anesthetized anus and gently dilate the anal sphincter muscles. The anus can be maintained in the open position by the insertion of a Park retractor (**Figure 72-3A**) or a Hill-Ferguson retractor (**Figure 72-3B**). An anoscope or vaginal speculum may be used if these retractors are not readily available in the Emergency Department. View the distal end of the foreign body. **Never insert instruments unless the foreign body is visualized. Blind insertion of instruments may push the foreign body more proximally or perforate the rectum. Never grasp a foreign body blindly. This can cause injury to the rectum upon removal of the instrument if the rectal mucosa is entrapped between the instrument and the foreign body.**

DIGITAL EXTRACTION TECHNIQUE

Foreign bodies within reach may be grasped with the fingers and extracted. This often proves very difficult as the foreign body will be coated with lubricant, mucus, and/or stool. Instruct the patient to bear down as if having a bowel movement. The intraabdominal pressure generated in this way may expel the foreign body. The foreign body may become entrapped against the sacrum. Insert a finger into the rectum to dislodge the foreign body from against the sacrum as the patient continues to bear down. Attempt one of the techniques described below if digital extraction is ineffective.

FOLEY CATHETER TECHNIQUE

A Foley catheter has been successfully used to aid in the extraction of rectal foreign bodies.[5–7] This is especially helpful if the foreign body is made of glass, an inverted bottle or can, large, or present for more than 12 to 24 hours. Pulling these types of foreign bodies can result in the formation of a vacuum proximally and inhibit their extraction.

Liberally lubricate a Foley catheter. Insert the Foley catheter between the foreign body and the rectal mucosa. Advance the catheter until the balloon is proximal to the foreign body (**Figure 72-4A**). Fluoroscopy, if available, can be used to confirm the location of the balloon and guide the removal of the foreign body.[13] Inflate the balloon with 30 mL of saline or water. Inject air with a syringe through the Foley catheter to break the vacuum proximal to the foreign body. Remove the syringe so that air can move freely through the Foley catheter and prevent a vacuum from becoming reestablished. Apply constant, gentle, and steady traction to the Foley catheter. This will prevent the foreign body from migrating proximally. It may also move the foreign body distally so that it can be grasped and extracted with fingers or an instrument. The use of two to four circumferentially placed Foley catheters may apply evenly distributed traction to extract the foreign body more easily.

ENDOTRACHEAL TUBE TECHNIQUE

An endotracheal tube has been used in place of a Foley catheter by some physicians (**Figure 72-4B**). The advantage of using an endotracheal tube is that it is relatively stiff and can apply more traction than a Foley catheter to help remove the foreign body. Unfortunately, there are also disadvantages. The endotracheal tube is larger and less flexible than a Foley catheter. This may result in difficulty advancing it past the foreign body. The larger and stiffer endotracheal tube can more easily lacerate the rectal mucosa and perforate the rectum. For these reasons, the use of an endotracheal tube cannot be recommended.

SPOON TECHNIQUE

The removal of smooth, round, fragile, or glass foreign bodies can be problematic. This can include lightbulbs, balls, fruits, and vegetables. These foreign bodies can be extracted with a pair of large spoons. Liberally lubricate the posterior surface of a pair of spoons. Insert a Foley catheter to eliminate the vacuum proximal to the foreign body. Insert the spoons until they are cupping the foreign body (**Figure 72-4C**). Grasp and gently squeeze the handles of the spoons so that they hold the foreign body. Withdraw the spoons and the foreign body.

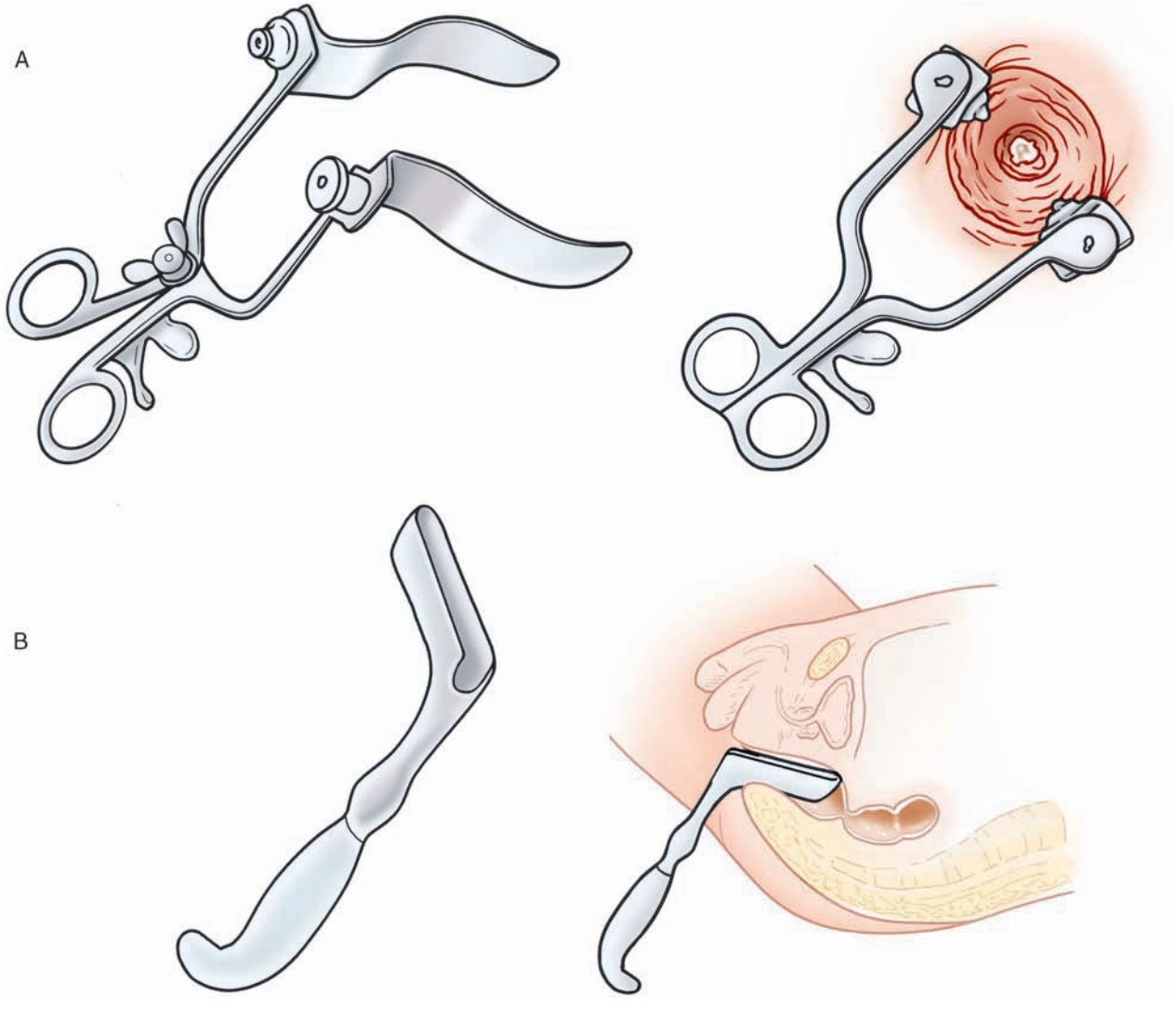


FIGURE 72-3. Retractors placed in the anus allow for better exposure and easier extraction of the foreign body. **A.** The Park retractor. **B.** The Hill-Ferguson retractor.

A more readily available alternative to large spoons are obstetric forceps. These have also been successfully used to extract a rectal foreign body. **The use of obstetric forceps cannot be recommended due to their large size, unfamiliarity to most Emergency Physicians, and the potential to perforate the rectum.**

RING FORCEPS OR TENACULUM TECHNIQUE

Rectal foreign bodies that are not fragile may be grasped with a ring forceps or tenaculum and then extracted. Insert a Foley catheter to eliminate the vacuum proximal to the foreign body. Firmly grasp the foreign body with a ring forceps or a tenaculum (**Figure 72-4D**). A tenaculum has teeth on its distal tips. These may be advantageous as the teeth can grip and firmly hold the foreign body, making the extraction easier. **This must be performed under direct visualization to ensure that the rectal mucosa is not entrapped between the instrument and the foreign body.** Apply gentle, firm traction to extract the foreign body.

VACUUM EXTRACTION TECHNIQUE

A vacuum dart or obstetrical vacuum extractor may be used to extract a rectal foreign body.[6,8] Emergency Physicians are usually not trained in the proper use of a vacuum extraction device. It may be beneficial to have an Obstetrician, Gynecologist, Family Practitioner with obstetric experience, or a Nurse Midwife to assist with this technique.

Insert a Foley catheter to eliminate the vacuum proximal to the foreign body. Place the vacuum cup of the device onto the foreign body. **Ensure that none of the rectal mucosa is entrapped between the rim of the suction cup and the foreign body.** Apply the suction to seal the cup against the foreign body. **Recheck to ensure that none of the rectal mucosa has become entrapped.** Apply steady traction to extract the foreign body.

MISCELLANEOUS TECHNIQUES

Numerous other techniques have been devised to remove a rectal foreign body.[9–12] These include the use of proctoscopes and snares, de Pezzer catheters, cyanoacrylate glue, clamps covered with rubber tubing, a tonsil snare, Sengstaken–Blakemore tubes, and plaster of Paris. Cyanoacrylate glue can be used to attach a handle to the foreign body. The foreign body can be extracted by withdrawing the handle after the glue has dried. A Sengstaken–Blakemore tube can be inserted into a foreign body with a small opening (e.g., glass bottle, soda can, etc.). Inflate the balloons and apply traction to extract the foreign body. Plaster of Paris can be used to fill a hollow object and allowed to harden around a tongue blade (**Figure 72-4E**). This is

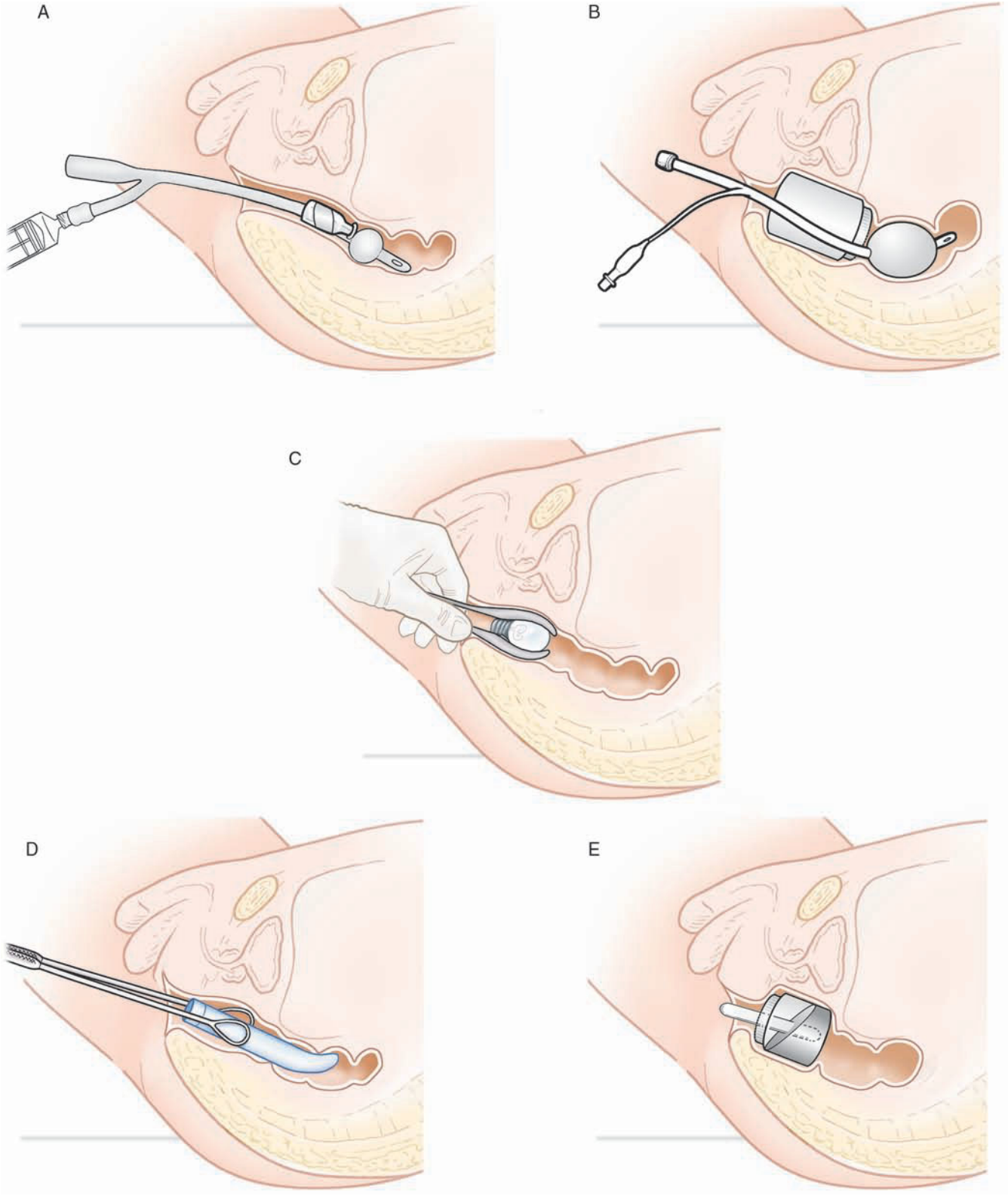


FIGURE 72-4. A sampling of methods to remove rectal foreign bodies. **A.** Foley catheter technique. **B.** Endotracheal tube technique. **C.** Spoons to remove a fragile object. **D.** Ring forceps technique. **E.** Plaster and a tongue depressor are placed in a jar. After the plaster cures, the tongue depressor can be used as a handle to remove the jar.

analogous to making a popsicle on a stick. The major disadvantage of using plaster of Paris is that it generates heat as it hardens. This heat may damage the rectal mucosa or shatter a glass bottle. The technique used and the choice of devices are limited only by one's imagination.

ASSESSMENT

Examine the rectum with a rigid rectosigmoidoscope to assess the mucosa for tears or perforations after the foreign body is extracted. Some physicians believe that this examination is not necessary if the

patient is asymptomatic, the foreign body is smooth, it was extracted atraumatically, and no complications arose from the extraction procedure. These patients may be discharged with follow-up as an outpatient for rectosigmoidoscopy. If obvious damage to the mucosa exists, the patients should remain in the hospital for observation. The patient should remain NPO and be prepared for possible surgery. Other indications for admissions include abdominal pain, significant bleeding, or the suspicion of a rectal perforation. Broad-spectrum intravenous antibiotics should be administered if a rectal perforation is suspected.

Perform a digital rectal examination to document the presence and quality of anal sphincter tone after the procedure. This should be delayed until the effects of any general, local, or regional anesthesia have dissipated. Rectal tone that is decreased or diminished from the initial (i.e., preprocedural) digital rectal examination requires the consultation of a General or Colorectal Surgeon.

AFTERCARE

Patients may be discharged home after the extraction procedure if they are asymptomatic, have normal rectal tone, and have no complications demonstrated on rigid rectosigmoidoscopy. They should be instructed to return to the Emergency Department immediately if they develop abdominal pain, pelvic pain, bright red blood per rectum, or a fever.

COMPLICATIONS

The major complications include rectal bleeding, rectal perforation, and damage to the anal sphincter. **Since the patient may very well have presented with these complications, it is important to document them or their absence on the initial (i.e., preprocedural) examination.** Rectal bleeding is common after a difficult extraction. It is important to rule out a perforation. This can be performed with the rigid rectosigmoidoscope after the extraction. Most perforations occur at the rectosigmoid junction, approximately 15 to 16 cm from the anus. Perforation above the peritoneal reflection will result in peritonitis and free air noted under the diaphragm on upright plain radiographs. Perforation below the peritoneal reflection may take several days to manifest pelvic pain, signs of a pelvic abscess, or sepsis. If there is no evidence of perforation or significant mucosal damage, the patient may still be discharged. However, large amounts of bleeding or significant mucosal damage require observation at the least. A Gastrografin enema without the use of the balloon may be used to identify a perforation if there is significant concern that it exists. Patients with perforation of an unprepared rectum require surgical intervention and broad-spectrum intravenous antibiotics. Any evidence of acute sphincter damage requires a surgical evaluation for possible debridement. The majority of these lesions are observed, allowed to heal secondarily, and then repaired surgically.

SUMMARY

The majority of rectal foreign bodies can undergo transanal extraction. Removal of rectal foreign bodies should include an appropriate history and physical; biplane abdominal radiographs; relaxation of the anal sphincter; firm attachment to the foreign body and slow, firm traction extraction; and postextraction rectosigmoidoscopy. Inpatient observation is indicated if the rectal mucosa is traumatized. The patient should be taken to the Operating Room if the foreign body cannot be removed in the Emergency Department, for pain control, if a perforation is suspected, or if removal may result in secondary injury.

SECTION 6

Orthopedic and Musculoskeletal Procedures

73 Bursitis and Tendonitis Therapy

Dedra Tolson

INTRODUCTION

Bursitis and tendonitis are frequent complaints evaluated in the Emergency Department. Bursitis represents an acute or chronic inflammation of the bursa. Similarly, tendonitis involves inflammation surrounding the bony insertion sites of the tendons. Typically, these complaints are treated conservatively with reduction of inflammation as the goal. Treatment often includes rest, elevation, application of cold and heat, and the introduction of anti-inflammatory agents. However, joint and soft tissue injections are helpful for both the diagnosis and therapy of a variety of musculoskeletal complaints. Diagnostic goals include a means for fluid aspiration and to provide symptom relief of the affected body part. Therapeutic goals include delivery of local anesthetics for acute pain relief, delivery of corticosteroid for suppression of inflammation, and increased mobility.[1] Injection therapy along with the above generalized treatment guidelines are a critical component of a multifaceted treatment regimen that should be considered by the Emergency Physician.

Definitive care can often be easily initiated by the administration of a steroid injection during the patient's earliest presentation. It has been shown that the clinical response to injectable corticosteroids is quite positive.[2–5] The techniques of aspiration and injection are easily mastered. These techniques are generally safe and effective when appropriate guidelines are followed.[1] While injection therapy can be effective, it must be remembered that this treatment should not replace cessation or modification of the offending activity if identified.

ANATOMY AND PATHOPHYSIOLOGY

Bursae are round, fluid filled, pad-like sacs or cavities. There are roughly over 160 bursae in the body. They are usually located at sites of friction such as joints, or in areas where tendons pass over bony prominences. Bursae are lined with a synovial membrane and contain synovial fluid. Their primary purpose is to reduce friction when movement occurs and to provide a mechanical advantage for tendon function. Bursitis often results from trauma, chronic overuse, inflammatory arthritis such as rheumatoid arthritis, crystal deposition, and infection.

Tendons are fibrous connective tissue bands attaching muscles to bones. A synovial sheath containing synovial fluid surrounds most tendons. Tendons mainly transmit forces from muscle to the skeleton. Pathologic findings are typified by inflammation, mucoid degeneration, and fibrinoid degeneration.[6]

Bursitis and tendonitis are often grouped together because the history, symptomatology, physical examination findings, and the treatment for these two inflammatory processes often coincide. **Corticosteroid injections serve to decrease inflammation, provide pain control, and promote healing. The goal of injection into tendon sheaths and bursae is to attain concentrated steroid levels to maximize the local anti-inflammatory effect while minimizing systemic effects.**

INDICATIONS

Injections of corticosteroids should be performed for an inflammatory bursitis or synovitis when systemic therapy is contraindicated and as an adjunct to physical therapy or systemic therapy. Many inflammatory conditions, including articular and nonarticular processes, are improved with local corticosteroid injection therapy.[1,7,8] The articular processes that are helped by injection therapy include gout, pseudogout, spondyloarthropathies, rheumatoid arthritis, neuritis, osteoarthritis, and crystalloid arthropathies. The nonarticular processes that are helped by injection therapy include bursitis, periarthritis, adhesive capsulitis, tenosynovitis, epicondylitis, trigger points, ganglion cysts, entrapment syndromes, tendonitis, plantar fasciitis, and neuritis.

CONTRAINDICATIONS

Both absolute and relative contraindications should be assessed when corticosteroid injection therapy is contemplated. The absolute contraindications include overlying cellulitis, septic arthritis, adjacent acute fracture, bacteremia, unstable joints, joints containing a prosthesis, and a history of an allergy or anaphylaxis to local anesthetics. Relative contraindications include inaccessibility of the joint, joints requiring radiographic guidance to ensure proper needle placement, meniscal or labral tears as a cause of symptoms, joints with loose bodies as a cause of symptoms, coagulopathy, anticoagulant therapy, or greater than three injections annually into a weight-bearing joint. Systemic conditions such as renal failure, cardiac failure, hypertension, diabetes, and other conditions that may be affected by the injection of corticosteroids should also be considered prior to proceeding with any injection therapy.

EQUIPMENT

- Povidine iodine or chlorhexidine solutions
- Sterile gloves
- Sterile drapes and towels
- 18 gauge needles, 1.5 to 2 in. long
- 22 gauge needles, 1.5 to 2 in. long
- 23 gauge needles, 1.5 to 2 in. long
- 25 gauge needles, 1.5 to 2 in. long
- Syringes (1, 5, and 10 mL)
- Injectable steroidal preparation (**Table 73-1**)
- Licocaine (1% and 2%) without epinephrine
- Bupivacaine (0.25% and 0.50%) without epinephrine
- Mepivacaine (1%) without epinephrine
- Adhesive bandages (to be placed postinjection)

TABLE 73-1 Corticosteroid Preparations Available for Injection

Generic name	Trade name	Strength (mg/mL)	Relative potency	Dose range (mg)	Biological half-life (h)
Hydrocortisone acetate	Cortef Solu-Cortef	25	1	12.5–100	8–12
Triamcinolone acetonide	Kenalog-10	10	2.5	4.0–40	18–36
	Kenalog-40	40	10.0		
Triamcinolone hexacetonide	Aristospan	20	8	4.0–25	18–36
Dexamethasone acetate	Decadron, Hexadrol, Dexone	4, 8	20–30	0.8–4.0	36–54
Betamethasone sodium phosphate	Celestone	6	20–30	1.5–6.0	36–54
Methylprednisolone acetate	Medrol, Depo-Medrol, Solu-Medrol	20, 40, 80	5, 10, 20	4.0–30	18–36

PATIENT PREPARATION

Explain the procedure, its risks, and its benefits to the patient and/or their representative. Obtain a written informed consent to perform the procedure. Position the patient so that they are comfortable and the injection site is easily accessible. Identify the injection site using the appropriate anatomic landmarks. It may be necessary to outline structures with a skin pencil when landmarks are difficult to palpate. Clean any dirt and debris from the skin. Apply povidone iodine or chlorhexidine solutions over the injection site and surrounding skin. Allow it to dry. Generally, sterile drapes and gloves are recommended for the novice but are not absolutely necessary depending upon operator experience.[9,12] A no-touch technique is indicated if a sterile field is not created.

TECHNIQUES

Medication dosing in bursae and soft tissue injections is influenced by the bursa size, the presence or absence of synovial fluid, the presence or absence of edema, the severity of synovitis, and the steroid preparation selected. **Table 73-1** summarizes the characteristics of commonly available corticosteroid preparations. The duration of action is chiefly dependent on the solubility of the preparation. For example, a dose of 20 to 30 mg of methylprednisolone acetate or equivalent is appropriate for large spaces such as the subacromial, olecranon, and the trochanteric bursae. This can be increased to a 30 to 40 mg dose if a large amount of synovial fluid is present. A dose of 10 to 20 mg is appropriate for intermediate size bursae present in the wrists, knees, and heels. A dose of 5 to 15 mg is appropriate for tendon sheaths. Triamcinolone hexacetonide and acetonide are the least soluble preparations available. The local effects of these steroid preparations may take several days for effects to be noticed initially, but these effects will ultimately last weeks or months. More soluble preparations such as hydrocortisone acetate have effects that last a few days. Many physicians prefer triamcinolone due to its prolonged duration of action. **Corticosteroids are often mixed with a local anesthetic solution prior to injection. The local anesthetic solution provides immediate pain relief for the patient. It also confirms for the physician that the injection was placed at the appropriate anatomic site.** If less volume is needed for the injection, consider using higher concentrations of local anesthetics such as 2% lidocaine instead of 1%.

Injection techniques for pediatric patients are not different than those for adults. However, smaller injected volumes maybe required depending on the age and size of the child. Soft tissue corticosteroid injections should be performed by a Rheumatologist or an Orthopedic Surgeon as these injections can affect bone growth, cartilage growth, and damage growth plates.

The sites for joint injections are typically based on anatomic landmarks. When superficial bursitis, tendonitis, and large effusions are involved, ultrasound may be helpful if available and depending upon physician experience. When deep bursae are involved or the target structure is difficult to reach, ultrasound can be helpful.[6,10,11] The deep injections requiring ultrasonographic guidance may require a specialist. The procedure can be time consuming and difficult to perform for the Emergency Physician who does not possess the skills and experience with ultrasound-guided procedures.[6,10,11]

SUBACROMIAL BURSITIS

The subacromial bursa lies between the rotator cuff muscles inferiorly (i.e., supraspinatus, infraspinatus, teres minor, and subscapularis muscles) and the overlying acromion, teres major muscle, and deltoid muscle. It cushions the coracoacromial ligament from the supraspinatus muscle. The subacromial space contains the long head of the biceps, the rotator cuff tendons, and the subacromial bursa. The syndromes of calcific tendonitis, supraspinatus tendonitis, and subacromial bursitis are so similar that the signs of each are difficult to distinguish. Anatomic proximity may cause associated irritative inflammation of adjacent structures, so that these conditions often overlap and coexist. Pain from these syndromes is elicited by shoulder abduction.

Patients often present holding the affected arm in a protective fashion against the chest wall. The classic sign of subacromial bursitis is tenderness over the greater trochanter that disappears with arm adduction. The "subacromial painful arc" is painful active abduction of the shoulder with maximal pain occurring between 70° and 100° of abduction. This differs from acromioclavicular joint inflammation, which results in a painful arc from 120° to 180° of shoulder abduction.

Three techniques are described to inject the subacromial bursa: the lateral approach, the anterior approach, and the posterior approach. The lateral approach is the most commonly used technique. Some prefer the anterior (or subcoracoid) approach provided that the practitioner has good familiarity with the anatomic landmarks. However, the anterior approach is more difficult for the less experienced to perform.

Place the patient seated upright or supine on a gurney. Palpate the indentation under the acromion process of the scapula for the lateral approach. This indentation is located between the acromion process and the greater tuberosity of the humerus. Fill a syringe with 1 mL of local anesthetic solution and 1 mL of a selected corticosteroid such as dexamethasone. Apply a 22 to 25 gauge needle to the syringe. Insert the needle into the indentation and direct it superomedially. Advance the needle until the tip touches the inferior surface of the acromion (**Figure 73-1**). Inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

Alternative approaches include the anterior and posterior approaches. Position the patient as above for the anterior approach. Identify the coracoid process of the scapula. Insert the needle 1.5 cm lateral to the coracoid process. Direct the needle horizontally and posteriorly. Advance the needle approximately 2.5 cm to gain direct access to the subacromial space. Inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

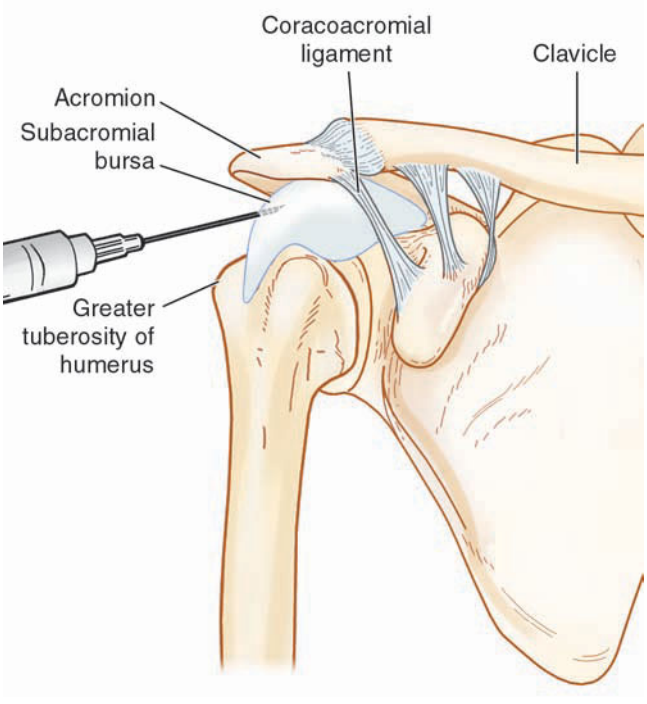


FIGURE 73-1. Lateral approach for subacromial bursitis.

The posterior approach may also be used. The distance from the coracoacromial ligamentous arch in this approach is great and may limit efficacy. Place the patient sitting upright with the effected forearm resting in their lap. Palpate the most lateral point of the acromion process posteriorly. Insert the needle at this landmark. Aim the needle toward the center of the humeral head and at an upward angle of 10° (**Figure 73-2**). Advance the needle 3 to 5 cm until the bursa is entered. Inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

SHOULDER IMPINGEMENT SYNDROME

A shoulder impingement syndrome results from rotator cuff, particularly the supraspinatus muscle, compression between the humerus and the coracoacromial arch. This is part of a pathophysiologic continuum with an endpoint of complete rotator cuff rupture in some cases. A history of overhead activities such as painting a ceiling is

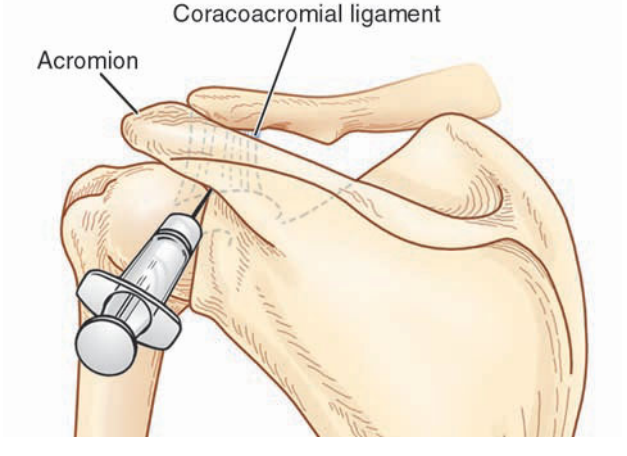


FIGURE 73-2. Posterior approach for subacromial bursitis.

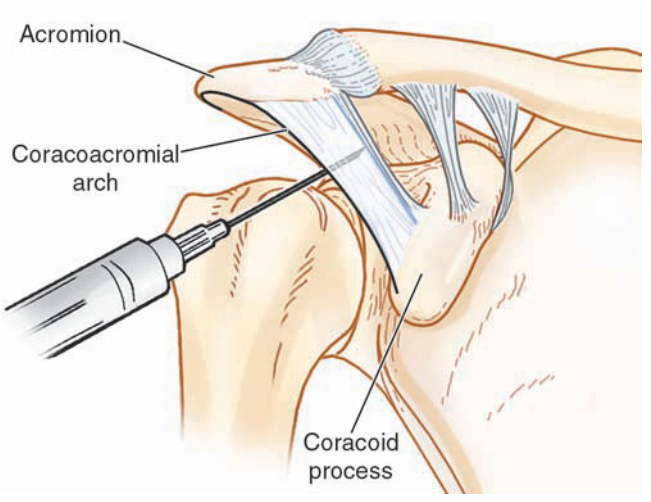


FIGURE 73-3. Injection for painful arch (impingement) syndrome.

common. The clinical hallmark is a painful arch of abduction from 60° to 120°. Pain typically begins at 60° to 70° of abduction and is maximal from 100° to 120°. Tenderness at the tendon insertion site over the greater tuberosity of the humerus may be present.

The impingement injection test may separate the pain of impingement from other causes of shoulder pain. First, the examiner prevents scapular rotation by holding the patients scapula against their rib cage. Extend the patient's affected arm in forced forward elevation. Pain with this movement may signify a number of inflammatory shoulder conditions. Repeat this maneuver after injecting 10 mL of local anesthetic solution beneath the anterior acromion process. The absence of pain after local anesthetic injection defines an impingement syndrome.

Place the patient sitting upright or supine on a gurney. Identify the coracoacromial ligament, which is found by palpating the coracoid process and the tip of acromion process. The coracoacromial ligament connects these two bony points (**Figure 73-3**). This ligament is a thick, dense, fibrous band. Fill a syringe with 80 mg of triamcinolone and 2 mL of bupivacaine or mepivacaine. Apply a 22 to 25 gauge needle to the syringe.[12] Insert the needle under the coracoacromial arch and inject the steroid–anesthetic mixture (**Figure 73-3**). **The plunger should depress easily and without resistance. Forceful injection indicates that the tip of the needle is within the rotator cuff tendons.** Advance the needle another 0.5 cm and reattempt the injection, seeking minimal resistance. Withdraw the needle and apply a bandage.

BICIPITAL TENDONITIS

The long head of the biceps tendon passes through the bicipital groove of the humerus (**Figure 73-4**). In this condition, the inflamed tendon is tender to palpation along the anterior humerus. Yergason's test is a clinical indicator of bicipital tendonitis. Flex the patient's elbow 90°. Grasp the patient's affected arm as if shaking hands. A positive test is the elicitation of pain in the biceps muscle while the examiner provides resisted supination to the patient's hand. Lipman's test is another clinical indicator of bicipital tendonitis. Tenderness of the bicipital tendon as it is rolled or plucked within the bicipital groove is considered a positive test. In general, pain causes restricted motion. Shoulder elevation will aggravate the patient's symptoms.

Place the patient seated with the affected arm externally rotated 20°. The bicipital groove and tendon are now pointing directly anterior. Fill a syringe with 10 to 15 mg of triamcinolone and 2 mL

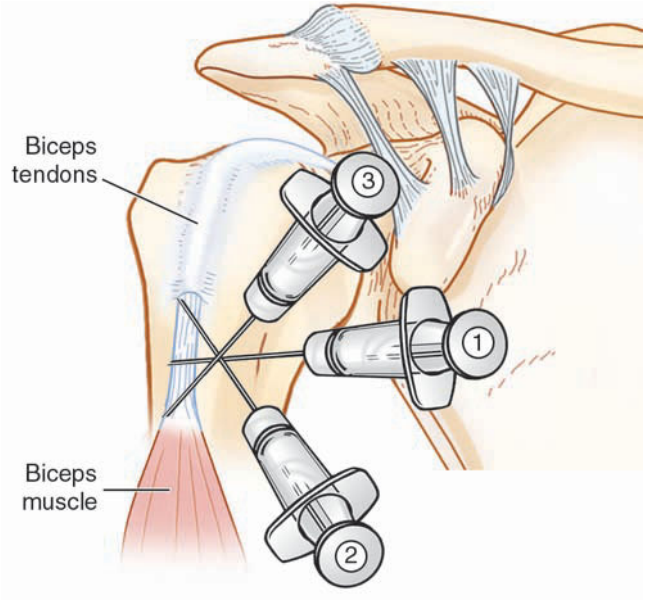


FIGURE 73-4. Injection for bicipital tendonitis.

of local anesthetic solution. Apply a 22 to 25 gauge needle to the syringe. Palpate the bicipital tendon and identify the point of maximal tenderness. Insert and direct the needle into the tendon sheath and aim toward the border of the bicipital groove at the site of maximal tenderness (**Figure 73-4**). Inject one-third of the dose into the peritendinous space (**Figure 73-4(1)**). **Confirmation of the needle placement within the tendon sheath is made by free flow of the steroid–anesthetic mixture with minimal resistance. Difficulty depressing the plunger indicates that the tip of the needle is within the tendon.** If resistance to injection occurs, withdraw the needle slightly and aim more parallel to the tendon to allow penetration of the sheath and not the tendon substance. Withdraw the needle to just under the skin and redirect it 2.5 cm superiorly, touching the border of the bicipital groove, and inject another one-third of the dose (**Figure 73-4(2)**). The final one-third of the dose is deposited by again withdrawing the needle to the subcutaneous area and redirecting the tip 2.5 cm inferiorly to the first injection site and touching the border of the bicipital groove (**Figure 73-4(3)**). Withdraw the needle and apply a bandage.

LATERAL EPICONDYLITIS (TENNIS ELBOW)

Lateral epicondylitis, or tennis elbow, is pain at the origin of the wrist and finger extensor muscles. Pain is elicited on palpation of the lateral epicondyle of the humerus. It is also elicited during resisted wrist extension. A history of playing racquet sports or doing manual labor is common.

Locate the injection site by palpating the base of the lateral epicondyle with the elbow flexed 90°. Fill a syringe with 1 mL of local anesthetic solution, 1 mL of methylprednisolone, and 0.5 mL of dexamethasone. Apply a 22 to 25 gauge needle to the syringe. Alternatively, mix the local anesthetic solution with 40 mg of triamcinolone. A total volume of 2 mL is required. Insert the needle in the indentation between the lateral epicondyle and the radial head, beginning at the radial head (**Figure 73-5A**). Slowly advance the needle toward the lateral epicondyle. **The radial nerve runs in this area, and care must be taken not to penetrate and inject the nerve.** Paresthesias and pain will be felt if the needle enters the nerve.

Inject 0.5 mL of the steroid–anesthetic mixture into the teno-periosteum at the base of the lateral epicondyle. Withdraw the needle until the tip is at the level of the radial head while simultaneously infiltrating with 0.25 mL of the steroid–anesthetic mixture. Infiltrate 0.5 mL of the steroid–anesthetic mixture when the tip of the needle reaches the level of the radial head. Redirect the needle over the proximal extensor muscle bellies (**Figure 73-5B**). Inject the remaining steroid–anesthetic mixture in a fan-like pattern over the extensor muscle bellies (**Figure 73-5B**). Withdraw the needle and apply a bandage.

MEDIAL EPICONDYLITIS (GOLFER'S ELBOW)

Patients affected with medial epicondylitis, or golfer's elbow, are most commonly Little League pitchers, golfers, and bowlers. Pain is felt in the medial aspect of the elbow upon flexion and supination of the wrist. Tenderness is elicited on palpation just distal to the medial epicondyle. It is important to exclude an avulsion fracture of the medial epicondyle or a compression fracture of the subchondral

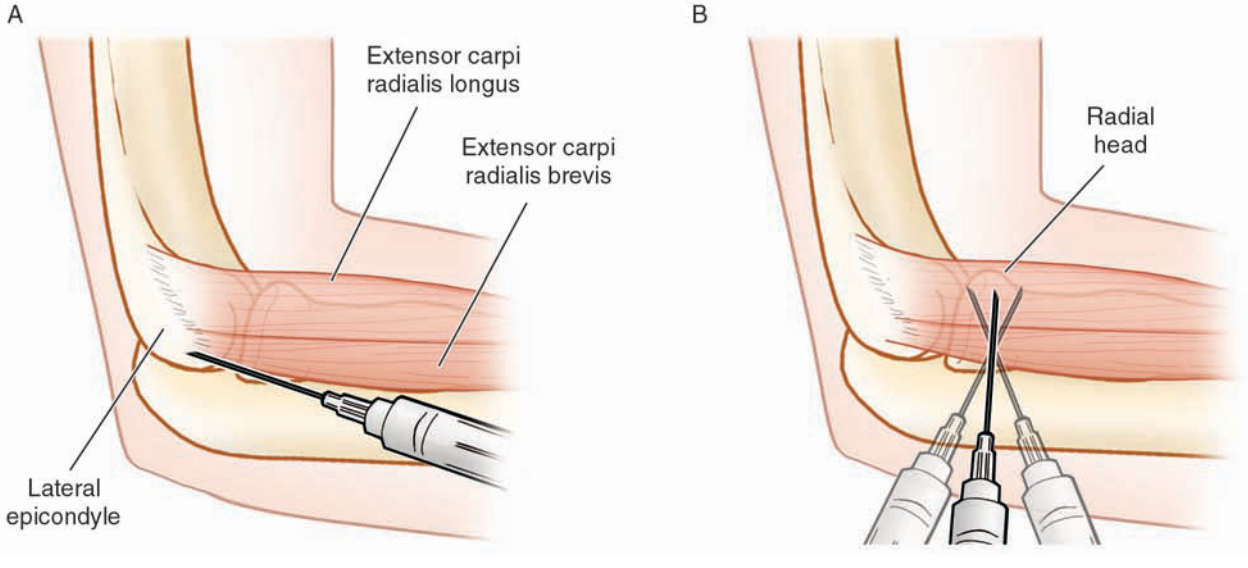


FIGURE 73-5. Injection for lateral epicondylitis. **A.** The needle is inserted at the level of the radial head and advanced to the base of the lateral epicondyle. **B.** The needle is redirected in a fan-like pattern over the muscle bellies.

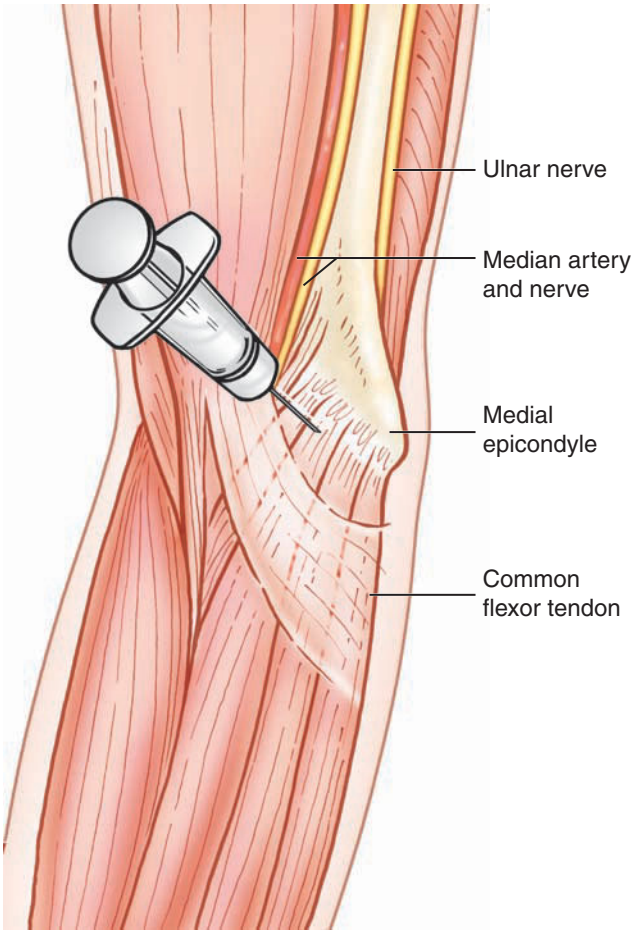


FIGURE 73-6. Injection for medial epicondylitis.

bone of the lateral condyle or radial head in children with nonfused epiphyses. Radiographs are suggested to exclude these causes.

Place the patient supine on a gurney. Place the arm in 90° of external rotation and abducted 90°. Flex the elbow 90°. Prepare a steroid–anesthetic mixture similar to that used for lateral epicondylitis. Identify by palpation the volar surface of the medial epicondyle. Insert the needle 2 cm proximal to the medial epicondyle and advance it distally to the tenoperiosteal region (**Figure 73-6**). **The ulnar nerve is better protected than the radial nerve, as it runs posterior to the epicondyle. Proximal needle insertion prevents striking the ulnar nerve.** Paresthesias and pain are indicators of nerve penetration. Inject 1.5 mL of the steroid–anesthetic mixture over the medial epicondyle while withdrawing the needle. Withdraw the needle and apply a bandage.

OLECRANON BURSITIS

Olecranon bursitis is usually sterile even though the olecranon bursa is the most frequent site of a septic bursitis. The bursa is located subcutaneously overlying the olecranon process of the ulna. Olecranon bursitis is not very painful except for the discomfort due to bursal expansion. An enlarged olecranon bursa may limit elbow extension. Studies have demonstrated that corticosteroid injection is superior to oral regimens for resolution of bursal inflammation.[13] Simple aspiration without corticosteroid injection is often followed by reoccurrence. **Since the olecranon bursa is the most common site of a septic bursitis, aspiration with fluid analysis is recommended before corticosteroid injection unless infection can be ruled out clinically.**

Seat the patient upright with their elbow flexed 90°. Fill a syringe with 30 to 40 mg of triamcinolone and 1 mL of local anesthetic solution. Insert an 18 gauge needle on an empty syringe into the most dependent aspect of the bursal sac. Aspirate the bursal fluid to drain it completely. The bursa may be "milked" by palpation and compression of the tissues toward the draining needle. Hold the needle securely. Remove the syringe while the tip of the needle remains within the bursa. Attach the syringe containing the steroid–anesthetic mixture. Inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage. Wrap the elbow region with an elastic compression bandage (Jones compression dressing) for 7 to 10 days. Instruct the patient to limit elbow movement for 7 to 10 days to prevent reaccumulation of the fluid.[14]

DEQUERVAIN'S TENOSYNOVITIS

DeQuervain's tenosynovitis is an inflammation of the tendon sheaths of the abductor pollicis longus and extensor pollicis brevis muscles as they cross the wrist (**Figure 73-7A**). The precise cause is unknown. Excessive friction from overusing the thumb and wrist such as repetitive and excessive gripping and grasping may be a possible etiology. Cases have been seen in bricklayers, golfers, those who sew, and piano players. Pain is elicited by the classic Finkelstein test, in which the patient deviates the wrist ulnarly while holding the thumb between the palms and fingers (**Figure 73-7B**). Palpation along the course of the tendon will also cause pain.

Fill a syringe with 40 mg of triamcinolone and 1 to 2 mL of mepivacaine or bupivacaine. Apply a 25 gauge needle to the syringe. Bending the needle approximately 30° at its base makes it easier to negotiate the area and insert the needle alongside the tendon.[14] Introduce the needle through the skin overlying the point of maximal tenderness. This is usually just distal to the radial styloid process (**Figure 73-8**). Inject the steroid–anesthetic mixture into the tendon sheath. **Resistance to injection signifies that the tip of the**

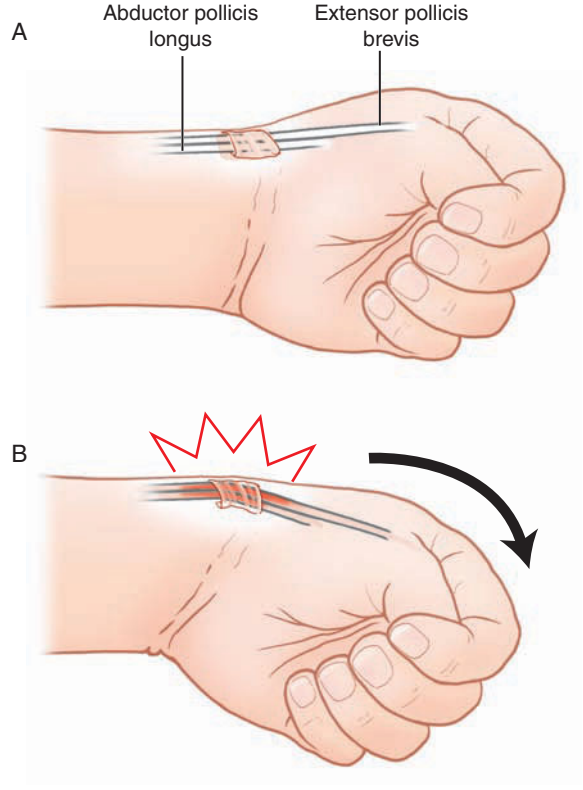


FIGURE 73-7. DeQuervain's tenosynovitis. **A.** Anatomy. **B.** Finkelstein's test.



FIGURE 73-8. Injection for DeQuervain's tenosynovitis.

needle is within the tendon. Withdraw the needle slightly and reinject, feeling for the loss of resistance. Withdraw the needle and apply a bandage. Apply a light thumb splint for approximately 10 days. The splint is especially useful at night or when there is significant activity.

TROCHANTERIC BURSITIS

Trochanteric bursitis typically affects women in the fourth to sixth decades of life. It also occurs in runners, ballet dancers, and as a form of overuse or trauma to the hip. Hip pain often prevents the patient from sleeping on the affected side. Pain is also severe with walking, especially up stairs. The deep trochanteric bursa lies between the tendon of the gluteus maximus and the greater trochanter of the femur. Another lies between the gluteus medius and the greater trochanter (**Figure 73-9**). Pain is elicited on palpation of the greater trochanter of the femur. Pain can be reproduced by hip adduction in superficial bursitis or on a resisted active abduction in deep bursitis.

The principal bursa lies between the gluteus maximus and the posterolateral prominence of the greater trochanter. Pain may radiate from the greater trochanter down the lateral or posterior thigh, mimicking sciatica or hip joint disease. In contrast to these syndromes, passive range of motion of the hip is nearly painless in the trochanteric bursitis. However, active abduction of the affected hip while the patient is lying on the unaffected side increases symptoms. Pain is also elicited by abduction and external rotation of the hip.

Place the patient prone on a gurney. Fill a syringe with 80 mg of triamcinolone and 3 to 10 mL of local anesthetic solution. Apply a 22 to 23 gauge needle on the syringe. Insert the needle at the point of maximal tenderness and aimed toward the greater trochanter. Advance the needle until the tip strikes the greater trochanter. Withdraw the needle 1 to 2 mm and inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

ISCHIAL BURSITIS

The ischial bursa lies between the ischial tuberosity and the overlying gluteus maximus (**Figure 73-9**). It becomes inflamed from trauma or prolonged sitting on a hard surface. Pain may radiate down the back of the thigh and mimic sciatica. Pain can be elicited by applying pressure over the ischial tuberosity.

Place the patient prone on a gurney. Fill a syringe with 30 to 40 mg of triamcinolone and 5 to 10 mL of local anesthetic solution.

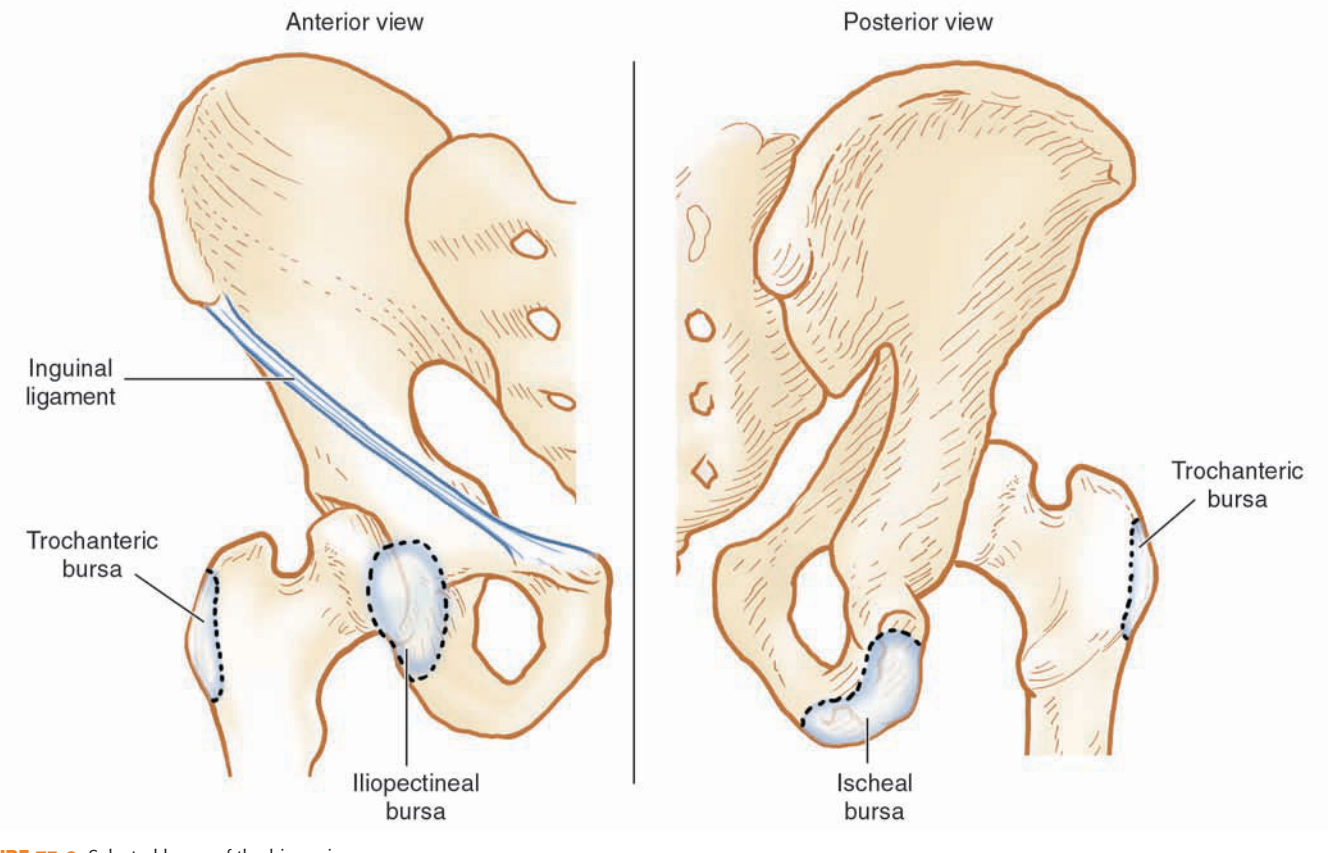


FIGURE 73-9. Selected bursa of the hip region.

Apply a 22 to 23 gauge needle to the syringe. Insert the needle over the most prominent section of the ischium. Hip flexion may facilitate palpation of the ischium in obese patients. **Care must be taken not to injure the sciatic nerve.** Striking the nerve will cause paresthesias across the buttocks and down the leg. Advance the needle until it contacts the ischial tuberosity. Withdraw the needle 2 to 3 mm and inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

ILIOTIBIAL BAND SYNDROME

Patients with iliotibial band syndrome present with lateral knee pain. This condition is commonly seen in cyclists, dancers, long-distance runners or walkers, and football players. These patients have a painful limp that is exacerbated with walking or running. Climbing stairs or walking up an incline will increase their pain. Tenderness is elicited with the patient lying supine and knee flexed 90°. Instruct the patient to extend their knee as you press over the lateral femoral condyle. Pain will be localized to the lateral femoral condyle. The patient will have pain at 30° of flexion as the iliotibial band slides over the condyle. A positive Rinne test occurs when the patient stands with their weight on the affected leg and flexes their knee. Pain at 30° of flexion is considered in a positive test.

Place the patient supine on a gurney. Fill a syringe with 80 mg of triamcinolone and 2 mL of local anesthetic solution. Apply a 22 to 25 gauge needle to the syringe. Typically, at 30° of flexion, the iliotibial band is at the midpoint of the lateral femoral condyle (**Figure 73-10**). Support the patient's leg in this position to bring the tendon to its most superficial point. Identify the point of maximal tenderness as the patient flexes their knee. Insert the needle perpendicular to the skin and 1 cm inferior to the point of maximal tenderness. Aim the needle superiorly. Inject the steroid–anesthetic mixture in an arc from anterior to posterior. The goal is to deposit corticosteroid in the tendon sheath and the surrounding inflamed tissues. **Resistance to injection indicates that the tip of the needle is within the tendon.** Withdraw the needle slightly and reinject, feeling for the loss of resistance. Withdraw the needle and apply a bandage.

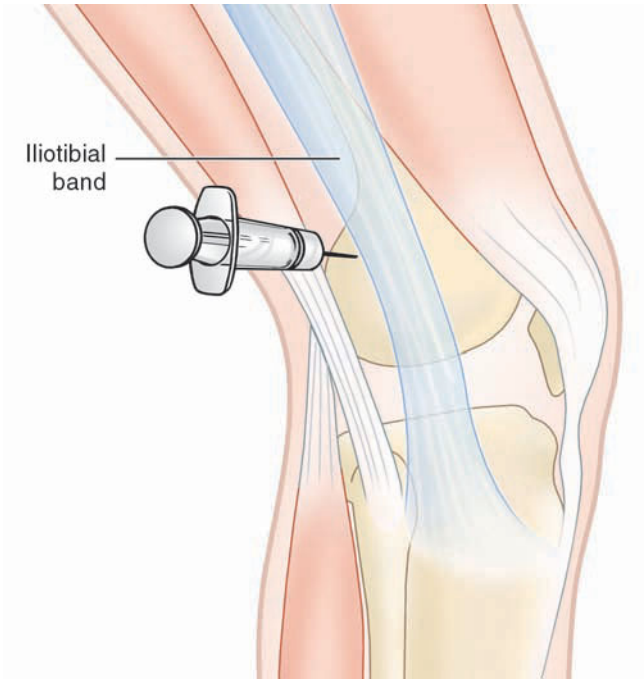


FIGURE 73-10. Injection for iliotibial band syndrome. The knee is flexed 30° to bring the tendon to its most superficial position overlying the midportion of the lateral femoral condyle.

ANSERINE BURSITIS

Anserine or pes anserine bursitis is an inflammation of the bursa located 5 cm below the medial joint line of the knee at the tibial insertion of the gracilis, sartorious, and semitendinosus muscles (**Figure 73-11**). The anserine bursa is superficial to the tibial insertion of the medial collateral ligament. The syndrome occurs predominately in overweight women with osteoarthritis of the knees. It may also be found in equestrians. The anserine bursa will be tender to palpation.

Place the patient supine with the affected leg externally rotated. Identify the anteromedial joint line of the knee. The bursa is located inferior to the joint line at the insertion of the sartorius, gracilis, and semitendinosus tendons (**Figure 73-11**). Palpate the area of maximal tenderness at this site. Fill a syringe with 40 mg of triamcinolone and 2 to 4 mL of local anesthetic solution. Apply a 23 to 25 gauge needle to the syringe. Insert the needle and direct its tip into the bursa at the point of maximal tenderness. Inject the steroid–anesthetic mixture into the bursa. Withdraw the needle and apply a bandage.

PREPATELLAR BURSITIS

Prepatellar bursitis is caused by direct pressure, such as when a person is kneeling on a firm surface. It is also known as nun's, rug cutter's, or housemaid's knee. Tenderness and/or crepitance is elicited by direct palpation overlying the patella. Extreme knee flexion causes pain. There is often a fluctuant, well-circumscribed, and warm bursal pouch overlying the patella. The prepatellar space is a common site for septic bursitis. Aspiration with fluid analysis is recommended to rule out an infection before any corticosteroid injection is considered.

Place the patient supine on a gurney with the affected knee slightly flexed. Note that the bursa is very superficial and may be entered by passing the needle just through the skin and subcuticular tissues (**Figure 73-11**). Fill a syringe with 30 to 40 mg triamcinolone and 1 to 2 mL of local anesthetic solution. Apply a 23 to 25 gauge needle to the syringe.[14] Insert the needle into the bursa at the point of maximal fluctuance. Inject the steroid–anesthetic mixture into the bursa. Withdraw the needle and apply a bandage.

INFRAPATELLAR BURSITIS

The infrapatellar bursa has two components (**Figure 73-11**). The superficial infrapatellar bursa lies between the patellar ligament and the skin. The deep infrapatellar bursa lies between the patellar ligament and the anterior tibia. Inflammation of the superficial bursa occurs due to friction from the overlying skin. Clinically, there is no pain with passive flexion. Active knee flexion and extension causes pain in the deep infrapatellar bursa. Edema and tenderness may be found on both sides of the patellar tendon.

Place the patient supine on a gurney with the affected leg and knee extended. Palpate the patellar tendon. Identify the superficial inflamed bursa. Fill a syringe with 20 mg of triamcinolone and 1 mL of local anesthetic solution. Apply a 23 to 25 gauge needle to the syringe. Insert the needle into the superficial bursa and inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

Patients with deep infrapatellar bursitis have maximal tenderness and swelling both medially and laterally to the patellar tendon. Fill a syringe with 30 mg of triamcinolone and 1 to 2 mL of local

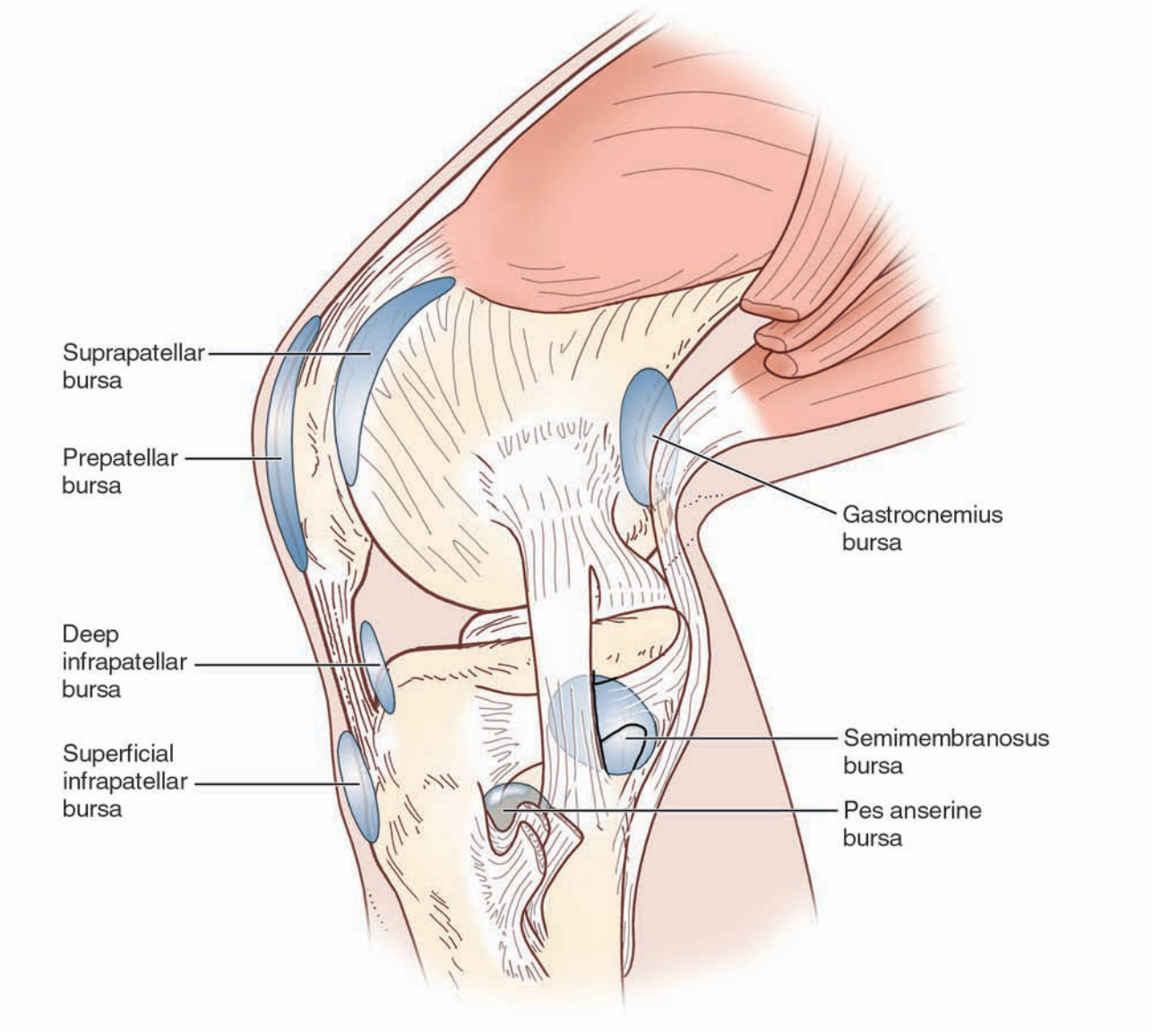


FIGURE 73-11. Bursae of the knee.

anesthetic solution. Apply a 23 to 25 gauge needle on the syringe. Insert the needle into the infrapatellar bursa, either medially or laterally to the patellar tendon. Attempt to aspirate, although fluid accumulation is minimal and usually no return will be found. Inject the steroid–anesthetic mixture. Withdraw the needle and apply a bandage.

ACHILLES TENDONITIS

Achilles tendonitis causes tightness and pain in the heel region upon first awaking. This discomfort improves with ambulation. The Achilles tendon will be tender to palpation and may be visually swollen. Corticosteroid injection around the Achilles tendon has been associated with tendon rupture.[15] Therefore, this injection is reserved for the Podiatrist, Rheumatologist, or the Orthopedic surgeon.[15]

PLANTAR FASCIITIS

Plantar fasciitis is a common problem presenting to the Emergency Department and the primary care physician. Patients typically complain of medial heel pain, particularly after standing for a long period of time. These patients have minimal to no swelling but feel acute tenderness to palpation over the calcaneal insertion of the plantar fascia. Maximum tenderness is palpated just beneath the spring ligament at the insertion of the plantar fascia on the calcaneous. Radiographs may demonstrate a calcaneal spur. However, the presence of a spur does not correlate with plantar fasciitis. Patients may have plantar fasciitis with or without a calcaneal spur. The optimal therapy for these patients is to elevate the heel with a felt heel pad inserted in the shoe. In addition, they may begin stretching exercises that are designed to stretch the plantar fascia. This often relieves the condition without an injection. In significant cases where conservative therapy is unsuccessful, injection of the calcaneal insertion of the plantar fascia with a steroid–anesthetic mixture is advocated.

Place the patient supine on a gurney with the affected leg externally rotated. Fill a syringe with 20 mg of triamcinolone and 1 mL of local anesthetic solution. Apply a 25 gauge needle on the syringe. Insert the needle into the medial aspect of the foot and aimed just anterior to the base of the calcaneous (**Figure 73-12**). Advance the needle 1.5 cm and inject the steroid–anesthetic mixture. Withdraw



FIGURE 73-12. Injection for plantar fasciitis.

the needle and apply a bandage. The patient should avoid weight bearing for 3 to 4 days and immediately begin oral nonsteroidal anti-inflammatory drugs.

ASSESSMENT

The patient must be observed for several minutes after the injection. Reexamine the patient to compare pre- and postinjection tenderness and mobility. The patient's symptoms should abate within a few minutes from the local anesthetic. Lack of relief indicates deposition of the steroid–anesthetic mixture away from the target structure. In these cases, a second attempt may be performed if the injection site can be properly identified. Otherwise, refer the patient to their primary care physician, a Rheumatologist, or an Orthopedic Surgeon for reevaluation and reassessment.

AFTERCARE

Instruct the patient to limit movement and/or weight bearing of the affected area after a corticosteroid injection. The duration of rest is dependent on the injection site. Larger and weight-bearing joints may require up to 2 to 3 weeks of rest, with range-of-motion exercises encouraged. Immobilization with splints or bandages may be necessary to prevent weight-bearing. A rehabilitation program including range-of-motion exercises, stretching, and strengthening may be recommended depending upon the chronicity and severity of the presenting condition.

COMPLICATIONS

Local infection is rare after corticosteroid joint injection and occurs from 1 in 17,000 to 50,000 injections.[1,8,16,17] A local reaction consisting of swelling, tenderness, and warmth may occur a few hours postinjection and last up to 2 days. This is known as the "postinjection flare" or "steroid flare."[9] It is self-limited, and responds to ice packs and nonsteroidal anti-inflammatory drugs. The etiology of the steroid flare is attributed to preservatives in the steroid suspension inducing a local synovitis. Steroid flares occur in approximately 2% of patients injected with corticosteroids.[1]

Tendon rupture is a theoretical complication thought to be due to corticosteroids weakening the collagen matrix. Tendon ruptures after corticosteroid injections have been reported, but direct causality has not been established.[15,18–21] Rupture is more likely if the injection is made into the tendon matrix rather than the synovial sheath, if the patient does not rest the tendon appropriately after the injection, or with multiple repeat injections.

Subcutaneous fat atrophy and atrophy of the overlying skin may develop if the steroid is injected less than 5 mm beneath the skin surface. A depigmentation in darker-skinned individuals may also occur due to superficial steroid injections. The depigmentation typically resolves spontaneously over a period of 6 months to 1 year.

SUMMARY

Local corticosteroid injections are useful diagnostic and therapeutic adjuncts for the Emergency Physician. Many patients with an inflammatory bursitis or tendonitis will benefit greatly from these simple and effective injections. Mastery of the techniques is quite easy. They require a familiarity with the indications, the local anatomy, and the injectable corticosteroid preparations. Complications associated with the injection of a steroid–anesthetic mixture are minimal if it is not injected into an infected space.

74 Compartment Pressure Measurement

Matt Kleinmaier and Sanjeev Malik

INTRODUCTION

The ability to diagnose a compartment syndrome is a critical skill for the Emergency Physician (EP). Early identification of a compartment syndrome can enable the appropriate treatment and may facilitate limb salvage. A compartment syndrome begins when an imbalance of volume and pressure within a myofascial compartment results in diminished blood flow.[1] A compartment syndrome has been classically described in the early literature as a Volkmann ischemic contracture following vascular insufficiency in the forearm.[3]

A compartment syndrome can occur in almost any muscle group that is contained within a confined fascial space. Common locations include the leg, forearm, and gluteal area. There are many causes of a compartment syndrome. These include protracted muscle ischemia secondary to necrosis from a contusion, swelling secondary to volume overload states or a fracture, or a thrombus in a vessel that traverses the compartment. In the Emergency Department (ED), a compartment syndrome is most commonly associated with long bone fractures or blunt trauma.[2] Most compartment syndromes are caused by trauma; 58% of all cases are due to fractures of the tibia or forearm.[27] Other etiologies for a compartment syndrome include complications from a coagulopathy, dialysis, surgery, or states of obtundation (**Table 74-1**).[4–6]

Identifying a compartment syndrome in a timely fashion can be challenging. The sensitivity and specificity of manual palpation to identify a compartment syndrome is 24% and 55%, respectively.[34] Manual palpation has a positive predictive value of 19% and a negative predictive value of 63%.[34] **Thus, manual palpation cannot be used to rule in or rule out a compartment syndrome. The hallmark symptom is persistent and progressive pain that is disproportionate to the underlying cause.** The pain typically increases with passive motion. **A catastrophic mistake is to attribute the etiology of the patient's pain solely to the underlying problem, such as the fracture or trauma.**[7,8] Other signs and symptoms associated with a compartment syndrome occur late in the course and include paresthesias of the involved nerve, paralysis of the involved muscle group, pallor of the skin, and diminished pulses.[9] Waiting for the development of all the clinical signs and symptoms is an invitation for permanent and dangerous sequelae, including muscle necrosis and possible loss of a limb. **Measurement of elevated**

TABLE 74-1 Common Causes of a Compartment Syndrome

Anticoagulation therapy or coagulopathy
Bleeding into compartment
Burns which involve muscle
Exercise-induced (chronic exertional compartment syndrome)
External compression
Iatrogenic closure of fascial injuries
Immobility
Improper casting or tight dressings
Infusion of fluids into muscle compartment (blown forearm IV)
Nephrotic syndrome (lower extremity swelling)
Reperfusion injury after prolonged OR positioning or tourniquet use
Seizures (increased capillary permeability)
Trauma
Long bone fractures
Blunt trauma (Crush injury)
Vascular injury
Venous thrombus

tissue pressure within the muscle compartment is currently the most common objective means of diagnosing this syndrome. Compartment pressure measurement provides objective support for the diagnosis of a clinically suspected compartment syndrome, leading to the appropriate treatments designed to salvage the afflicted limb.

Numerous methods have been evaluated to diagnose a compartment syndrome.[35] The inflammatory biomarkers and proteins released from damaged muscle are either late markers or nonspecific to distinguish between muscle injury from trauma versus a compartment syndrome. MRI is not reliable or specific to identify the early changes of a compartment syndrome. Pulsed phase-locked loop (PPLL) ultrasound identifies subtle movements of the fascia and may be helpful in the diagnosis. Further investigations using this technology are required before it can be used clinically. Radionuclide imaging is not feasible in the acute setting of the ED due to its lack of specificity, the complexity of the procedure, the time required for testing, and the inability to perform repeated measurements. Near-infrared spectroscopy measures changes in oxygenated hemoglobin and tissue perfusion. Further investigations using this technology are required before it can be used clinically in the diagnosis of a compartment syndrome. Pulse oximetry cannot be used to measure intracompartmental oxygenation. It can measure if distal blood flow is present but is limited due to collateral circulation and the loss of pulses being a late finding for a compartment syndrome. Laser Doppler flowmetry measures microvascular perfusion and has potential in the future when more clinical information regarding its use becomes available. Tissue ultrafiltration requires the extraction of tissue fluid and the time consuming measurement of biomarkers. Differences in vibratory sensation using a 256 cycle tuning fork show some promise in the diagnosis of a compartment syndrome. It cannot be used in young children, patients that cannot appropriately communicate, and those with an altered sensorium. Tissue hardness measurement techniques evaluate skin surface pressure and are in the early stages of testing. Direct nerve stimulation is not for the early evaluation of a compartment syndrome because nerve damage is a later finding. Finally are the invasive techniques to measure compartment pressure, which are the focus of this chapter.

ANATOMY AND PATHOPHYSIOLOGY

The anatomy of a compartment syndrome is variable, as it can occur in any enclosed muscle group. Any muscle tissue that is confined in space by fascia, skin, or any external forces (e.g., casting material) is a potential site for the development of a compartment syndrome. The muscles, nerves, and vasculature within the affected muscle group are all potentially compromised by a prolonged ischemic state followed by swelling. A basic knowledge of the anatomy of commonly affected compartments is necessary to successfully and safely perform compartment pressure measurement.

The initial imbalance of a compartment syndrome occurs between the volume and pressure within the myofascial compartment. The arterial inflow and venous outflow diminish as either intracompartmental volume or pressure increases. The blood begins to be shunted via capillaries into the muscle tissue. This compensatory shunting of blood further disturbs the volume–pressure balance, resulting in impaired tissue oxygenation.[2,9,10]

The extent of the tissue damage is determined by the duration of ischemia. Numerous experimental studies have documented a lack of muscle viability after 6 to 8 hours of total ischemia and a lack of nerve viability after 8 hours of total ischemia.[11,12] Thus, reversing the ischemia well before this time period is crucial to restoring tissue function. The definitive factor in the development of a compartment syndrome is the alteration of the pressure gradient between arterial and venous flow. Measurement of the intracompartmental pressures is used to determine the extent of ischemia.

The pressure of a healthy muscle compartment ranges between 0 and 8 mmHg.[13] Although there is no absolute value that determines the presence of a compartment syndrome, values above 30 to 35 mmHg are considered abnormal and should be the cutoff point for performing a fasciotomy.[9,14,15] Although this value is referred to commonly, several studies confirm that a compartment syndrome does not develop definitively at or above this pressure threshold.[16,17] A prospective study of patients with isolated lower leg fractures without clinical signs of compartment syndrome showed significant elevations in compartment pressure compared to the contralateral normal leg (35.5 ± 13.6 mmHg in the injured leg vs. 16.6 ± 7.5 mmHg in the control leg; $P = 0.0001$).[33] Other studies use a compartmental pressure that is within 10 to 30 mmHg of the patient's diastolic pressure as one of the indications for a fasciotomy.[2,11] Finally, a measurement that is within 10 to 30 mmHg of the patient's mean arterial pressure is also suggested as an indication for a fasciotomy.[18] **Nonetheless, if the compartmental pressure is 30 mmHg or greater, one must consider the development of a compartment syndrome and the need to perform a fasciotomy.**

Studies have investigated the correlation between perfusion pressure (diastolic blood pressure minus compartment pressure, also known as delta pressure) and compartment syndrome, with compartment syndrome suggested if delta pressure is less than 30 mmHg.[2,11,27] In equivocal cases, newer adjunctive and noninvasive testing such as T2-weighted MRI[28] and near-infrared spectroscopy[28,29] may be helpful if available. Despite advances in testing, there is as yet no gold standard for diagnosis, and compartment syndrome remains a clinical and operative diagnosis.

A compartment syndrome can occur in any muscle group. This includes the hand, foot, thigh, arm, and intercostal spaces, to name a few. This chapter reviews the anatomy of the two most common sites of a compartment syndrome, the leg and the forearm.

LOWER EXTREMITY: LEG

The lower leg consists of four distinct muscle compartments: anterior, lateral, deep posterior, and superficial posterior (**Figure 74-1**). A general understanding of the components of each compartment is important.[19,20]

The anterior compartment contains the four extensor muscles of the leg. These muscles function together to dorsiflex the foot. The deep peroneal nerve travels through this compartment to innervate the extensors and provide sensory innervation to the web space

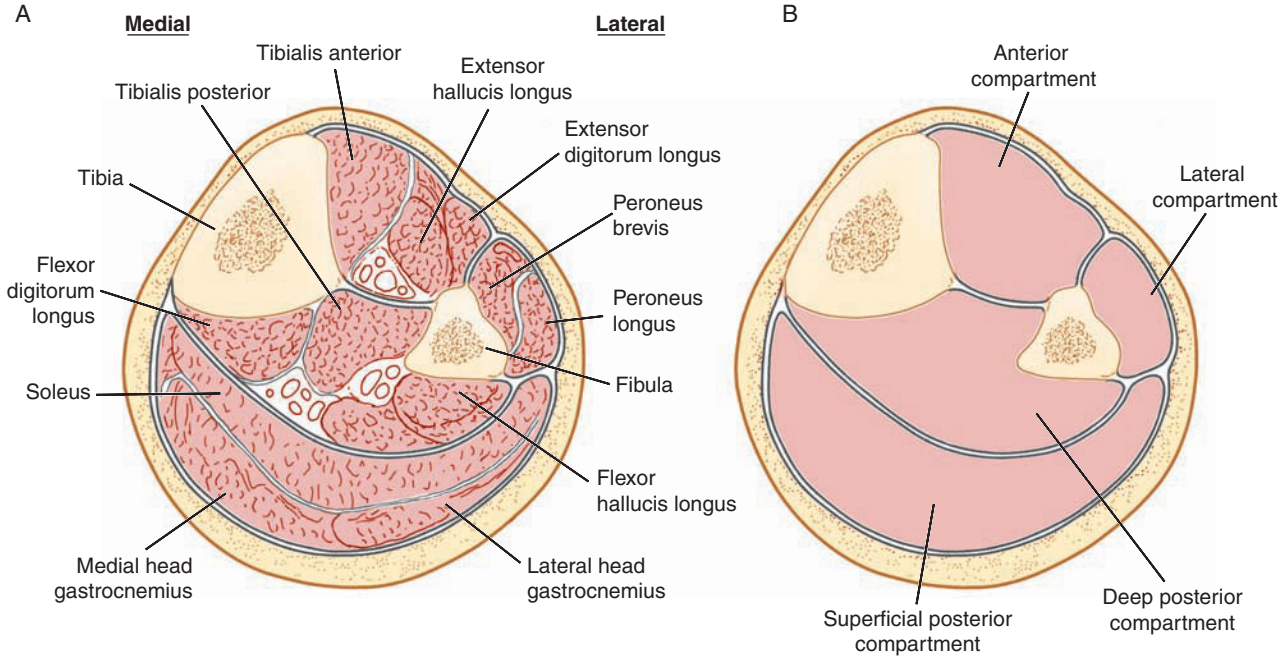


FIGURE 74-1. Cross section through the middle of the right leg demonstrating the four compartments. The size and proportion of the compartments change as one travels proximally or distally from this middle section. **A.** The anatomy. **B.** The compartments.

between the first and second toes. The anterior tibial artery travels through this compartment and provides bloodflow to its contents.

The lateral compartment contains the peroneus longus and brevis muscles. Their chief function is to evert the foot, with some consequent abduction and plantarflexion of the foot. The major nerve in the lateral compartment is the superficial peroneal nerve to supply motor innervation to the compartment muscles and sensory innervation to the lower leg and dorsum of the foot.

A fascial layer divides the posterior muscle group into superficial and deep compartments. The superficial posterior compartment contains the muscles of plantarflexion (gastrocnemius, soleus, and plantaris tendons). No major nerves or blood vessels travel in the superficial compartment. The deep posterior compartment contains the four deep flexor muscles (flexor digitorum longus, flexor hallucis longus, tibialis posterior, and popliteus). This group of muscles contributes to inverting and adducting the foot in addition to flexing the toes and foot. The primary sensory innervation is from the tibial nerve, which courses through the deep posterior compartment. The tibial nerve supplies most of the muscles of the posterior compartment before dividing into several branches that provide sensory innervation to the sole of the foot. The posterior tibial artery and the peroneal artery are also contained within this compartment.

Although any of these compartments can suffer from ischemia, **the deep posterior compartment and the anterior compartment have the highest incidence of developing a compartment syndrome.**[17] It is difficult to simply observe the patient in the face of a normal compartmental pressure when they clinically present with increasing pain and the features suggestive of a compartment syndrome. **Thus, multiple compartmental syndrome readings must be taken when the suspicion is high and the compartmental pressures are normal.**

UPPER EXTREMITY: FOREARM

The forearm consists of three compartments that are interconnected at various levels (**Figure 74-2**).[20,21] This interconnection is significant because release of the pressure in one compartment will reduce some of the pressure into the adjacent compartments. **The volar compartment is most at risk for development of a compartment syndrome in traumatic injuries of the forearm.**

The forearm includes the volar, dorsal, and mobile wad compartments (**Figure 74-2**). The volar compartment contains all of the hand and forearm flexor muscles, the median and ulnar nerves, and the radial, ulnar, and common interosseous arteries. The mobile wad contains the brachioradialis, the extensor carpi radialis brevis, and the extensor carpi radialis longus muscles. No major arteries or nerves are contained within this compartment. The radial artery and a branch of the radial nerve may sometimes lie between the mobile wad and the volar compartment. The dorsal compartment contains the hand and forearm extensor muscles, the posterior interosseous artery, and the posterior interosseous nerve.

INDICATIONS

The earliest and most reliable indication for measuring compartment pressures is the development of increasing pain in a tense and swollen muscle group.[2] This pain tends to be disproportionate to the underlying cause (e.g., fracture, soft tissue contusion, thrombus, etc.). Pain that increases with passive motion of the affected muscles is also an indication for compartmental pressure measurement. Sensory deficits and paresis of the affected muscles are two late findings for the development of compartment syndrome.[9] **It is important to remember that the presence of palpable pulses and capillary refill do not rule out an evolving acute compartment syndrome.** The absence of pulses may suggest arterial injury or hypovolemia. One must measure and monitor all compartments at risk if the patient is obtunded or unreliable. This usually refers to the forearm and lower leg compartments in the multiple trauma patient.

Have a very low threshold for measuring pressures within a muscle compartment. Compartmental pressures must be measured if a compartment syndrome is considered as a diagnosis. Do not rely solely on the compartmental pressure measurements

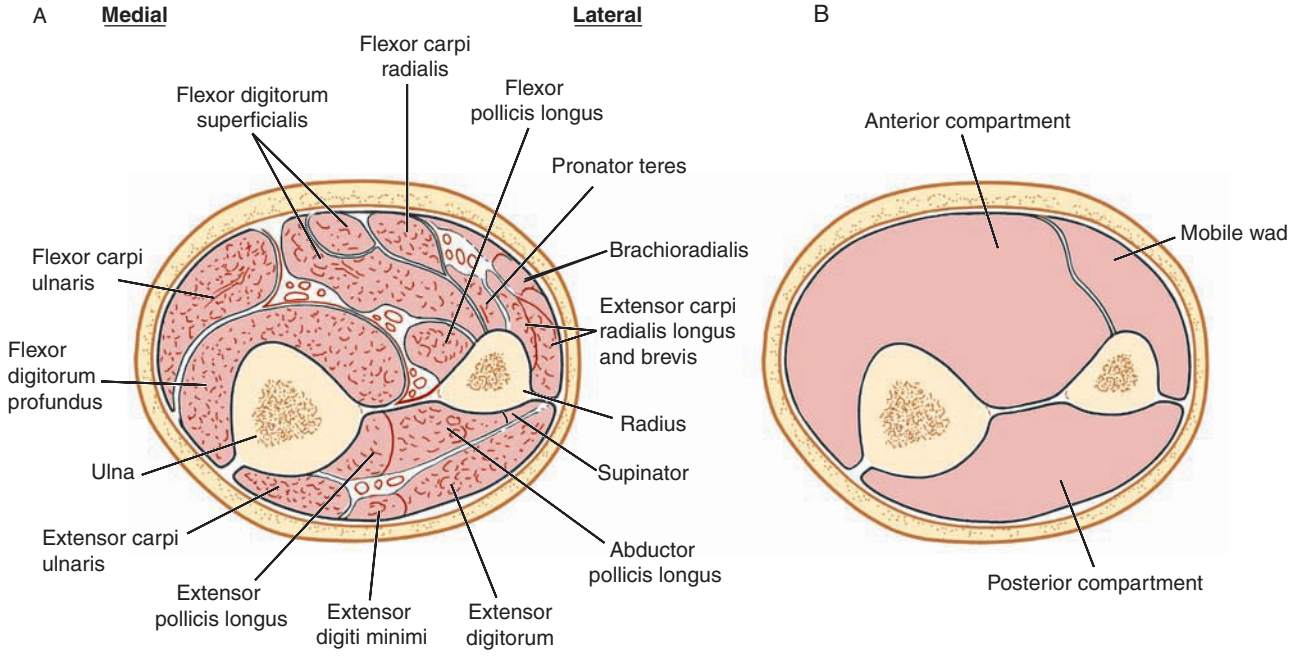


FIGURE 74-2. Cross section through the middle of the right forearm demonstrating the dorsal and volar compartments separated by the line of the radius, the ulna, and the interosseous membrane. **A.** The anatomy. **B.** The compartments. The mobile wad forms a distinct muscle compartment coursing along the radius.

to make a decision regarding the need for fasciotomy. A compartment syndrome is primarily a clinical diagnosis. Pressure measurements should be taken in each compartment at risk, in at least two sites within the compartment. If concern persists, serial measurements or continuous pressure measurement should be performed even if initial pressures are normal or only mildly elevated. Compartment pressures should be interpreted in the clinical context of the patient; normal compartment pressures do not rule out the diagnosis.

CONTRAINDICATIONS

There are no absolute contraindications to the measurement of compartment pressures. Given the importance of prompt diagnosis, compartment pressure measurements should be performed while evaluating for coexistent traumatic injuries. The EP can still assess the compartmental pressures even though the patient may be undergoing other invasive and/or surgical procedures. **Time is of the essence. Postponing compartmental pressure measurements or a fasciotomy may lead to irreversible damage to the affected extremity.**

EQUIPMENT

General Supplies

- Povidone iodine or chlorhexidine solution
- 4 × 4 gauze squares
- Sterile drapes or towels

Needle (Whiteside) Manometer Technique

- 18 gauge needles, 1.5 in. long
- 20 mL syringe
- Three-port, four-way stopcock
- Intravenous extension tubing
- Sterile saline
- Mercury manometer

Stryker Monitor System

- Stryker pressure monitor unit
- Sterile quick pressure monitor set (single use, contains: needle, syringe, diaphragm chamber)

Arterial Manometer Technique

- 18 gauge needle or Angiocath
- Sterile saline
- Arterial line tubing and manometer (identical to that used for arterial line)

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Discuss the low risk of infection or bleeding, and the possibility of obtaining erroneous values. Written informed consent should be obtained from the patient and/or their representative if possible. If the patient is unable to consent and no representative is available, proceed after documentation of the medical necessity.

Wash away any blood, dirt, or debris on the patient's skin. Apply povidone iodine or chlorhexidine solution to the skin around the puncture sites. The measurement of compartment pressures is considered a sterile procedure and the EP should don a hat, mask, sterile gloves, and a sterile gown. Create a sterile field with either surgical towels or drapes. Identify the landmarks for needle insertion and mark the skin puncture sites.

The exact location at which to measure the intracompartmental pressures is not clearly defined. There were no clearly established guidelines for determining the appropriate location for compartmental pressure measurements in patients with fractures prior to the recent study of Heckman et al.[24] The results of their study suggest that measurements must be performed at the level of the fracture as well as locations proximal and distal to the zone of the fracture. A 5 cm distance was used from the fracture site to the proximal and distal needle insertion sites. In the absence of a fracture, insert the needle at the point of maximal tightness of the compartment, as

TABLE 74-2 Needle Insertion Sites for the Compartments of the Leg

Compartment	Needle insertion site	Insertion depth (cm)
Anterior	1 cm lateral to the anterior tibial ridge and directed perpendicular to the long axis of the leg	1.0–3.0
Lateral	Just anterior to the posterior border of the fibula and directed toward the fibula	1.0–1.5
Superficial posterior	3 cm medial or lateral to a vertical line drawn through the midcalf	2.0–4.0
Deep posterior	Just posterior to the medial border of the tibia, directed posterolaterally and toward the posterior border of the fibula	2.0–4.0

TABLE 74-3 Needle Insertion Sites for the Compartments of the Forearm

Compartment	Needle insertion site	Insertion depth (cm)
Anterior	1.5 cm medial to a vertical line drawn through the middle of the forearm	1.0–2.0
Mobile wad	Perpendicular to the long axis of the radius and into the muscles lateral to the radius	1.0–1.5
Posterior	1 to 2 cm lateral to the posterior aspect of the ulna	1.0–2.0

well as in at least two other sites within the compartment. General anatomic landmarks for needle insertion into the various compartments of the lower leg and forearm are described in **Tables 74-2 & 74-3**, and graphically depicted in **Figure 74-3**. **The authors recommend using the highest measured intracompartmental pressure in making the decision for further intervention.**

TECHNIQUES

Several techniques for measuring compartmental pressures have been developed. Some use isolated intracompartmental pressure measurements while others monitor pressure continuously. Obtaining isolated intracompartmental pressure measurements is most important in the ED. Whitesides et al. described the needle manometer method utilizing a manual manometer and a saline–air meniscus in standard IV tubing connected to a 16 gauge needle.[22] Stryker (Stryker Instruments, Kalamazoo, MI) introduced an electronic system consisting of a reusable digital pressure monitor and a single-use measurement set with a needle, diaphragm chamber, and sterile saline flush.[23] More recently, a technique involving a 16 gauge angiocatheter or needle connected by arterial line tubing to a standard manometer has been described.[30] While all three of these methods will be discussed in this chapter, recent data suggest that the Stryker method and the arterial manometer method are significantly more accurate, are more convenient, and require only a small number of components readily available in most EDs than the needle manometer method.[31,32]

While each of these techniques may be performed with a standard straight needle, all are more accurate if used with a special side-ported needle or slit catheter, if available.[32] Similar measurement systems that introduce a wick or slit catheter into the tissue have been shown to be equally effective. For simplicity's sake, explanations of these techniques have been omitted, as they are rarely performed.

NEEDLE MANOMETER TECHNIQUE

Begin by setting up the system (**Figure 74-4A**). Attach the hub of a 20 mL syringe to the middle port of a three-way stopcock. Attach one end of the intravenous extension tubing to one of the ports of the stopcock. Attach an 18 gauge needle to the free end of the intravenous extension tubing. Insert a second 18 gauge needle into a container of sterile normal saline to release the vacuum. Insert the 18 gauge needle attached to the intravenous extension tubing into the normal saline so that the needle port is well immersed. Open

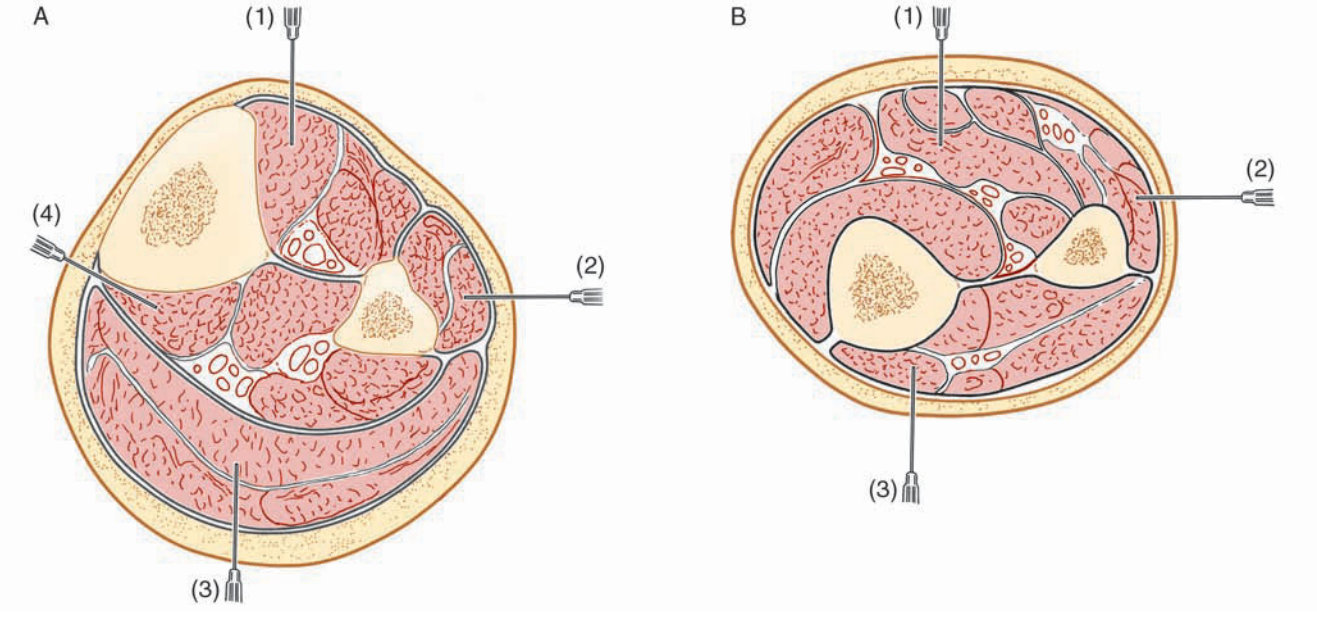


FIGURE 74-3. Needle insertion sites to measure intracompartmental pressures. **A.** The leg compartments: anterior (1), lateral (2), superficial posterior (3), and deep posterior (4). **B.** The forearm compartments: anterior (1), mobile wad (2), and posterior (3).

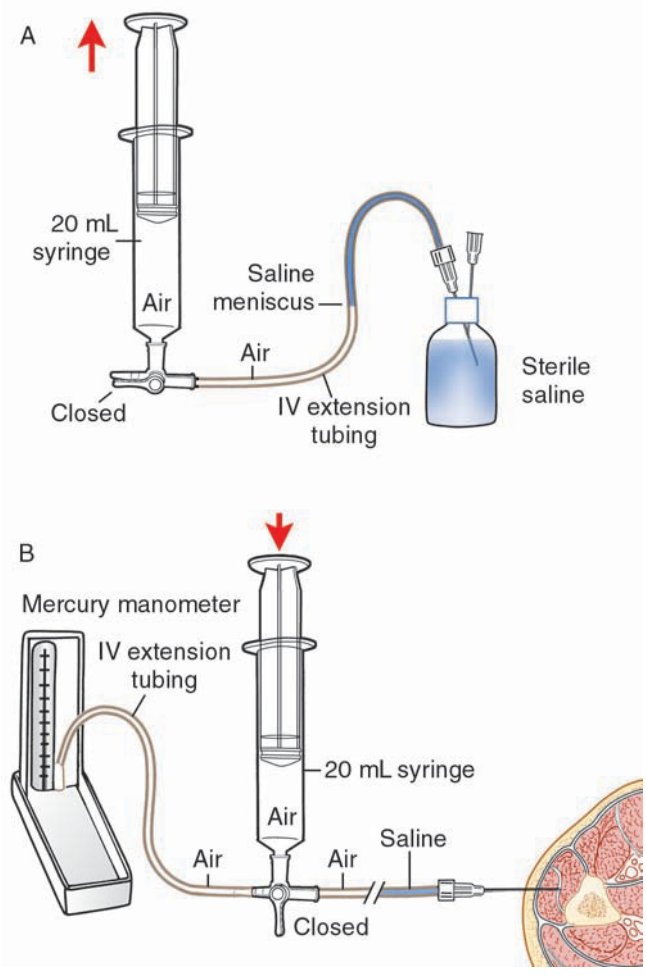


FIGURE 74-4. The needle manometer technique. **A.** The initial system setup. **B.** The final system should form a closed system of space from the manometer through the tissue space.

the stopcock ports only to the syringe and the extension tubing. Aspirate the saline to fill one-half of the length of the intravenous extension tubing. **Make sure that no bubbles enter the system.** Turn the stopcock valve so that the port to the saline is closed.

Attach a second piece of intravenous extension tubing to the remaining open port of the stopcock (**Figure 74-4B**). Attach the opposite end of this tubing to a manometer or arterial pressure monitor. Remove the 20 mL syringe from the system and aspirate 15 mL of air into the syringe. Reattach the syringe to the stopcock. Remove the extension tubing with the 18 gauge needle from the saline container.

Insert the 18 gauge needle into the affected muscle compartment (**Figure 74-4B**). Turn the stopcock valve so that all three ports are open. Position the intravenous extension tubing with the normal saline so that the meniscus of the saline–air interface is exactly level with the tip of the needle inserted into the patient's tissue. **The position of the saline–air interface in relation to the tip of the needle is important for an accurate intracompartmental pressure measurement.**

The saline–air interface will form a meniscus when the needle is in the patient. The meniscus will be convex-shaped away from the patient when the tissue pressure is greater than the pressure within the system (**Figure 74-5A**). **Depress the plunger of the syringe gradually and delicately to increase the pressure within the system.** The shape of the meniscus begins to flatten as the plunger is

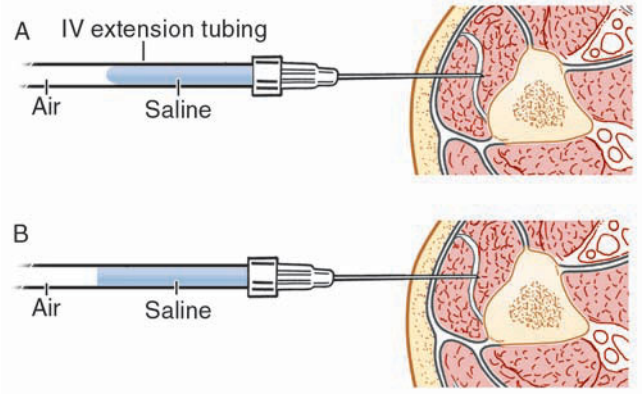


FIGURE 74-5. The air–saline interface. **A.** The air–saline meniscus will form a convex shape away from the patient when the tissue pressure is greater than the pressure of the system. **B.** The meniscus will flatten out when the pressure within the system equals that of the tissue.

depressed. **The point where the meniscus is flat and the saline column begins to move equals the pressure within the compartment (Figure 74-5B).** Note and document the pressure on the manometer.

It is important to equilibrate the system between measurements. With the needle still positioned in the tissue, pull back on the syringe plunger until the manometer reads 0 mmHg. Withdraw the needle from the tissue. This will prevent any saline from being deposited in the tissue. The same needle can then be reinserted in another location to obtain additional pressure measurements if sterile technique was used throughout the procedure.

The needle puncture sites will bleed. It is important to complete the procedure by properly dressing these puncture wounds. Apply gauze over the puncture sites and tape it in place.

STRYKER METHOD

The Stryker intracompartmental pressure monitor system is a self-contained device that is convenient, accurate, and relatively easy to use (**Figure 74-6**). The unit should be kept in a secure, yet easily accessible location. The pressure monitor is a battery operated, reusable unit with a digital display (**Figure 74-6A**). The quick pressure monitor pack is a disposable, single-patient-use kit that contains a needle, the diaphragm chamber, and a saline-filled syringe (**Figure 74-6B**).

Turn the pressure monitor unit on. The digital display should read 0 to 9 mmHg. The steps for setting up the system must be performed using sterile technique. Take the diaphragm chamber from the quick pressure monitor pack. This chamber ensures sterility between the system and the patient. Place the 18 gauge, 2.5 in side-ported needle firmly on the smaller tapered stem of the diaphragm chamber (**Figure 74-7A**). **This needle must remain sterile.** Uncap the 3 mL syringe filled with sterile normal saline and screw it onto the larger stem of the diaphragm chamber (**Figure 74-7A**). Open the clear plastic lid of the monitor unit. Place the needle–diaphragm chamber–syringe unit on the monitor such that the diaphragm chamber sits in the well (**Figure 74-7B**). Push down gently so that the diaphragm chamber is firmly and evenly positioned on the monitor. Close the cover so that a snap is heard at the latch site.

Hold the monitor unit so that the needle is at a 45° angle from the horizontal. Depress the plunger of the syringe to pass saline through the diaphragm chamber and needle until saline drips from the tip of the needle. This will remove any air within the system. Position the needle next to the skin at the angle needed for insertion.





FIGURE 74-6. The Stryker intracompartmental pressure monitor system. **A.** The Stryker pressure monitor unit. Note the power switch, zero button, and digital readout. Under the clear plastic cover, the round well will secure the disposable drum, while the syringe will clip into the plastic bracket at right. **B.** The quick pressure monitor pack contains (*from left to right*): an 18 gauge, 2.5 in side-ported needle, the diaphragm chamber, and a 3 mL syringe filled with sterile saline.

Press the "zero" button on the pressure monitor. The display should read "00" after a few seconds. **Insert the needle into the desired compartment at the same angle used during the zeroing process (Figure 74-8).** Slowly inject 0.3 mL of saline into the compartment. This volume of fluid is used to equilibrate with the interstitial fluids. Wait a few seconds as the system is measuring the compartmental pressure. The final compartmental pressure measurement will be displayed on the digital screen. Remove the needle from the patient.

Reset the system to zero before taking additional measurements. This is accomplished by positioning the needle at a new site and desired angle of insertion and pressing the zero button. This must be repeated between each measurement. Apply bandages over the skin puncture sites.

An optional indwelling slit catheter set is also available for use on the Stryker pressure monitor. This set substitutes a slit catheter, breakaway needle, and extension tubing for the side-ported needle. The slit catheter is intended to be left within the patient so that multiple sequential intracompartmental pressure measurements may be obtained. This is not intended for use in the ED.

ARTERIAL MANOMETER TECHNIQUE

The third method of checking compartment pressures in the ED requires only an 18 gauge needle or angiocatheter, arterial line tubing, and an arterial manometer set up as if for an arterial line. For a one-time reading, use a straight or side-port needle. If continuous

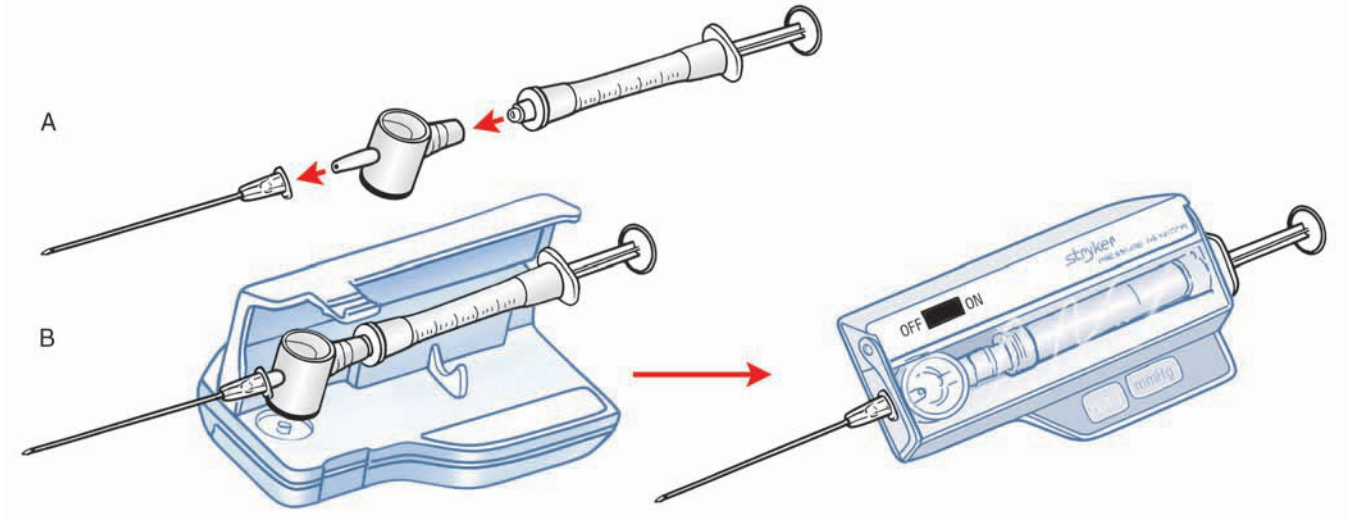


FIGURE 74-7. Assembly of the Stryker system. **A.** The contents of the quick pressure monitor pack are assembled. **B.** The assembled needle–diaphragm–syringe is placed onto the monitor unit.

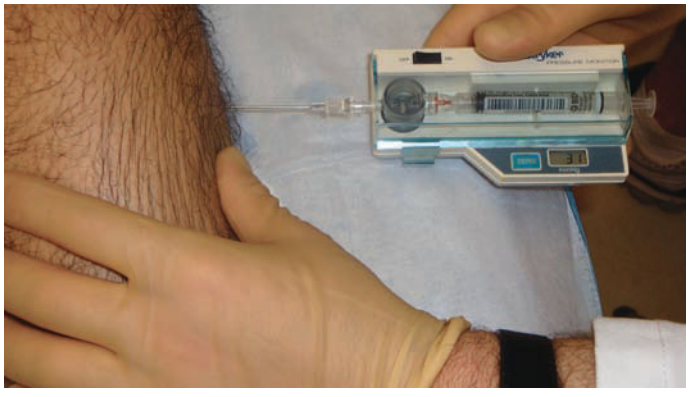


FIGURE 74-8. The needle is inserted into the desired compartment and the pressure measurement read on the digital display.

compartment pressure monitoring is preferable, use an 18-gauge angiocatheter. Attach the desired needle or angiocatheter to the end of the arterial line tubing, which leads to the prepared arterial manometer. Flush the entire line with sterile saline. Place the tip of the needle adjacent to the skin insertion site and zero the system. Insert the needle into the compartment and slowly infuse 0.3 mL of sterile saline to equilibrate the system with the interstitial pressure. The manometer will provide continuous real-time measurement of the compartment pressure for as long as the needle or angiocatheter remains in place.

AFTERCARE

Control any bleeding from the skin puncture sites with direct pressure. Apply gauze and tape dressings to all puncture sites. Perform and document a repeat neurovascular exam of the extremity distal to the procedure site.

COMPLICATIONS

There should be no complications for the patient if sterile technique is maintained throughout this procedure. Inserting a needle into a tissue compartment introduces the theoretical risk of infection or damage to the nerves or vessels. No study has shown this to be a significant complication.

A realistic complication of the procedure is obtaining erroneous values. The greatest risk to the patient is if an artificially low pressure is obtained and the needed fasciotomy is not performed. Although false high-pressure readings may also be obtained, the consequences of receiving an unnecessary fasciotomy are less disastrous.

It is important to understand how the mechanics of the needle-manometer system can alter the pressure readings. Injection of normal saline into the tissue will raise the pressure reading. The manometer reading will not accurately reflect the pressure of the compartment if the needle is inserted into a tendon rather than the muscle. A piece of tissue from the compartment can obstruct the needle and lead to erroneous pressure measurements. Failing to match up the saline–air meniscus with the level of the needle in the tissue can produce false pressure measurements as well.

One must take multiple pressure measurements around the injury site. To decide whether or not to perform a fasciotomy on an isolated pressure reading is to proceed without all the necessary data. It becomes difficult to simply observe the patient when they clinically present with increasing pain and features suggestive of a compartment syndrome when the compartmental pressure measurement is normal. Thus, multiple readings must be taken when suspicion is high and the compartment pressures are read as normal.

SUMMARY

A compartment syndrome is a well-documented phenomenon. The clinical presentation is variable and changes over time. It is a difficult clinical diagnosis that is critical for the EP to make in a timely fashion. While the most common sites are the lower leg and forearm, compartment syndrome can occur in any muscle compartment of the body. Determining the pressure within a compartment is a fundamental and essential tool to aid in this diagnosis. Many methods exist for the measurement of compartment pressures. Use of the traditional needle manometer system, the Stryker pressure monitor kit, and the arterial manometer are three established techniques that can easily be performed in the ED. These techniques represent the standard of practice in most EDs. Other methods using noninfusing catheter tips and emission tomography are under investigation as potentially noninvasive procedures.[25,26] Any concern for a compartment syndrome should be followed up with an emergent Orthopedic Surgeon or General Surgeon consultation in the ED, as continuous observation and repeated measurements are often indicated. Pressures over 30 mmHg or within 30 mmHg of the diastolic blood pressure warrant an emergent evaluation for a possible fasciotomy and limb salvage.

75 Fasciotomy

Justin Mazzillo, Sobia Ansari, and Eric F. Reichman

INTRODUCTION

A compartment syndrome is a serious and sometimes catastrophic entity that can lead to irreversible local and systemic damage.[1] It typically results from increased interstitial pressure in a closed and confined space that leads to inadequate perfusion and impaired function of the tissues contained within that space. Locally, a compartment syndrome may lead to loss of function, contractures, rhabdomyolysis, infection, and amputation. This can be followed by systemic complications such as renal failure, sepsis, and possibly death.[2] Common causes of a compartment syndrome include circumferential burns, constrictive dressings, crush injuries, electrical injuries, exercise, external compression of a limb, external trauma to the extremity, open or closed fractures, reperfusion after a vascular insult, snakebites, and tight fitting casts or splints (**Table 74-1**).[1–20]

The difficulty in diagnosing a compartment syndrome is that the physical examination is a poor indicator of the degree of microcirculatory compromise.[3] The diagnosis requires a high level of suspicion on the part of the Emergency Physician. Refer to Chapter 74 regarding the complete details of a compartment syndrome. **Maintaining a low threshold for performing a fasciotomy can be the safest course for the patient. The prognosis is more favorable if a fasciotomy is performed soon after the onset of symptoms.** If delayed, there may be little or no benefit to performing a fasciotomy.

ANATOMY AND PATHOPHYSIOLOGY

The anatomy of a compartment syndrome is variable, as it can occur in any enclosed muscle group. Any muscle tissue that is confined in space by fascia, skin, or any external forces (e.g., casting material) is a potential site for the development of a compartment syndrome.

The muscles, nerves, and vasculature within the affected muscle group are all potentially compromised by a prolonged ischemic state followed by swelling. A basic knowledge of the anatomy of commonly affected compartments is necessary to successfully and safely perform a fasciotomy.

The initial imbalance of a compartment syndrome occurs between the volume and pressure within the myofascial compartment. The arterial inflow and venous outflow diminish as either intracompartmental volume or pressure increases. The blood begins to be shunted via capillaries into the muscle tissue. This compensatory shunting of blood further disturbs the volume–pressure balance, resulting in impaired tissue oxygenation.

Skeletal muscles, major nerves, and major blood vessels of the extremities are contained within a noncompliant connective tissue membrane known as the investing or deep fascia. Connective tissue septa from the investing fascia to the bones of the extremities form compartments within the extremity. Each fascial compartment has a relatively constant range of pressure within it in which perfusion is maintained.[3] Under normal circumstances, the compartment pressure is ≤10 to 12 mmHg. Any of the previously mentioned insults may set off a cascade of events. This includes edema, hemorrhage, and/or external compression. The pressure within the compartment begins to rise. A critical pressure is reached within the compartment and perfusion is impaired. This results in altered metabolic processes, muscle cell death, cell wall dysfunction, and vascular compromise. This eventually leads to extravasation of intracellular contents and edema within the enclosed space, further raising compartment pressures.[4]

Increased intracompartmental pressure, from edema or hemorrhage within the compartment or from external compression, affects perfusion. Compartmental perfusion is a dynamic process, which is maintained by arterial blood pressure and limited by the absolute compartment pressure. Elevated compartmental pressure leads to venous outflow obstruction and eventually tissue ischemia.

Skeletal muscle and peripheral nerves can survive under ischemic conditions for up to 4 hours before irreversible damage begins to occur. At 6 hours of ischemia, muscle and nerve injury may still be reversible. Ischemia for greater than 8 hours, however, will lead to irreversible damage to muscles and nerves.[5] The resulting ischemic contractures of the extremities were described over 100 years ago by Richard Von Volkmann and are now referred to as "Volkmann's ischemic contracture." Treatment of a compartment syndrome with a fasciotomy was first suggested in 1906 by Bardenheuer.[6]

The pertinent anatomy for each fasciotomy described is included in the respective techniques section. Refer to Chapter 74 for the details of the anatomy, pathophysiology, evaluation, and diagnosis of a compartment syndrome.

Clinical signs of a compartment syndrome consist of the 5 "Ps" for any region at risk. These include pain out of proportion to exam, paresthesias, pallor, pulselessness, and paralysis. Some may choose to include poikilothermia as the sixth "P."[4] These clinical findings are generally late findings and may be completely absent early in the course of the disease process. Measure the compartment pressures when any signs or a clinical suspicion exists for a compartment syndrome. Refer to chapter 74 for the complete details of compartment pressure measurement.

INDICATIONS

Classically, it has been taught that a fascial compartment with an absolute pressure of greater than 30 mmHg will require a fasciotomy. Other factors besides the absolute compartmental pressure contribute to tissue perfusion and should be taken into account when deciding to perform a fasciotomy. Hypertension may be protective of perfusion whereas hypotension may further compromise perfusion.[1] More recently, a "delta *P*" or ΔP of less than 30 mmHg has been suggested as a better indication for performing a fasciotomy.[3] The ΔP is calculated as the difference between the diastolic blood pressure and the absolute or measured compartment pressure.

Maintaining a low threshold for performing a fasciotomy can be the safest course in patients who are at risk of extremity ischemia.[7] Any patient with the appropriate history and any of the clinical signs of a compartment syndrome should be considered a candidate for a fasciotomy. Strongly consider performing a fasciotomy if the patient has a fascial compartment with a $\Delta P < 30$ mmHg. An absolute compartment pressure ≥30 mmHg, or ≥20 mmHg if the patient is hypotensive, combined with any clinical signs of a compartment syndrome is an indication for a fasciotomy. The prognosis is favorable if the fasciotomy is performed within 30 hours of symptom onset.[8] If delayed longer, there is usually little or no benefit. This is particularly true if the fasciotomy is performed greater than 2 days after the onset of symptoms.

CONTRAINDICATIONS

A fasciotomy in the setting of a true compartment syndrome has few absolute contraindications. Any life-threatening conditions must first be addressed. If performed beyond the third or fourth day after symptom onset, there is a high incidence of severe infections.[8] A fasciotomy should not be performed if the Emergency Physician is not familiar with the local anatomy or the technique.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Face mask and cap
- Sterile gloves and gown
- Sterile drapes or towels
- Equipment for compartment pressure measurement (refer to Chapter 74)
- 4 × 4 gauze squares
- # 10 scalpel blade on a handle
- Tissue forceps
- Metzenbaum scissors
- Curved forceps
- Surgical retractors
- Kerlix dressings
- Splint material

PATIENT PREPARATION

Perform and document a thorough neurological and vascular examination of the affected extremity.[1] Remove any constrictive dressings, casts, and/or splints that may be contributing to the increased compartment pressures. Place the patient supine on the gurney so that the limb at risk is at heart level. If time is permissible and a Surgeon is available, it may be more appropriate to perform the fasciotomy in the Operating Room by an experienced Surgeon. This is often not possible and the fasciotomy must be performed in the Emergency Department.

Inform the patient and/or their representative of the risks, benefits, complications, and aftercare associated with a fasciotomy. The procedure must be performed using strict aseptic technique.

The Emergency Physician and any assistants must be wearing sterile gloves, a sterile gown, a face mask, and a cap. Clean the extremity of any blood, dirt, and debris. Apply povidone iodine or chlorhexidine solution to the extremity and allow it to dry. Apply sterile drapes or towels to isolate the extremity and form a sterile field. Collect and place all required supplies on a bedside table covered with a sterile drape. Using a sterile marking pen, draw the incision lines onto the skin prior to making any incisions.

A fasciotomy is a painful procedure. If the patient is conscious, some form of analgesia is required. The infiltration of local anesthetic solution provides appropriate analgesia. Ensure that the toxic dose of the selected local anesthetic solution is not exceeded (Chapter 123). Alternatives include a regional nerve block (Chapter 126) or procedural sedation (Chapter 129).

TECHNIQUES

THE ARM

The arm consists of three compartments (**Table 75-1 & Figure 75-1**).[9] The anterior compartment contains the biceps, brachialis, and coracobrachialis muscles. The posterior compartment contains the triceps muscle. The proximal anterolateral arm contains the deltoid compartment.

A fasciotomy of the arm requires two longitudinal incisions. Decompress the anterior compartment with a longitudinal incision over the entire anterior surface of the arm overlying the biceps muscle (**Figures 75-1 & 75-2A**). Decompress the posterior compartment with a longitudinal incision on the posterior surface of the arm overlying the triceps muscle (**Figures 75-1 & 75-2B**). Use a #10 scalpel blade to cut through the skin and subcutaneous tissues down to the level of the investing fascia. Carefully cut the fascia parallel to the skin incision with a scissors. The fascial incision should be the same length of the skin incision. **Use caution so as not to cut the muscle itself.**

A fasciotomy of the deltoid compartment muscle may occasionally be indicated. The deltoid muscle has three heads that are separated by septae. Therefore, it is often necessary to decompress each muscle belly.[10] Begin the skin incision over the anterior origin of the deltoid muscle (**Figure 75-3**). Extend the incision superiorly and laterally, going just lateral to the acromion process. Continue the incision posteriorly along the origins of the posterior deltoid muscle. Use a #10 scalpel blade to cut through the skin and subcutaneous tissues down to the level of the investing fascia. **The cutaneous branch of the axillary nerve becomes superficial inferior and posterior to the acromion and continues anteriorly over the lateral deltoid muscle. It should not be cut when performing a fasciotomy.** It may be necessary to decompress each fascial compartment. Carefully cut open the fascia of the anterior deltoid muscle with a scissors. **Use caution so as not to cut the muscle itself.** Measure the compartment pressure in the remaining two compartments. Sometimes, decompressing one compartment allows the remaining compartment(s) to spontaneously decompress. If elevated, incise the fascia of the second compartment. Measure the pressure of the remaining compartment. If elevated, incise the fascia of that compartment.

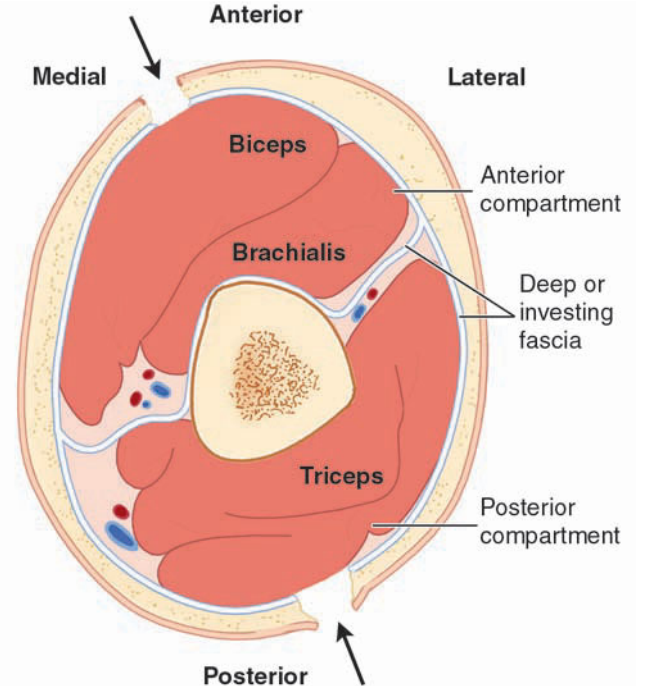


FIGURE 75-1. The compartments of the arm. Fasciotomy incisions have been made (arrows) by cutting through the skin, subcutaneous tissues, and deep or investing fascia.

TABLE 75-1 The Compartments of the Arm and Their Contents

Compartment	Contents
Anterior	Biceps muscle
	Brachialis muscle
	Coracobrachialis muscle
	Brachial artery
	Median Nerve
	Ulnar Nerve
	Musculocutaneous nerve
	Lateral cutaneous nerve
	Antebrachial nerve
	Radial nerve
Posterior	Triceps muscle
	Radial nerve
	Ulnar nerve
Deltoid	Anterior deltoid muscle
	Lateral deltoid muscle
	Posterior deltoid muscle
	Axillary nerve

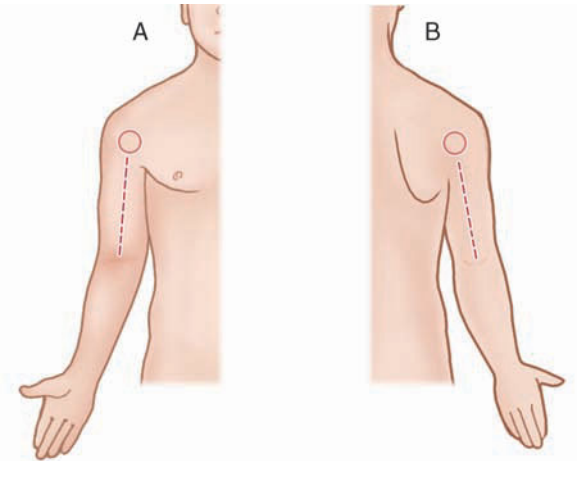


FIGURE 75-2. Fasciotomy incisions of the arm. **A.** Anterior compartment. **B.** Posterior compartment.

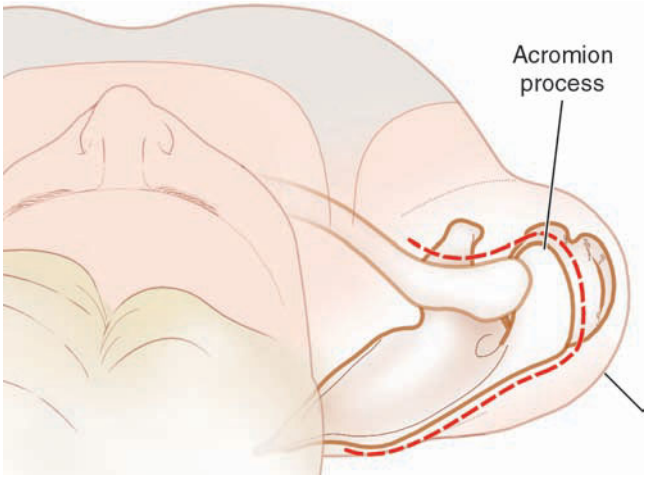


FIGURE 75-3. Fasciotomy incision for the deltoid compartment.

TABLE 75-2 The Compartments of the Forearm and Their Contents

Compartment	Contents
Lateral (mobile wad)	Brachioradialis muscle
	Extensor carpi radialis longus muscle
	Extensor carpi radialis brevis muscle
Dorsal	Extensor carpi ulnaris muscle
	Extensor pollicis longus muscle
	Abductor pollicis longus muscle
	Extensor pollicis brevis muscle
	Extensor digitorum communis muscle
	Posterior interosseous artery
	Interosseous perforators from the anterior interosseous artery
	Posterior interosseous nerve
Volar	Flexor pollicis longus muscle
	Flexor carpi ulnaris muscle
	Flexor carpi radialis longus muscle
	Flexor carpi radialis brevis muscle
	Palmaris longus muscle
	Flexor digitorum superficialis muscle
	Flexor digitorum profundus muscle
	Pronator teres muscle
	Pronator quadratus muscle
	Radial artery
	Ulnar artery
	Anterior interosseous arteries
	Median nerve
	Ulnar nerve
Carpal tunnel	Extrinsic flexor tendons
	Median nerve

THE FOREARM

The forearm is one of the most common regions afflicted by a compartment syndrome.[1,11,12] The forearm consists of three compartments that are interconnected at various levels. This interconnection is significant because release of the pressure in one compartment will reduce some of the pressure in the adjacent compartments. **The volar compartment is most at risk for development of a compartment syndrome in traumatic injuries of the forearm.**[11] This is followed by the dorsal compartment then the lateral compartment. The lateral compartment is the easiest compartment to decompress because it is located superficially.[5]

The forearm includes the volar, dorsal, and mobile wad compartments (**Figure 75-4**). The contents of each forearm compartment are listed in **Table 75-2**. The volar compartment contains all of the hand and forearm flexor muscles, the median and ulnar nerves, and the radial, ulnar, and common interosseous arteries. The mobile wad contains the brachioradialis, the extensor carpi radialis brevis, and the extensor carpi radialis longus muscles. No major arteries or nerves are contained within this compartment. The radial artery and a branch of the radial nerve may sometimes lie between the mobile wad and the volar compartment. The dorsal compartment contains the hand and forearm extensor muscles, the posterior interosseous artery, and the posterior interosseous nerve.

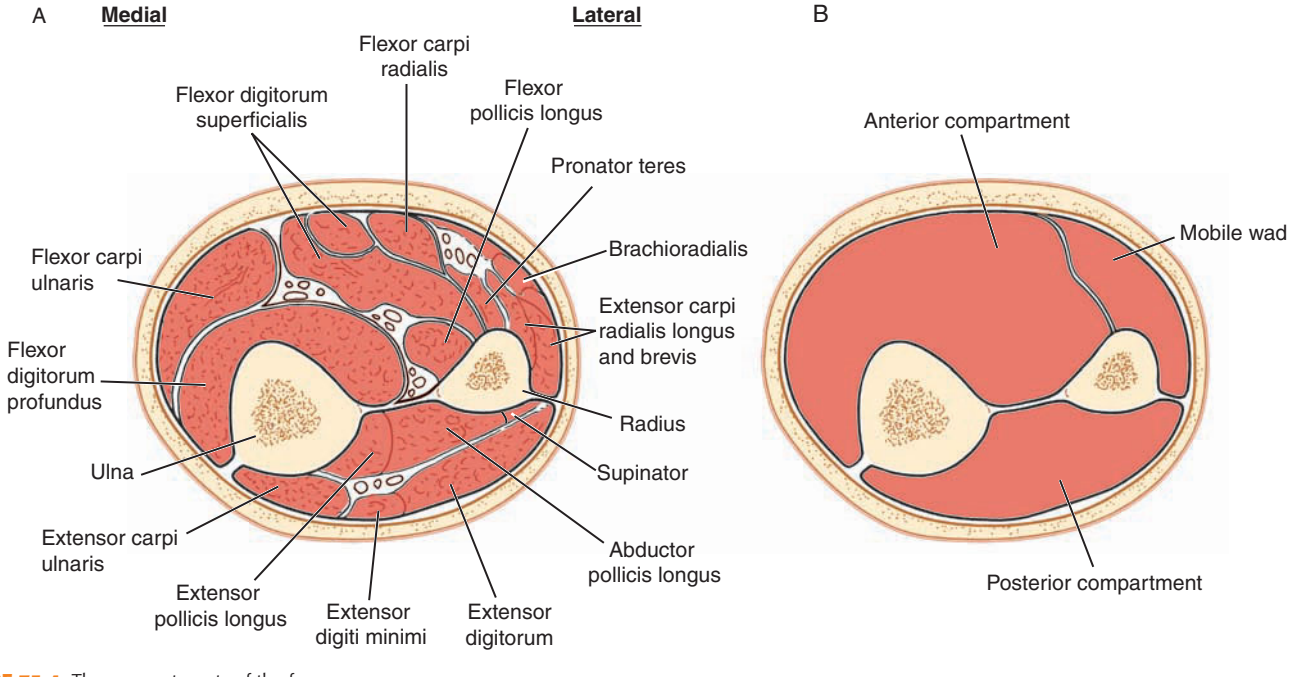


FIGURE 75-4. The compartments of the forearm.

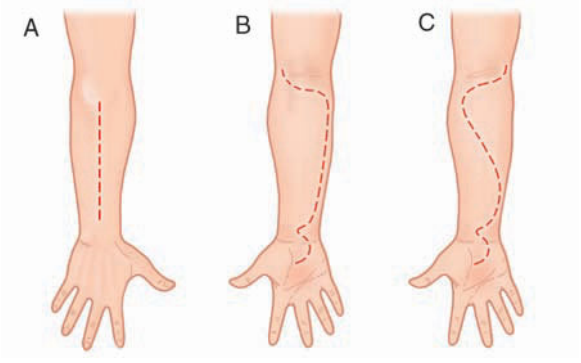


FIGURE 75-5. Fasciotomy incisions for the forearm. **A.** The dorsal incision. **B.** The anterior volar-ulnar incision. **C.** The volar curvilinear incision.

The volar and dorsal compartments can be further subdivided into superficial and deep muscles. Evaluation of the deep muscles becomes important when these muscles are preferentially injured. This includes electrical injury as the bone transmits thermal injury to adjacent muscles, crush injuries, sepsis, and prolonged external pressure on the forearm.

Decompression of the volar compartment can lead to the simultaneous decompression of the other compartments. Thus, a volar fasciotomy is generally performed first.[11] There are multiple approaches to making the incision for a forearm fasciotomy (**Figure 75-5**). This section chapter will describe the volar-ulnar incision for the anterior fasciotomy (**Figure 75-5B**). Some authors feel that this incision is associated with the least amount of iatrogenic injury.[1,12,13]

Place the patient supine with their arm supinated on a bedside table to decompress the volar compartment. Begin the incision proximally and laterally to the antecubital fossa. Extend the incision transversely and distally across the antecubital fossa until it reaches the anteromedial aspect of the antecubital fossa. Continue the incision distally on the anteromedial surface of the forearm toward the wrist. Just proximal to the wrist, extend the incision in an S-shape toward the radial aspect of the forearm while remaining just proximal to the wrist. **Do not extend the incision as lateral as the radial artery pulse.** Continue the incision back medially to the midline of the wrist. Continue down the midline of the wrist and make a turn along the thenar crease. **Be sure to incise deep enough to include the superficial fascia along the length of the entire forearm without cutting into the muscles or tendons.**

Identify the median nerve proximally. Release the bicipital aponeurosis at the level of the antecubital fossa and overlying the median nerve. Retract the flexor carpi ulnaris muscle medially and the flexor digitorum superficialis muscle laterally. Follow the median nerve all the way to the carpal tunnel. Decompress the median nerve at the carpal tunnel. **Be careful not to injure the ulnar artery, ulnar nerve, and the palmar cutaneous branch of the median nerve.** Incise the superficial palmar fascia in the midline followed by incising the transverse carpal ligament in the midline.

At this point, the superficial forearm contents are completely open and the deep contents of the volar compartment are exposed. Inspect the flexor digitorum profundus, flexor pollicis longus, and pronator quadratus muscles. Using aseptic technique, measure the pressures within the deep muscles to determine whether the fascia covering these muscles needs to be incised. If the muscle pressures are greater than 15 to 20 mmHg, incise the deep fascial coverings.

The major disadvantage to the volar-ulnar incision is that the mobile wad is not easily accessible via this incision. If the mobile wad is at risk, it may be reached through the dorsal incision (**Figure 75-5A**) as described below. It may also be reached through a different volar approach such as the volar-curvilinear incision (**Figure 75-5C**).

If a fasciotomy is indicated for the dorsal compartment, place the patient prone if not contraindicated and their arm extended on a bedside table. If the patient is supine, completely flex the supinated arm so that the dorsal surface is exposed. Make the incision along a line between the lateral epicondyle of the humerus and the distal radioulnar joint (**Figure 75-5A**). Be sure to incise the fascia along the entire length of the incision. **It is important to avoid incising too deep at the wrist and cutting the extensor retinaculum.** If the skin is adequately undermined, the mobile wad will be accessible via this approach.

Although the carpal tunnel does not contain muscle bellies and is thus not a true compartment, it can achieve acute compartment syndrome physiology.[10] Some authors recommend routinely decompressing the carpal tunnel during a forearm fasciotomy while others maintain that doing so is of limited benefit.[7,14] This decision is left to the Physician performing the fasciotomy. Many important structures run through the carpal tunnel including the median nerve. Structures within the carpal tunnel become compromised at pressures greater than 40 mmHg. The signs and symptoms will be similar to a chronic carpal tunnel syndrome, but more severe.

A carpal tunnel release can be performed as part of the forearm fasciotomy as described above or as an isolated procedure. To perform an isolated carpal tunnel release, begin the skin incision on the proximal portion of the hand between the thenar and hypothenar creases.[10,14] Extend the incision proximally toward the flexor crease of the wrist. Make a slight ulnar deviation of the incision so that the flexor crease is not crossed at a 90° angle. This will prevent injury to the palmar branch of the medial nerve as it courses between the palmaris longus and the flexor carpi radialis tendons. Reflect the skin edges to identify the superficial palmar fascia and the transverse carpal ligament. Make a longitudinal midline incision though the superficial palmar fascia and the transverse carpal ligament.

THE HAND

There are 11 compartments in the hand. This includes the midpalm, hypothenar, thenar, adductor pollicis, four dorsal interosseous, and three palmar or volar interosseous compartments (**Figure 75-6 & Table 75-3**).[10] Each hand compartment is completely isolated from

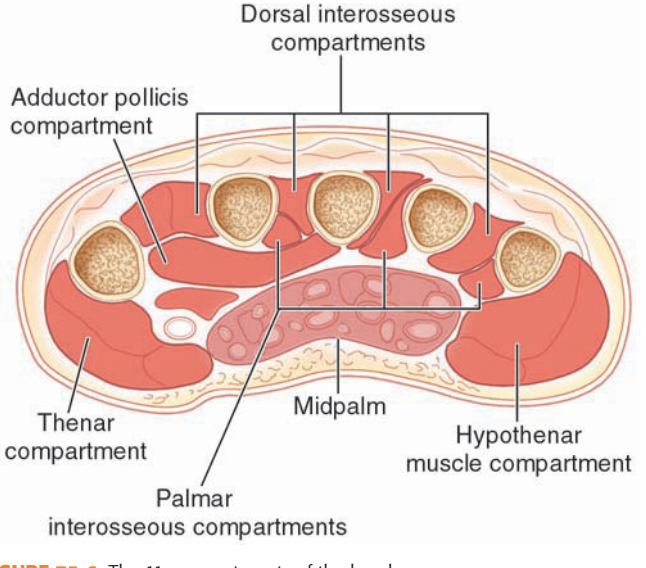


FIGURE 75-6. The 11 compartments of the hand.

TABLE 75-3 The Compartments of the Hand and Their Contents

Compartment	Contents
Midpalm	Extrinsic flexor tendons
	Lumbrical muscles
	Superficial palmar vascular arches
	Deep palmar arches
	Common digital arteries
	Common digital nerves
	Proper digital nerves
Thenar	Abductor pollicis brevis muscle
	Flexor pollicis brevis muscle
	Opponens pollicis muscle
Hypothenar	Abductor digiti minimi muscle
	Flexor digiti minimi muscle
	Opponens digiti minimi muscle
Dorsal interossei	Dorsal interossei muscles
Volar interossei	Volar interossei muscles
Adductor pollicis	Adductor pollicis muscle

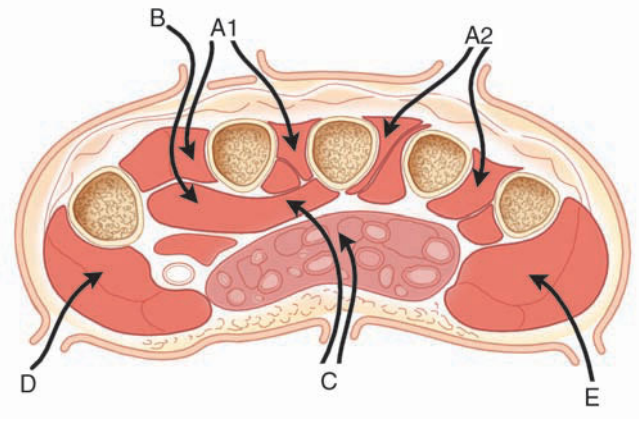


FIGURE 75-7. Fasciotomy incisions for the hand. **A.** Dorsal and palmar interosseous compartments. **B.** The adductor pollicis compartment. **C.** The midpalm compartment. **D.** The thenar compartment. **E.** The hypothenar compartment.

the others. Decompression or release of one compartment will not help to decompress any of the others. The pressures required to cause an acute compartment syndrome in a hand compartment may be as low as 15 to 20 mmHg.

Decompress the dorsal interosseous, palmar interosseous, and adductor compartments through dorsal incisions (**Figure 75-7**). Decompress the first and second dorsal interosseous compartments with a 3 to 4 cm long incision over the second metacarpal (**Figure 75-7A(1)**). Extend the incision into the fascia on both sides of the metacarpal to access the compartments. Continue deeper, using gentle blunt dissection, to access the adductor compartment on the radial aspect and the first palmar interosseous compartment on the ulnar aspect (**Figure 75-7B**). Decompress the third and fourth dorsal interosseous compartments with a 3 to 4 cm long incision over the fourth metacarpal (**Figure 75-7A(2)**). Incise the fascia on both sides of the metacarpal to access the compartments. Use gentle blunt dissection to access the second palmar interosseous compartment on the radial aspect and the third palmar interosseous compartment on the ulnar aspect.

To perform a fasciotomy of the thenar compartment, make a 3 to 4 cm long longitudinal skin incision over the thenar muscles on the lateral aspect of the hand, just volar to the first metacarpal (**Figures 75-7D & 75-8**). Continue the incision through the subcutaneous tissues until the thenar muscle fascia is visible. Carefully incise the fascia with a scissors. **Be careful to not cut the underlying muscle.**

To access the hypothenar compartment, make a 3 to 4 cm long longitudinal incision along the ulnar aspect of the fifth metacarpal over the hypothenar muscles (**Figures 75-7E & 75-8**). Continue the incision through the subcutaneous tissues until the hypothenar muscle fascia is visible. Carefully incise the fascia with a scissors. **Be careful to not cut the underlying muscle.**

The midpalm compartment of the hand is located between the thenar and hypothenar compartments (**Figure 75-6**). Make a 3 to 4 cm long longitudinal incision in the middle of the hand, between the thenar and hypothenar muscles (**Figure 75-7C**). If a fasciotomy of the forearm or carpal tunnel has already been performed, that incision can be extended distally to gain access to the fascia of the midpalm compartment. Continue the incision through the subcutaneous tissues until the fascia is visible. Carefully incise the fascia with a scissors. **Be careful to not cut the underlying muscle.**

THE DIGITS

The digits do not contain muscle bellies or true fascial compartments (**Table 75-4 & Figure 75-8**). The ligaments and restrictive skin create a contained compartment that can exhibit large pressure

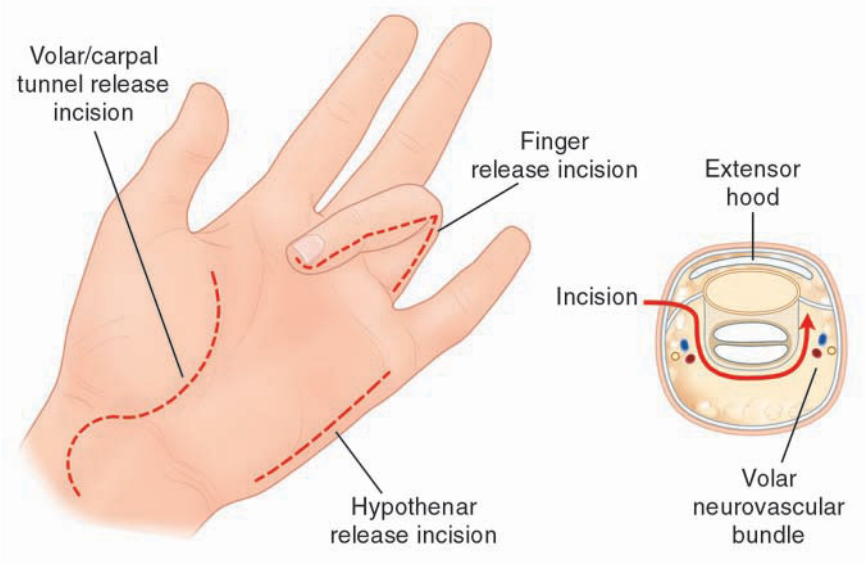


FIGURE 75-8. Fasciotomy incisions for the hand and fingers.

TABLE 75-4 The Compartments of the Digits and Their Contents

Compartment	Contents
Digits	Common palmar digital arteries Proper palmar digital arteries Proper palmar digital nerves Tendons Ligaments

increases, thus resulting in a compartment syndrome.[10] Cleland's and Grayson's ligaments are constrictive ligaments that encircle the finger and overlie the neurovascular bundles (**Figure 75-9**). Measurement of pressures in these "pseudocompartments" is very difficult. The indications for decompression are based more on clinical findings and suspicion. The fingers and toes have very similar anatomy and are managed in the same manner.

A fasciotomy of the digit is performed using a single midaxial longitudinal incision along the length of the digit. Make the incision along the ulnar aspect of the index, long, and ring fingers and along the radial aspect of the thumb and small fingers (**Figure 75-8**). **Be careful to avoid injuring the underlying neurovascular bundle.** Identify the neurovascular bundle and release any constrictive fascial bands from Cleland's or Grayson's ligaments (**Figure 75-9**). Continue dissecting along the palmar aspect of the flexor tendon sheath and release any vertical bands of connective tissue. If severe swelling is present with dysfunction of both the ulnar and radial neurovascular bundles, a second longitudinal incision can be placed on the opposite side of the digit to decompress the underlying neurovascular bundle.

THE THIGH

A compartment syndrome of the thigh is not common, despite how commonly femur fractures occur.[15] The pressure at which a compartment syndrome of the thigh develops is not known. A case report of three patients who developed a thigh compartment syndrome in association with a femur fracture noted that two of the patients had significant arterial bleeding into the thigh and the third had prolonged extrinsic compression of the leg. The Emergency Physician will need to rely on clinical signs and symptoms, measured pressures, as well as the mechanism of injury to make the diagnosis of a thigh compartment syndrome.

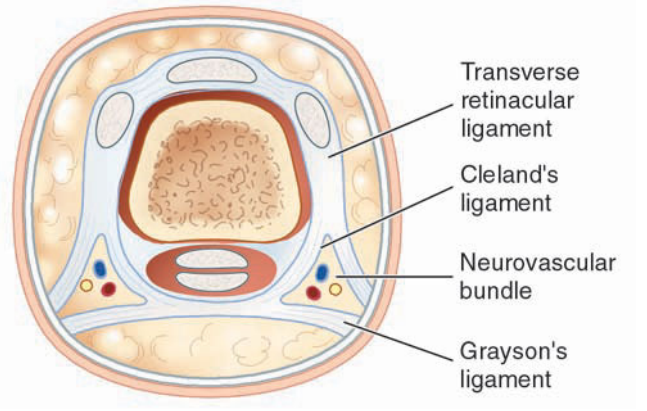


FIGURE 75-9. Cross section through a digit.

The thigh contains three compartments. These are the anterior, medial, and posterior compartments (**Figure 75-10**). They are separated from each other by intermuscular septa. The lateral intermuscular septum is the thickest of the three and separates the anterior and posterior compartments. The contents of the compartments are listed in **Table 75-5**.

Place the patient supine with their foot pointing upward. Expose the thigh from the iliac crest to the lateral epicondyle.[8] Begin the incision just distal to the intertrochanteric line and extend it to the lateral epicondyle (**Figure 75-11A**). Expose the iliotibial band, a thickening of the investing fascia, by subcutaneous dissection. Release the anterior compartment of the thigh by making an incision in the iliotibial band that parallels the skin incision. Retract the vastus lateralis muscle medially to expose the lateral intermuscular septum (**Figure 75-11B**). Make a 1.5 cm incision in the lateral intermuscular septum using Metzenbaum scissors. Extend the incision proximally and distally to decompress the posterior compartment. Once the anterior and posterior compartments have been decompressed, determine the pressure in the medial/adductor compartment. If the pressure is elevated, make a separate medial incision to release this compartment.

THE LEG

The leg is the most common location for a compartment syndrome.[1,6] A tibial fracture is the most common injury leading to a

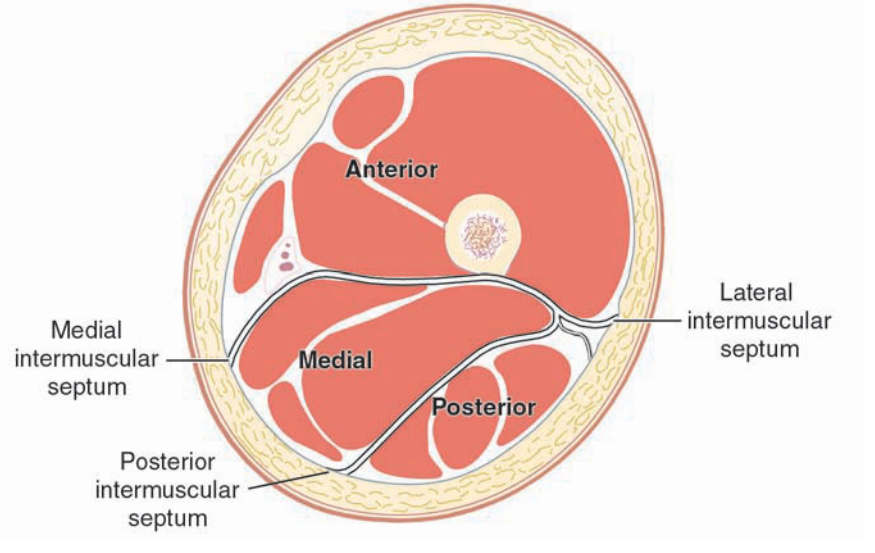


FIGURE 75-10. The compartments of the thigh.

TABLE 75-5 The Compartments of the Thigh and Their Contents

Compartment	Contents
Anterior	Sartorius muscle
	Iliacus muscle
	Pectineus muscle
	Psoas muscle
	Quadriceps femoris muscle
	Femoral artery and vein
	Femoral nerve
	Lateral femoral cutaneous nerves
Medial	Adductor longus muscle
	Adductor magnus muscle
	Adductor brevis muscle
	Obturator externus muscle
	Gracilis muscle
	Obturator artery and veins
	Profundus femoris artery and veins
	Obturator nerve
Posterior	Semitendinosus muscle
	Semimembranosus muscle
	Biceps femoris muscle
	Adductor magnus muscle
	Profundus femoris artery
	Sciatic nerve
	Posterior femoral cutaneous nerves

leg compartment syndrome.[17] The lower leg consists of four distinct muscle compartments: anterior, lateral, deep posterior, and superficial posterior (**Figure 75-12**).[8,16] A detailed list of the contents of each compartment is noted in **Table 75-6**.

The anterior compartment contains the four extensor muscles of the leg. These muscles function together to dorsiflex the foot. The deep peroneal nerve travels through this compartment to innervate the extensors and provide sensory innervation to the web space between the first and second toes. The anterior tibial artery travels through this compartment and provides bloodflow to its contents.

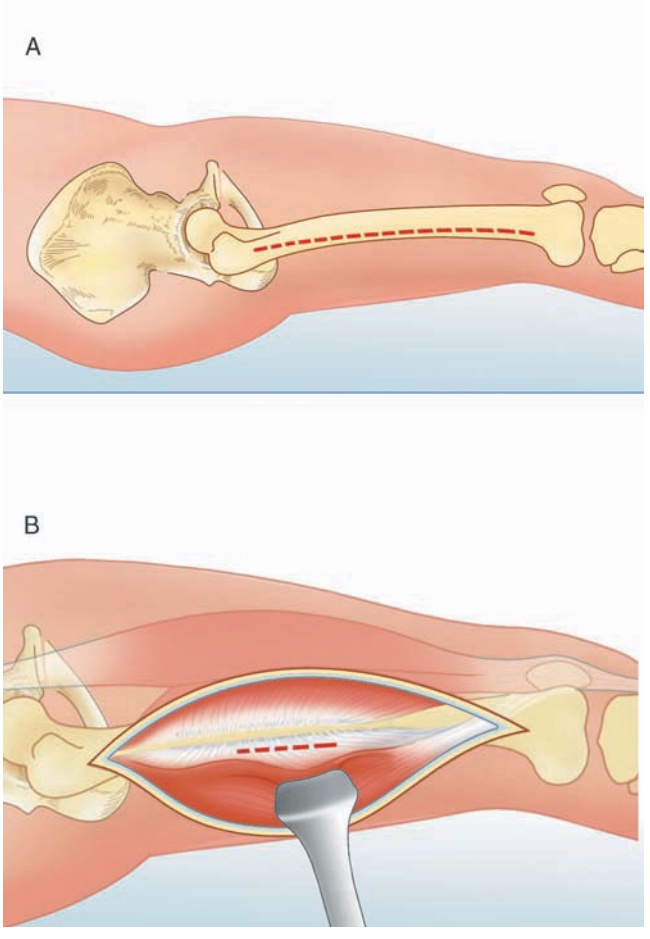


FIGURE 75-11. Fasciotomy of the thigh. **A.** The fasciotomy incision. **B.** The vastus lateralis muscle is retracted to expose the lateral intermuscular septum.

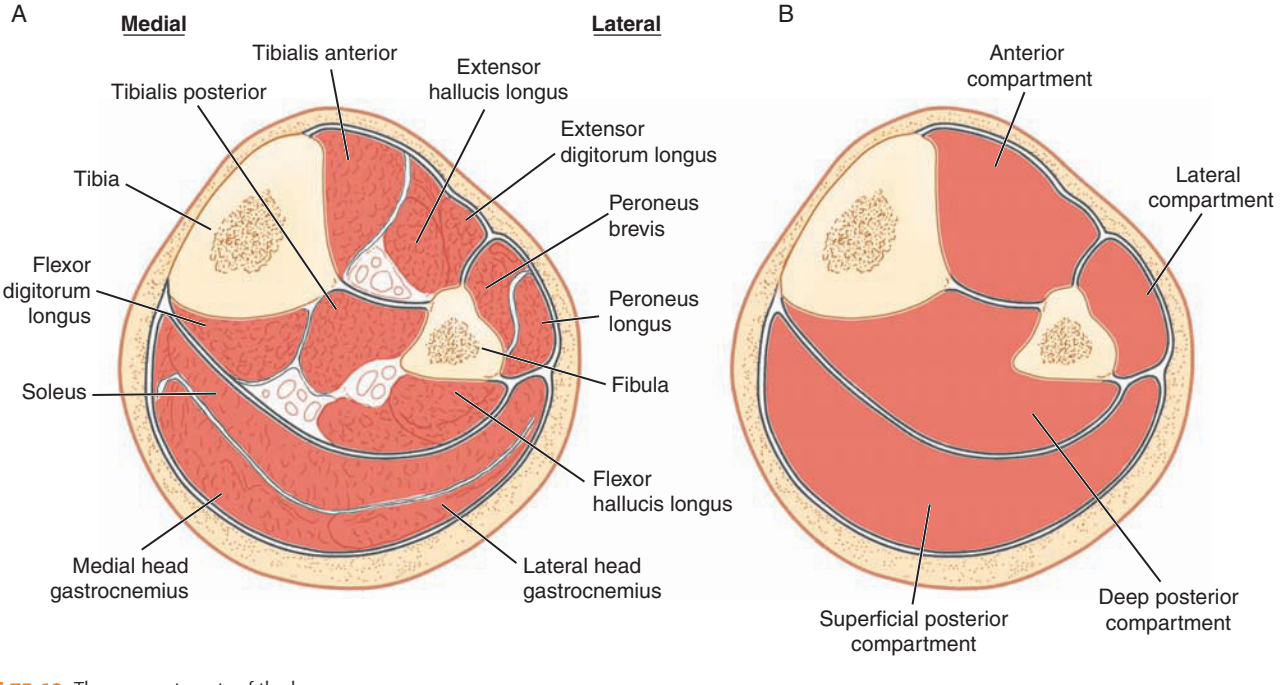


FIGURE 75-12. The compartments of the leg.

TABLE 75-6 The Compartments of the Leg and Their Contents

Compartment	Contents
Anterior	Tibialis anterior muscle
	Extensor hallucis longus muscle
	Extensor digitorum communis muscle
	Anterior tibial artery and vein
	Deep peroneal nerve
Lateral	Peroneus longus muscle
	Peroneus brevis muscle
	Superficial peroneal nerve
Superficial posterior	Gastrocnemius muscle
	Soleus muscle
	Plantaris muscle
	Sural nerve
Deep posterior	Tibialis posterior muscle
	Flexor hallucis longus muscle
	Flexor digitorum longus muscle
	Posterior tibial artery and vein
	Peroneal artery and vein
	Tibial nerve

The lateral compartment contains the peroneus longus and brevis muscles. Their chief function is to evert the foot, with some consequent abduction and plantarflexion of the foot. The major nerve in the lateral compartment is the superficial peroneal nerve to supply motor innervation to the compartment muscles and sensory innervation to the lower leg and dorsum of the foot.

A fascial layer divides the posterior muscle group into superficial and deep compartments. The superficial posterior compartment contains the muscles of plantarflexion (gastrocnemius, soleus, and plantaris tendons). No major nerves or blood vessels travel in the superficial compartment. The deep posterior compartment contains the four deep flexor muscles (flexor digitorum longus, flexor hallucis longus, tibialis posterior, and popliteus). This group of muscles contributes to inverting and adducting the foot in addition to flexing the toes and foot. The primary sensory innervation is from the tibial nerve, which courses through the deep posterior compartment. The tibial nerve supplies most of the muscles of the posterior compartment before dividing into several branches that provide sensory innervation to the sole of the foot. The posterior tibial artery and the peroneal artery are also contained within this compartment.

Although any of these compartments can suffer from ischemia, **the deep posterior compartment and the anterior compartment have the highest incidence of developing a compartment syndrome.**[21] It is difficult to simply observe the patient in the face of a normal compartmental pressure when they clinically present with increasing pain and the features suggestive of a compartment syndrome. **Thus, multiple compartmental syndrome readings must be taken when the suspicion is high and the compartmental pressures are normal.**

If the physical examination of the leg reveals clinical concern for a compartment syndrome of only one compartment, then a single-incision fasciotomy can be performed. However, in cases of prolonged limb compression or severe trauma, a double-incision fasciotomy for decompression of all compartments will be required.[16,18]

Perform an anterolateral incision to decompress the anterior and lateral compartments. Make a 20 to 25 cm long longitudinal incision between the fibular shaft and tibial crest (**Figure 75-13A**).[1] The incision will thus be located over the anterior intermuscular septum, allowing access to both the anterior and lateral compartments (**Figure 75-13C**). Undermine the skin edges to expose more of the fascial covering. Make a small transverse incision through the fascia at the midpoint of the incision to expose the intermuscular septum. **Be cautious not to cut the superficial peroneal nerve that lies just lateral to the septum.** Instruct an assistant to retract the skin edges. Open the anterior compartment using Metzenbaum scissors. Extend the facial incision longitudinally, both distally and proximally, the length of the skin incision. Next decompress the lateral compartment by incising the fascia longitudinally in a similar manner.

Perform a posteromedial incision to decompress the posterior compartments. The two posterior compartments can be decompressed with one skin incision (**Figure 75-13C**). Make a 20 to 25 cm long longitudinal incision 2 to 3 cm posterior to the posterior tibial margin (**Figure 75-13B**). Undermine the skin and subcutaneous

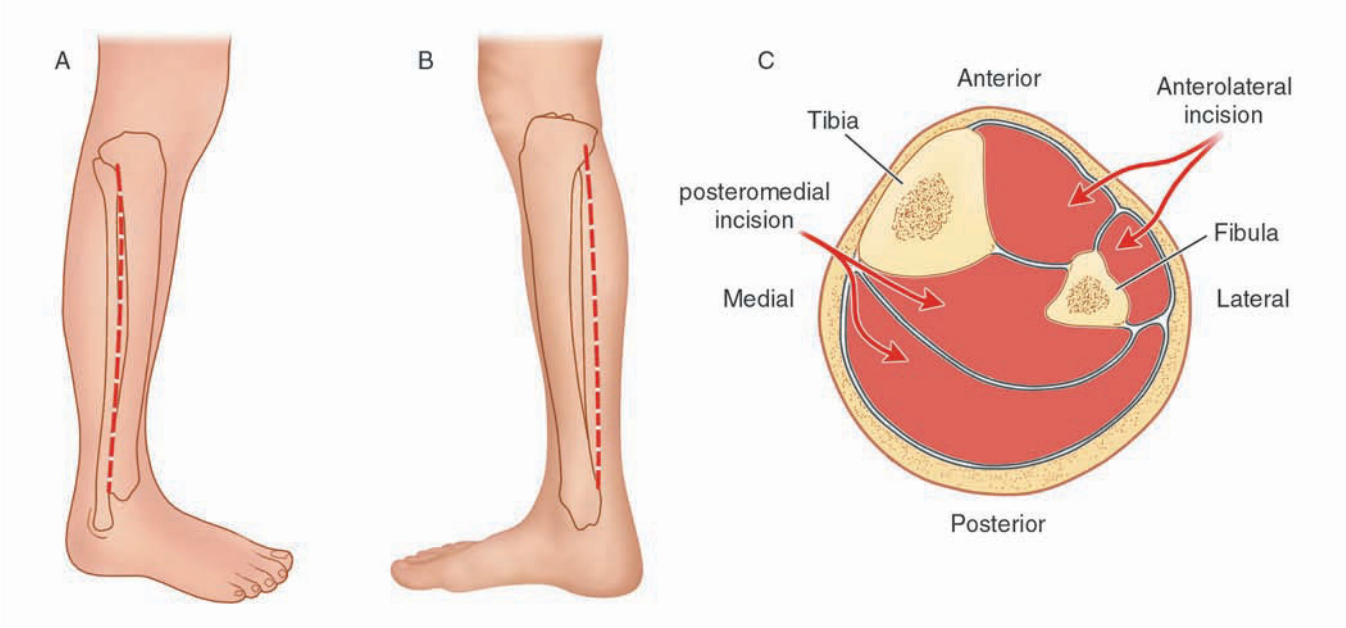


FIGURE 75-13. Fasciotomy incisions for the leg. **A.** The anterolateral incision. **B.** The posteromedial incision. **C.** Cross section through the leg demonstrating the fasciotomy incisions.

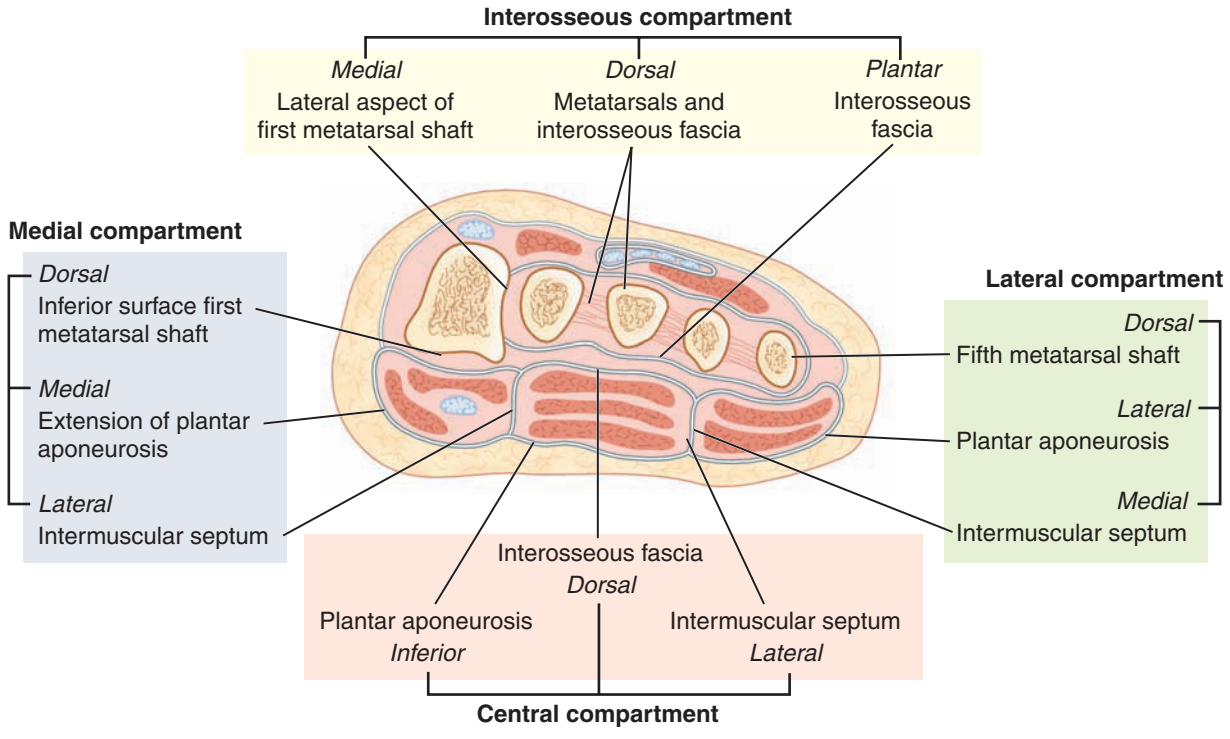


FIGURE 75-14. The compartments of the foot.

tissues on both sides of the incision. Instruct an assistant to retract the skin and subcutaneous tissue on both sides of the incision. Incise the fascia transversely to expose the septum dividing the deep and superficial posterior compartments. Decompress the superficial posterior compartment. Make a longitudinal incision posterior to the intramuscular septum, extending the length of the skin incision. Decompress the deep posterior compartment. Make a longitudinal incision starting from the anterior edge of the initial transverse incision. Extend this incision both proximally and distally.

THE FOOT

The number of compartments within the foot is a matter of controversy (**Figure 75-14**).[19] It was initially believed that there were four compartments. Further research has shown that up to nine compartments exist. Subsequent studies have shown that the barriers between many of these compartments break down at pressures greater than 10 mmHg, far less than that required to cause a compartment syndrome. For the sake of this chapter, we will divide the nine compartments into four groups: the intrinsic compartment that contains the four muscles between the first and fifth metatarsals, the medial compartment, the central compartment, and the lateral compartment.[20] A list of the contents of each compartment is noted in **Table 75-7 & Figure 75-14**.

There are two main incisions used to access the compartments of the foot and both approaches can potentially reach all of the compartments. The most popular approach is the medial approach (**Figure 75-15A**). Make the skin incision starting just below the medial malleolus. Continue the incision distally along the inferior border of the first metatarsal, but superior to the abductor muscle. Retract the skin edges. Identify the neurovascular bundle and retract it out of the way. Incise the fascia of the medial compartment. Continue incising laterally through the medial intermuscular septum of the medial compartment. The remaining compartments can be accessed by blunt dissection with a clamp or by performing additional incisions via the dorsal approach.

The dorsal approach can also be used to access all of the compartments but is best to access the interosseous compartments and the lateral compartment (**Figure 75-15B**). This approach is superior to the medial approach in the setting of metatarsal or Lisfranc fractures. Make the first incision along the medial aspect of the second metatarsal. Make the second incision along the lateral aspect of the fourth metatarsal. Incise the superficial fascia of each compartment and elevate the muscles off the bone for more effective decompression. Use a clamp to bluntly dissect, access, and decompress the remaining compartment (**Figure 75-14B**). The lateral compartment can be accessed and decompressed via the space between the fourth and fifth metatarsals. The central compartment can be accessed and decompressed via the spaces between the second and third and the third and fourth metatarsals. The medial compartment can be accessed and decompressed via the space between the first and second metatarsals.

ASSESSMENT

Aseptically measure all compartment pressures after each fasciotomy. As previously mentioned, many compartments communicate and a fasciotomy of one compartment may relieve the

TABLE 75-7 The Compartments of the Foot and Their Contents

Compartment	Contents
Intrinsic	Interosseous muscles
	Digital nerves
Medial	Abductor hallucis muscle and tendon
	Flexor hallucis brevis muscle
Central	Flexor digitorum brevis muscle
	Quadratus plantae muscle
	Adductor hallucis muscle
Lateral	Flexor digiti minimi muscle
	Abductor digiti minimi muscle

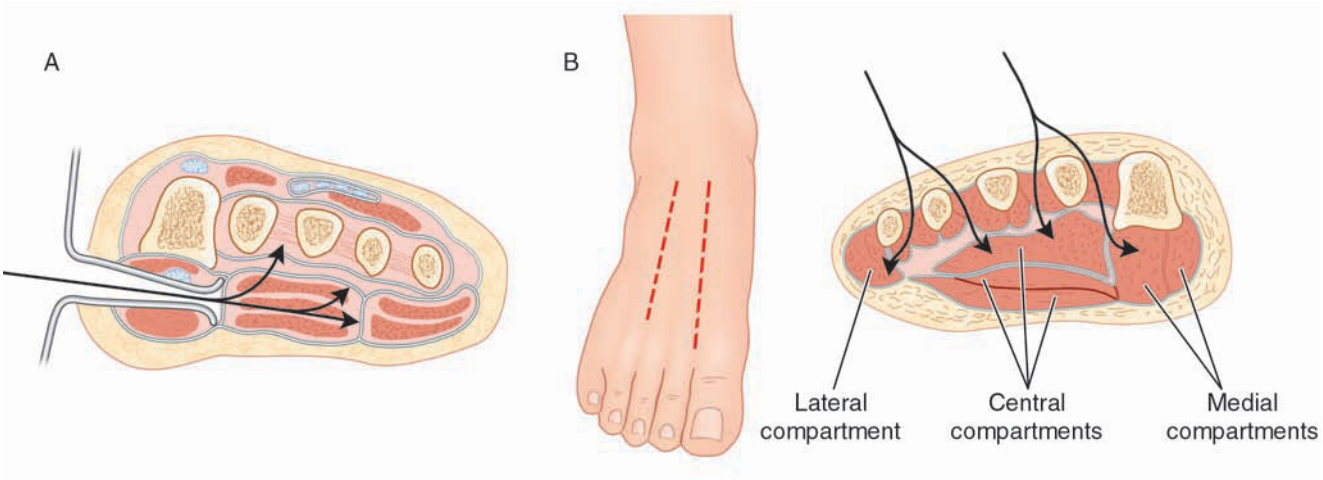


FIGURE 75-15. Fasciotomy incisions for the foot. **A.** The medial approach. **B.** The dorsal approach.

pressure in others and obviate the need for additional fasciotomies. **After the fasciotomy is complete, compartment pressures should be measured again to ensure successful decompression.** Check multiple readings throughout the same compartment.[1] If compartment pressures are still elevated, ensure that the fascia is completely incised and consider increasing the length of the fasciotomy.

AFTERCARE

Once decompressed, the wound is left open. Apply sterile saline-soaked gauze into the incisions followed by a nonrestrictive and bulky dressing wrapped around the limb. The dressing should be loose and allow the wound to easily drain.[12] Splint the limb to prevent contractures. In cases where the decompressed limb has a fracture, the limb must be splinted so that the fractured bones are in appropriate alignment.[13] Consult the appropriate Surgeon (e.g., Hand, Orthopedic, Plastic, or Trauma) to manage the patient. The decision to administer prophylactic antibiotics should be made in consultation with the Surgeon. Admit the patient for further surgical care.

COMPLICATIONS

The goal of surgical decompression is to open the tight fascial layers.[13] Minimizing the length of the skin incisions or limiting the number of compartments decompressed will lead to substandard results. Continued edema and postischemic hyperemia in the first hours after a decompression can lead to increased compartment pressures in adjacent compartments that were not decompressed.

There is a significant risk of an iatrogenic injury to arteries, nerves, tendons, and veins during the fasciotomy.[1] A thorough understanding of the local anatomy and the procedure will help to minimize these injuries. Adequate visualization using proper overhead lighting and proper retraction will further minimize injury.

The diagnosis of a compartment syndrome may be delayed because of a missed diagnosis or because the patient does not present immediately to the Emergency Department. The Emergency Physician may be faced with a situation in which the muscles of the limb are in varying stages of ischemia, irreversible injury, and contracture. In these cases, performing a fasciotomy may predispose the limb to secondary infection with subsequent gram-negative sepsis.[12] The Emergency Physician must weigh the risks and benefits before proceeding. Consider consulting a Surgeon to assist in the decision to perform a fasciotomy.

Infection after a fasciotomy is a definite possibility. While the use of aseptic technique is mandatory, it does not prevent subsequent infections. The presence of crush injuries, myonecrosis, poor perfusion, preexisting peripheral vascular disease, and the patient immune status can predispose the site to an infection. The decision to use of broad-spectrum prophylactic antibiotics should be made in consultation with a Surgeon.

Hemorrhage is often minimal when performing a fasciotomy. Most hemorrhage can be controlled with direct pressure. Small subcutaneous blood vessels transected during the procedure can be controlled with electrocautery or figure-of-eight sutures.

SUMMARY

Emergency Physicians must have an understanding of the signs and symptoms of a compartment syndrome. Always maintain a high level of suspicion in patients presenting with limb injuries. The technique itself is quite simple as long as the incision is made in the proper location. Performing a fasciotomy in a timely fashion can prevent serious and irreversible consequences.

76 Extensor Tendon Repair

Jaime Harper, Stanley Harper, and Ramasamy Kalimuthu

INTRODUCTION

The Emergency Physician (EP) commonly encounters lacerations or trauma to the dorsum of the hand and forearm. In evaluating these patients, the possibility of extensor tendon lacerations must be considered. The extensor mechanism of the hand and forearm is typically disrupted in association with penetrating trauma. It must be remembered, however, that blunt trauma, such as sudden forced flexion, can also result in injury to the extensor tendons. Performing an extensor tendon repair is an important skill in the EP's surgical armamentarium.

Although the diagnosis of an extensor tendon injury must be identified at the initial examination, the timing of the tendon repair is not a critical aspect of its management. Successful repair of extensor tendons may be accomplished acutely, or within a 7 day window following the injury.[1] One should also be aware that at some

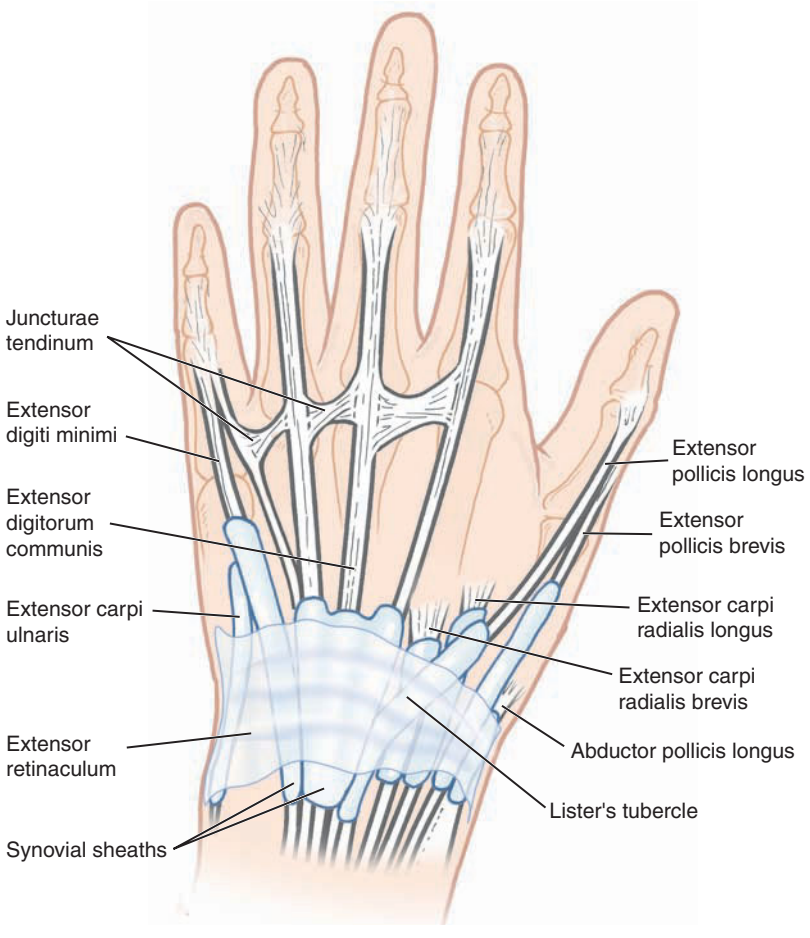


FIGURE 76-1. The extensor tendons of the hand begin just proximal to the extensor retinaculum. After exiting from under this encasing sheath, the tendons form an interconnected network as they cross the dorsum of the hand.

anatomic sites, splint immobilization of the damaged tendon can produce a similar outcome to surgical reapproximation. This is most evident in the conservative management of a mallet finger injury.

Repair of an extensor tendon by an EP requires them to have a familiarity with the anatomy of the region and be skilled in the surgical technique. Although complications of tendon repair are more frequently associated with flexor tendons, follow-up studies of extensor tendon repairs reveal similar pitfalls and problems.[2] Adhesions, loss of length, and diminished flexion can all complicate the repair of an extensor tendon.[3]

The anatomy of the extensor mechanism prevents tendon retraction far from the site of a laceration or partial disruption.[4] This is mostly due to the tethering of tendons by multiple interconnections as the tendons cross the dorsum of the hand. Additionally, the tendons over the dorsum of the hand are ensheathed in a paratenon layer of tissue. This covering is extrasynovial, thus containing the cut ends of the tendons in a tissue layer that prevents their wide separation. These properties frequently allow both ends of a lacerated extensor tendon to be located with local wound exploration, at which point they may be safely repaired.

The techniques for extensor tendon repair originate in studies of flexor tendons. **The goal of extensor tendon repair is to restore tendon continuity and function while minimizing interference from the repair itself.** The suture techniques of Kessler and Bunnell are two of the methods traditionally used in this repair. Modifications of these original methods have resulted in the greatest outcome measurements of tendon strength.[5] **Facility with these two suture techniques, as well as the anatomy, is essential to the repair of any extensor tendon in the Emergency Department (ED).**

ANATOMY AND PATHOPHYSIOLOGY

The extensor tendon mechanism is an intricate system of pulleys and levers coursing along the dorsum of the forearm, wrist, and hand.[6,7] The function of these tendons is to extend the fingers and wrist from a flexed position. This finger motion is complemented by the actions of the intrinsic hand muscle groups (i.e., lumbricals and interossei).

The elegant anatomy of the hand extensor mechanism is best appreciated in diagrammatic representation (**Figure 76-1**). The forearm tendons pass through the extensor retinaculum of the wrist to travel across the dorsum of the hand to each of the fingers. The extensor tendons are reinforced in the fingers by the lateral bands of the intrinsic hand muscles to form a complex tendon that inserts into the distal phalanx (**Figure 76-2**).

Knowledge of the anatomy of the extensor mechanism reveals certain salient points. The extensor retinaculum of the wrist is a complicated structure of fibrous canals through which the tendons pass and whose repair necessitates a Hand Surgeon's intervention. The paucity of soft tissue covering the dorsum of the hand makes the tendons quite vulnerable to penetrating trauma. The extensor tendons of the fingers are interconnected across the dorsum of the hand by the juncturae tendinum. This interconnection of tendons distributes the work of extension among the involved fingers. Redundancy is built into the extension of the first and small fingers with the presence of two separate extensor systems. An isolated tear of the extensor tendon of the index or small finger, therefore, may not result in lack of function because of the contributing band from the extensor digitorum communis

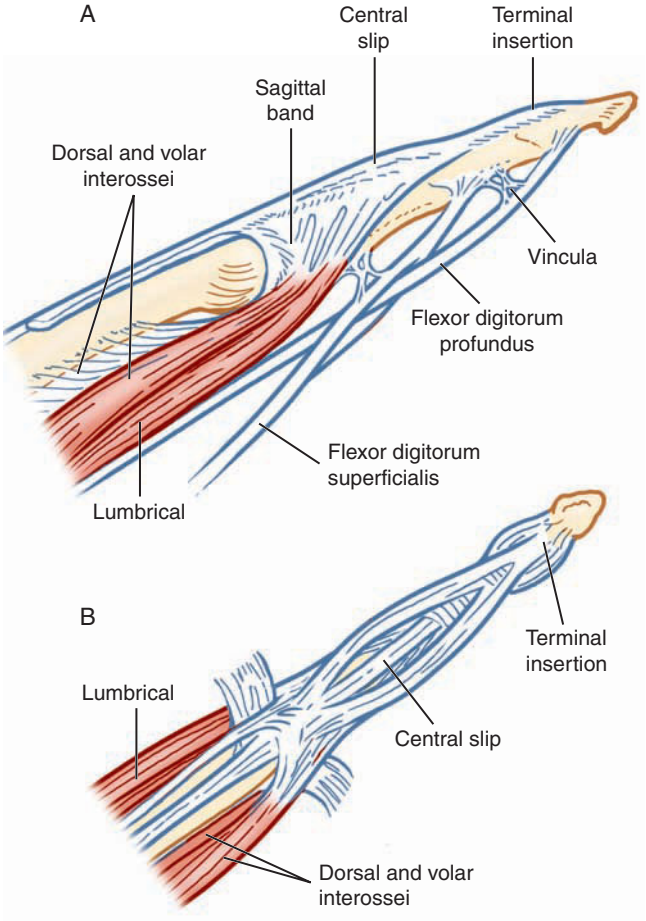


FIGURE 76-2. The central extensor tendons of the digits are reinforced and aided by the lateral bands of the interosseous and lumbrical muscles. The extensor tendon is tethered to the joint surface by a sagittal band, which forms a protective hood. **A.** Lateral view. **B.** Superior view.

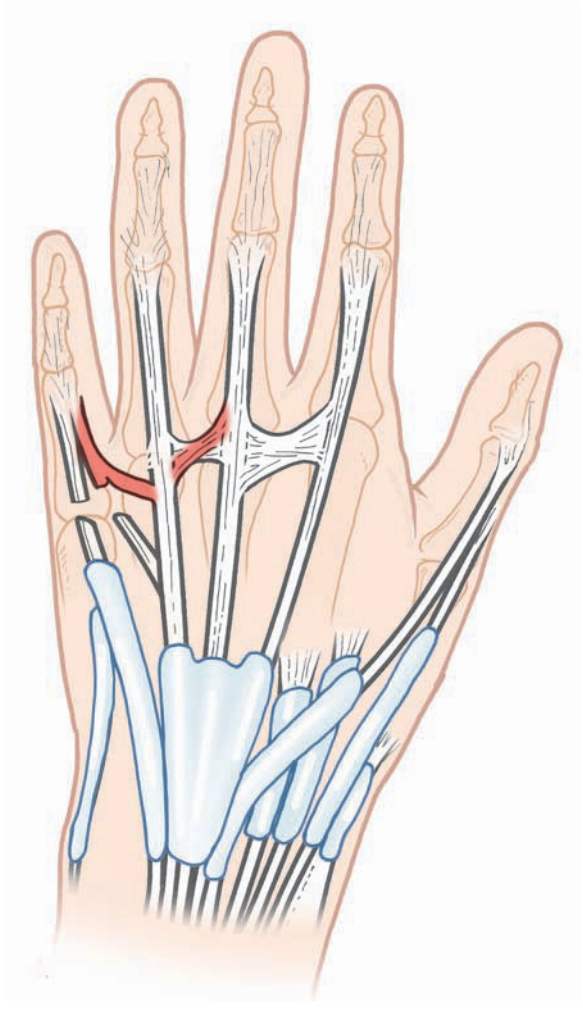


FIGURE 76-3. Division of an extensor tendon in the dorsum of the hand may still allow for full finger extension because of the communicating juncturae tendinum.

(**Figure 76-3**). It is important to realize that there is great anatomic variability in the detailed distribution of these tendons.

The location of an extensor tendon injury is important in determining whether tendon repair in the acute ED setting is feasible. A range of eight zones defines the location of an extensor tendon injury (**Figure 76-4**). The zone chart first described by Kleinert and Verdan helps to classify and organize the modes of repair.[8] The odd-numbered zones refer to areas over the joints, while the even-numbered zones refer to the bony areas. Although any zone can undergo injury and repair, the outcome is variable, depending upon the suture technique and the mode of rehabilitation.

INDICATIONS

The decision to surgically repair a lacerated extensor tendon is multifactorial. One must consider the extent of the tendon laceration, the involvement of other tissues (e.g., bone or joint space), and the location of the tendon injury. Studies that define a minimum laceration width that requires tendon repair have not been performed. **It is generally accepted that a laceration greater than 50% of the tendon width requires surgical repair.**[1] A tendon that has a laceration less than 50% of its width will usually heal with conservative management. **One must put the finger through its entire range of motion to confirm normal function and movement of the affected tendon prior to making the decision as to whether conservative management is appropriate.** A lacerated tendon that is associated with significant overlying skin loss, joint space penetration, or a bony fracture will require repair by an Orthopedic or Hand Surgeon.

Defining the location of the tendon injury according to the Kleinert zone system guides one in deciding what tendon lacerations can be safely repaired in the ED. Although there are no published guidelines on where these procedures should be performed, a thorough understanding of the extensor tendon's anatomy and a good dose of common sense are imperative.

The following zones and types of injury represent sites where extensor tendon repair in the ED is feasible with minimal complications. The thickness of the extensor pollicis longus allows for a core-type suture in zone 2 of the thumb. The broad configuration of the extensor tendon allows for a core-type suture in zone 4 of all digits. Isolated involvement of the extensor tendon allows for a core-type suture unless the joint is involved (rare) in zone 5 of the fingers. Isolated involvement of the extensor tendon allows for a core-type suture and good prognosis in zone 6 of the hand.

CONTRAINDICATIONS

There are definite contraindications to repairing an extensor tendon in the ED. First and foremost, the lack of skill on the part of the EP performing this repair may result in loss of function or may

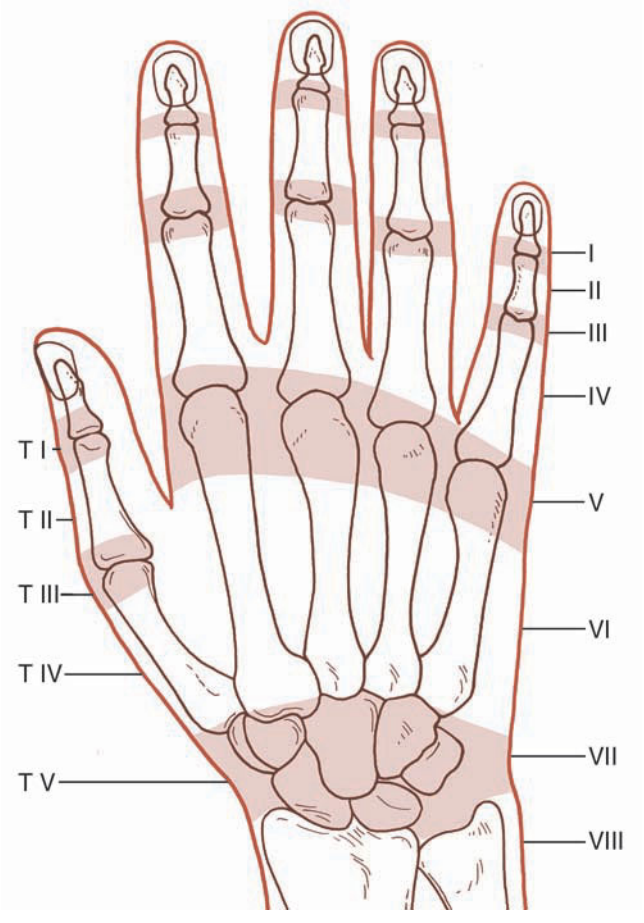


FIGURE 76-4. The extensor tendons of the hand are easily classified by the Kleinert zone system. The odd numbers represent joint spaces. The even numbers represent long bones. Note that the thumb zones are distinct from the other digits.

further compromise the patient's result. Consult an Orthopedic or Hand Surgeon if any doubt exists. The skin wound can be closed loosely, the hand splinted, and the patient referred for delayed repair. Surgical repair of the tendon is not recommended if less than 50% of the tendon is lacerated and the finger functions as well as the corresponding finger on the unaffected opposite hand. The presence of a bony fracture, an open joint space, or the lack of adequate soft tissue or skin covering are contraindications to repairing an extensor tendon in the ED. A tendon laceration as a result of a human bite wound is an absolute contraindication to closure and repair of the injury. The management and rehabilitation of these wounds necessitate consultation with the appropriate surgical specialist.

The Kleinert zone chart can be used to help determine the suitability of repairing an extensor tendon in the ED. The following zones on the forearm, wrist, and hand represent areas where wound care, skin closure, and splinting are highly recommended until an Orthopedic or Hand Surgeon can perform definitive surgical repair. Extensor tendon remnants may be too short in zone 1 of all digits. Except in the thumb, extensor tendons of the fingers that are very thin in zone 2 should not be repaired. Actual or potential joint or lateral band involvement in zone 3 of all digits should not be repaired. Actual or potential joint or sagittal band involvement in zone 5 of all digits should not be repaired. Actual or potential extensor retinaculum involvement in zone 7 should not be repaired. The actual or potential need for a tendon transfer in zone 8 requires an Orthopedic or Hand Surgeon.

EQUIPMENT

Digital or Hand Anesthesia

- Povidone iodine or chlorhexidine solution
- 10 mL syringe
- 25 to 27 gauge needle, 2 in. long
- Local anesthetic solution without epinephrine

Extensor Wound Irrigation and Preparation

- 250 to 500 mL of sterile saline or Ringer's lactate solution
- Irrigation set
- 60 mL syringe
- 16 gauge angiocatheter
- Intravenous tubing
- Personal protective equipment
- Blood pressure cuff, preferably automatic
- Overhead lamp or source of intense lighting

Extensor Tendon and Skin Repair

- Sterile surgical towels
- 4 × 4 gauze squares
- Forceps
- #11 blade disposable scalpel
- Needle driver
- Nonabsorbable, synthetic, and braided suture (4-0, 5-0, and 6-0 Ethibond or Mersilene)
- Nylon suture (4-0 and 5-0) for skin closure

Wound Dressing and Splint

- Topical antibiotic ointment
- Gauze squares
- Elastic gauze bandage
- Splinting materials

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the planned procedure to the patient and/or their representative. The broad risks to the procedure include, but are not limited to, bleeding, infection, nerve damage, additional tendon damage, temporary or permanent stiffness, and a need for additional operations in the future. Additionally, alternative forms of therapy should be discussed. Upon receiving verbal or written consent, the physician may proceed with prepping and positioning the patient.

Place the patient in a supine and comfortable position to minimize movement during the course of the procedure. Place the involved hand on a bedside procedure table ideally at the heart level so that the patient's arm is resting comfortably. Temporarily diminish arterial blood flow with either a digital tourniquet or a blood pressure cuff applied to the arm if vascular bleeding is active and obscures the site of repair. Padding should be applied under the tourniquet. The maximum tourniquet time should be less than 2 hours.[8] Any surgical procedure that takes this long should not be performed in the ED.

Anesthesia to the affected area can be accomplished with either a digital or wrist block. The choice of procedures depends upon the location and extent of the injury. Descriptions of these procedures can be found in Chapter 126, Regional Anesthesia. Once the patient has adequate anesthesia, the wound can be debrided and copiously

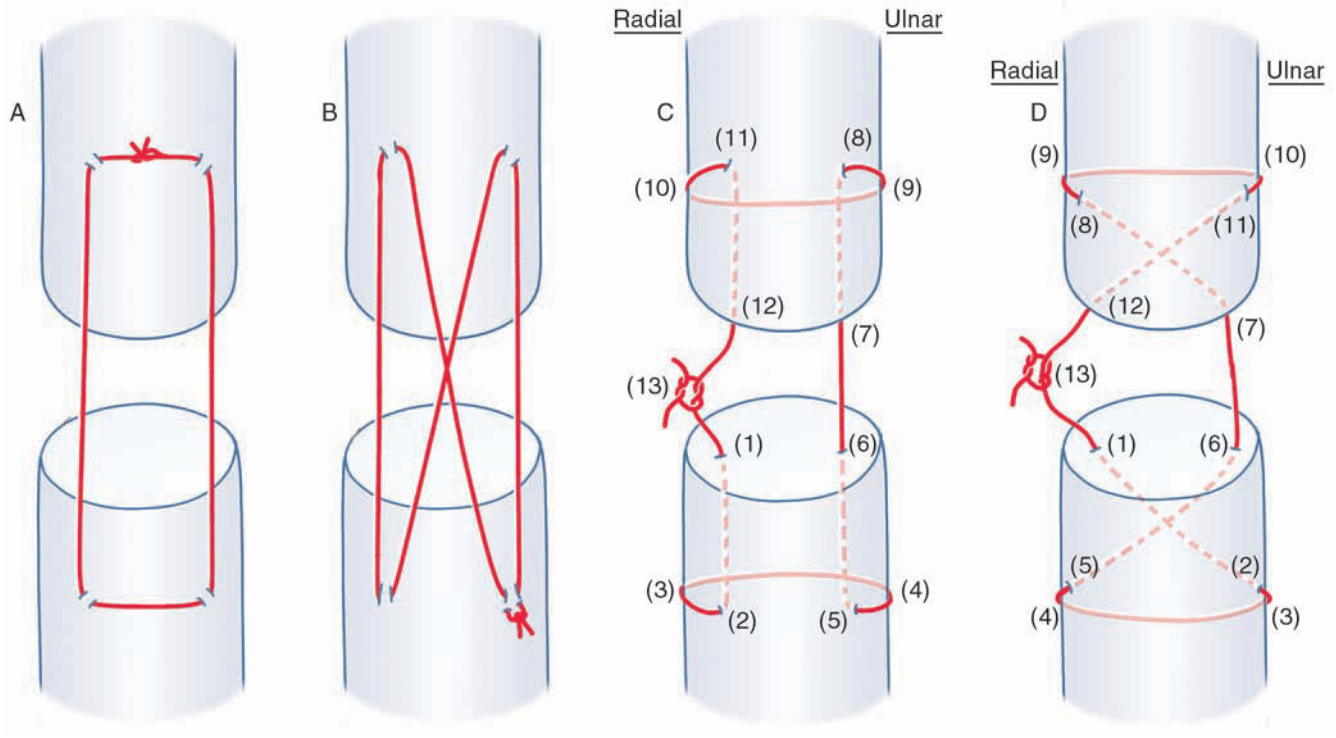


FIGURE 76-5. Suture techniques for extensor tendon repair. **A.** Mattress stitch. **B.** Figure-of-eight stitch. **C.** The modified Kessler stitch. The numbers represent the sequence of steps. **D.** The modified Bunnell stitch. The numbers represent the sequence of steps.

irrigated with 250 to 500 mL of sterile saline (if no open joint is involved). Following irrigation, the wound is considered sterile. All techniques must be aseptic from this point forward. Apply sterile drapes or towels to delineate a sterile field. Place a sterile drape over the bedside procedure table. Lay out the required instruments and suture material on the bedside procedure table.

TECHNIQUES

Many techniques are used to repair lacerated tendons. All of the original techniques were described with reference to flexor tendons. These techniques have been extended to include the repair of the extensor tendons. Four common suture techniques used for a "core" repair of the extensor tendon include the mattress stitch, the figure-of-eight stitch, the modified Bunnell stitch, and the modified Kessler stitch (**Figure 76-5**). No single stitch is optimal for any one zone of injury. The type of stitch must be individualized based on the properties of the tendon at the site of injury. While evidence exists that the modified Kessler and Bunnell stitches produce the greatest strength for a core-type tendon repair,[5] they may not be best suited for extremely thin tendons (such as in zones 4 or 6). Instead, a figure-of-eight or mattress stitch may be necessary. The Bunnell and Kessler techniques are more useful in round, thicker tendons such as the flexor tendons or more proximal extensor tendons.[5,10]

MODIFIED KESSLER STITCH

This "core" stitch is designed to place the direction of force perpendicular to the longitudinal axis of the tendon (**Figure 76-5C**). If the force of the suture is placed in the tendon's longitudinal axis, there is a tendency for the suture to pull through and shred the tendon.

Identify the two ends of the lacerated extensor tendon. **Handle the cut ends with maximal care. Blindly or bluntly grabbing the ends traumatizes the tendons and compromises the repair.** A retracted tendon can be held in place with a needle piercing it perpendicularly. Judiciously debride the tendon ends if they are jagged or dirty. This can be performed with a fresh 11-blade scalpel, cutting down against a wooden tongue depressor. **Do not remove too much length from the tendon.** Place the affected digit and wrist in maximum extension to facilitate approximation of the tendon ends.

Hold one end of the tendon gently with your fingers or a stitch. Introduce the needle into the cut end of the tendon (**Figure 76-5C(1)**). The entrance point should be about one-third of the diameter of the tendon, beginning on either its ulnar or radial side. For simplicity, we begin on the radial side. Pass the suture approximately 1 cm through the length of the tendon and exit dorsally (**Figure 76-5C(2)**). Wrap the suture around the tendon (**Figure 76-5C(3)**). Reenter the radial side of the tendon perpendicularly and 1 to 2 mm closer to the tendon end (**Figure 76-5C(3)**). Pull the suture straight through the tendon to exit on its ulnar side (**Figure 76-5C(4)**). Wrap the suture around the tendon (**Figure 76-5C(5)**). Enter the dorsal aspect of the ulnar half of the tendon (**Figure 76-5C(5)**). This entrance stitch must line up with the first dorsal stitch (**Figure 76-5C(2)**). Pass the needle through the length of the tendon to exit the end of the tendon (**Figure 76-5C(6)**). The needle must exit on the ulnar one-third of the tendon.

Repeat the same stitch on the opposing piece of the tendon. Pass the needle into the ulnar one-third of the tendon (**Figure 76-5C(7)**). Pass the suture approximately 1 cm through the length of the tendon and exit dorsally (**Figure 76-5C(8)**). Wrap the suture around the tendon (**Figure 76-5C(9)**). Reenter the ulnar side of the tendon perpendicularly and 1 to 2 mm closer to the tendon end (**Figure 76-5C(9)**). Pull the suture straight through the tendon to exit its radial side (**Figure 76-5C(10)**). Reenter the dorsal aspect of the radial half of the tendon (**Figure 76-5C(11)**). The stitch must line up with the previous dorsal stitch (**Figure 76-5C(8)**). Pass the

needle through the length of the tendon to exit the end of the tendon (**Figure 76-5C(12)**). The needle must exit on the radial one-third of the tendon.

The two free ends of the suture should be on the radial side of the tendon. Apply tension to the two free ends of the suture to gently approximate the ends of the lacerated tendon. **Do not apply so much force that the ends bunch up.** Secure the stitch with a knot that will remain buried between the tendon ends (**Figure 76-5C(13)**).

MODIFIED BUNNELL STITCH

This stitch follows the same principle as the Kessler stitch. It incorporates a crossing of the suture in its pathway (**Figure 76-5D**). Remember to minimize the handling of the tendon in performing this stitch. **Instrumentation of the tissue is detrimental to its nutritional supply and can lead to adhesions.** Ideally, one should immobilize the tendon ends with one's fingers or a single suture.

Enter the tendon end on the radial half and at approximately one-third of the diameter of the tendon (**Figure 76-5D(1)**). Pass the needle diagonally through the tendon and exit on the ulnar side (**Figure 76-5D(2)**). Wrap the suture around the tendon (**Figure 76-5D(3)**). Reenter the tendon on its dorsal half (**Figure 76-5D(3)**). Pass the needle directly through the tendon to exit the dorsal surface of the radial aspect of the tendon (**Figure 76-5D(4)**). Enter the radial side of the tendon (**Figure 76-5D(5)**). Cross the suture diagonally through the tendon to exit its ulnar end (**Figure 76-5D(6)**). The needle must exit through the ulnar one-third of the tendon end.

Repeat the same stitch on the opposing piece of the tendon. Pass the needle into the ulnar one-third of the tendon (**Figure 76-5D(7)**). Pass the needle diagonally through the tendon and exit on the radial side (**Figure 76-5D(8)**). Wrap the suture around the tendon (**Figure 76-5D(9)**). Reenter the tendon on its dorsal half (**Figure 76-5D(9)**). Pass the needle directly through the tendon to exit the dorsal surface of the ulnar aspect of the tendon (**Figure 76-5D(10)**). Wrap the suture around the tendon (**Figure 76-5D(11)**). Enter the ulnar side of the tendon (**Figure 76-5D(11)**). Cross the suture diagonally through the tendon to exit the radial end of the tendon (**Figure 76-5D(12)**). The needle must exit through the ulnar one-third of the tendon end.

The two free ends of the suture should be on the radial side of the tendon. Pull gently on the suture ends to approximate the ends of the lacerated tendon. **Do not apply so much force that the ends bunch up.** Secure the stitch with a knot, which will remain buried within the tendon ends (**Figure 76-5D(13)**).

AFTERCARE

Close the overlying skin with nylon suture, ideally everting the skin edges with a horizontal mattress suture. Apply topical antibiotic ointment. Apply 4 × 4 gauze squares to cover the wound. Apply an elastic bandage for protection. Splint the extremity to immobilize the repaired tendon and its associated muscle belly.

The patient may be discharged home with follow-up arranged within 24 to 48 hours with an Orthopedic or Hand Surgeon. Instruct the patient to elevate the extremity. They should return to the ED immediately if there is increased pain, numbness or tingling in the digits, if the digits become cold or blue, or if a fever develops. Pain can be controlled by the use of nonsteroidal anti-inflammatory drugs supplemented with an occasional narcotic analgesic.

Static immobilization may not be the optimal postoperative management for extensor tendon repairs. The affected tendon may benefit from early mobilization exercises or dynamic splinting depending upon the zone of injury. Dynamic extension splinting may produce fewer complications and less postoperative adhesions.[11–13] Tendon injuries in zones 1 to 4 can be temporarily immobilized in extension until follow-up by an Orthopedic or Hand Surgeon determines the definitive splinting management. Tendon injuries in zones 5 to 8 can be placed in a temporary static splint with the wrist in 30° of extension, the MCP joints in 15° of flexion, and the interphalangeal joints in full extension.

The aftercare of extensor tendon lacerations necessitates close follow-up by an Orthopedic or Hand Surgeon for the evaluation of tendon function, wound evaluation, and rehabilitation strategies. **Proper aftercare and hand rehabilitation is crucial to ensure successful results of a tendon repair.**

COMPLICATIONS

Surgical repair of any open wound or tendon laceration can result in unforeseen infections. Careful instructions for wound care and follow-up evaluations are important for early detection and treatment of tissue infection.

Failure of the tendon repair can be due to several etiologies. Disruption of the surgical repair, the formation of adhesions, and joint stiffness can produce an inadequate outcome.[9] It is rare to encounter these complications in the ED. Nonetheless, they are real complications that both the EP and patient must discuss before proceeding with the repair procedure.

SUMMARY

The repair of an extensor tendon laceration can and does occur in the ED. While the literature and authors have found that the use of the Bunnell and Kessler stitches for the repair of extensor tendon injuries produces good results, the mattress technique and figure-of-eight stitch may be more useful in the thinner extensor tendons. Effective communication with an Orthopedic or Hand Surgeon is imperative in optimizing the patient's outcome. Even if the tendon repair does not occur in the ED, the wound must be irrigated, explored, and closed for delayed surgical repair by an Orthopedic or Hand Surgeon. Postoperative rehabilitation is crucial to ensure an optimal outcome. Splinting in the ED should only be a temporizing immobilization procedure until rehabilitation therapy occurs.

77 Arthrocentesis

Eric F. Reichman, John Larkin, and Brian Euerle

INTRODUCTION

Arthrocentesis is the insertion of a needle into a joint cavity for the removal of synovial fluid and/or the injection of pharmaceutical agents into the joint cavity. Fluid can be aspirated from almost any joint. Arthrocentesis is used to diagnose and make treatment decisions regarding a joint. Obtaining synovial fluid is safe, simple, relatively pain free, inexpensive, and extremely beneficial to the patient.

Arthrocentesis may be diagnostic or therapeutic. Diagnostically, it is performed to identify the cause of an acute arthritis, to identify an intraarticular fracture, to identify the causes of an effusion, or to give a therapeutic trial of pharmaceuticals. It can also be therapeutic by relieving pain from elevated intraarticular pressure, to drain septic or crystal-laden fluid, or to inject pharmaceuticals. Ultrasound (US)-guided joint aspiration is a supplemental technique that improves several aspects of the arthrocentesis procedure.

TABLE 77-1 General Principles for Arthrocentesis

Know the anatomical relationships
Avoid piercing any tendons
Do not damage articular cartilage
Do not penetrate bone
Use sterile technique
Provide adequate analgesia
Place the joint in slight flexion
Apply distal traction to small joints
Apply compression to large joints
Enter the extensor surface
Use US guidance if available

Synovial fluid analysis will provide unique and valuable information about the affected joint.[32] It is the only method to definitively diagnose or rule out a septic arthritis. The fluid should be analyzed for the presence of crystals. A white blood cell count and differential may help identify the causes of an effusion. A Gram's stain can be quickly performed to identify bacteria in the synovial fluid. Bedside gross analysis of the fluid's physical properties such as clarity, viscosity, and color has been shown to be a reliable clinical predictor of a potentially septic joint.[30] A culture of the synovial fluid should be performed to definitively identify any microbiologic pathogen in the joint.

There are several general principles that should be followed when performing an arthrocentesis (**Table 77-1**). The Emergency Physician (EP) must know the anatomical relationships around the joint. The needle should go around and not through any tendons. Avoid piercing the articular cartilage, which is avascular and may not heal. Do not bounce the needle off the bone, as this is extremely painful for the patient. Insert the needle through the extensor surface of the joint. The synovial cavity is closest to the skin over the extensor surface of the joint. The extensor surface has fewer tendons and ligaments than the flexor surface. Most of the blood vessels and nerves are located on the flexor surface of the joint. Using the extensor surface of the joint for the procedure will avoid potential injury to these structures. Place the joint in slight flexion to maximize the size of the joint cavity. Apply distal in-line traction to the small joints of the wrists, hands, and feet to enlarge the joint cavity. This allows the needle to more easily enter the small joint spaces. Compression of large joints will mobilize peripheral fluid. This is helpful when the volume of synovial fluid is small. Compression may be applied manually or with an elastic bandage.

It is critical to use sterile technique to prevent the infection of a nonseptic joint as well as to ensure the joint fluid is uncontaminated for microbiological cultures. Sterile drapes, sterile gloves, and face masks are not needed to perform the procedure.[1–3] It is necessary to wear gloves to prevent transmission of blood-borne diseases to the EP.[1,4] The skin should be cleansed and prepped in the usual manner. The needle may then be grasped, with clean gloves, at the hub and inserted. As long as the skin and needle are not handled, sterile gloves are not required. This is sometimes difficult to master if the EP has little practice with the technique of arthrocentesis. It may be better to err on the side of conservatism and use sterile gloves and drapes; particularly with inexperienced EPs and in training situations.

US has been used by Interventional Musculoskeletal Radiologists and Rheumatologists to guide needles for joint injections and aspirations.[44,45] US guidance allows these procedures to be performed in a safer manner because the needle is less likely to injure nerves, tendons, and blood vessels. US also allows a comparison with the asymptomatic opposite-side joint. As bedside ultrasonography has become more commonly used in the ED, more EPs are appreciating and reporting on the benefits of its use in guiding arthrocentesis.[46–51] Arthrocentesis is commonly performed on the shoulder, elbow, hip, knee, and ankle joints. It may also be performed on other joints. US guidance can be a useful adjunct in all of these procedures.

There are several possible approaches for the use of US-guided arthrocentesis in the ED. Knee arthrocentesis is commonly performed with a high success rate using only the landmark-palpation technique. Many EPs feel comfortable performing this procedure without the routine use of US guidance. Wiler and colleagues compared US-guided versus standard landmark techniques for knee arthrocentesis and found that US guidance did not improve overall success.[50] Others may use US guidance in cases anticipated to be difficult, such as small effusions or prior joint surgery. Some EPs feel that US guidance improves the safety of arthrocentesis and thus choose to use it whenever an arthrocentesis is performed. This approach is especially appealing in light of the fact that US is noninvasive and does not add any risk to the procedure.

INDICATIONS

Arthrocentesis is indicated to evaluate the cause of an arthritis or a joint effusion (**Table 77-2**).[4–7] All patients presenting with an acute monoarthritis or an acute nontraumatic effusion should undergo arthrocentesis when the diagnosis is not clear based upon the history and physical examination. Analysis of the synovial fluid is essential to help differentiate inflammatory from noninflammatory causes of joint disease. **Arthrocentesis is the only reliable method to confirm the presence of an infectious agent as the cause of an arthritis.** The presence of crystals within the synovial fluid can diagnose gout or pseudogout from other crystal-induced arthritides. **Always keep in mind that two or more types of arthritis can coexist in a patient or in a single joint.[4]**

Arthrocentesis may be therapeutic.[8] A large effusion, regardless of the cause, stretches the joint capsule, causing pain and limiting range of motion. Removal of the fluid will decrease pain and increase the joint's range of motion. An effusion caused by inflammation or sepsis contains numerous mediators of inflammation. Removal of this synovial fluid will help to relieve the patient's discomfort. The removal of purulent fluid will decrease the number of organisms in the joint cavity and, theoretically, may limit further joint destruction.

Injection of therapeutic agents into nonseptic joints is commonly performed in the Emergency Department (ED). Local anesthetic solutions may be injected to relieve pain. A joint examination after trauma may be limited secondary to pain. Injection of local anesthetic solutions can relieve pain and allow an examination for ligamentous and joint instability. Corticosteroids are injected into joints to control inflammation and arthritis pain.

TABLE 77-2 The Indications for Performing an Arthrocentesis

To evaluate a monoarticular arthritis
To diagnose and treat a traumatic arthritis
To diagnose an intraarticular fracture
To diagnose an intraarticular ligamentous disruption
To relieve pain
To diagnose inflammatory versus noninflammatory disorders
To identify the cause of an effusion
To rule out an infection
To identify a crystal-induced arthritis
To inject therapeutic agents

Sometimes, corticosteroids and local anesthetic solutions are combined into one syringe and injected intraarticularly. The local anesthetic provides immediate pain relief and assures the EP of proper needle placement.

Arthrocentesis can be used to diagnose and treat traumatic arthritides. The traumatic event is usually acute, obvious, and followed by joint pain and swelling. Occasionally, the trauma is minimal or remote and not recalled by the patient. A traumatic effusion can be grossly bloody and, if acute, may contain a large amount of red blood cells. The bloody synovial fluid represents an intraarticular fracture or a disruption of an intraarticular structure. An intraarticular fracture may be suspected based on mechanism of injury and yet radiographic findings may be negative. The synovial fluid may then be evaluated for fat globules, which are released from the marrow cavity of the fractured bone, which confirm the presence of an intraarticular fracture.

The temporomandibular joint is a highly specialized joint that has a unique set of problems associated with it. Arthrocentesis can be an easy, minimally invasive, and efficient procedure used to solve some of these issues. Degenerative joint disease and joint lock are two examples of conditions that are amenable to therapeutic arthrocentesis, although much debate still exists concerning efficacy and therapeutic value of this procedure.

CONTRAINDICATIONS

There are no absolute contraindications to arthrocentesis. All contraindications are relative. The risks and benefits of the procedure should be evaluated and a decision made with the informed consent of the patient. **If a septic joint is suspected, it should be aspirated despite the presence of any relative contraindication. The benefit of the procedure outweighs any relative contraindication when compared to the morbidity of an undiagnosed septic arthritis.**

The presence of a suspected or known skin cellulitis, or other infection overlying the joint, is a relative contraindication. A dermatitis or skin lesion overlying the joint should also be avoided. The skin or subcutaneous tissue can harbor organisms that may contaminate the joint when the needle passes through the dermatitis or skin lesion. Often, an alternative site can be found to perform the arthrocentesis and avoid the above obstacles. If the needle is inserted into the joint through any potential or obvious source of infection, antibiotic treatment is required due to the theoretical risk of introducing an infection into the joint cavity.[5] In these cases, patients should be admitted for 23 hours of intravenous antibiotics whose spectrum covers skin flora.

Infections after arthrocentesis, in previously sterile joints, have been reported in bacteremic patients.[5] It is not clear whether the source of the septic arthritis was from the arthrocentesis or bacteremia coincidentally seeding the joint. It is recommended to avoid arthrocentesis in any patients with bacteremia or sepsis except to rule out a septic arthritis.

Patients may be coagulopathic due to heparin or Coumadin therapy, factor deficiencies, liver dysfunction, or many other causes. When possible, the coagulopathy should be reversed prior to arthrocentesis. Unfortunately, this is not always possible or practical. An experienced EP can safely perform the procedure without reversing the coagulopathy. Use the smallest needle gauge possible (i.e., 22 or 23 gauge) to aspirate the joint fluid. Avoid injury to the articular cartilage by identifying the anatomic landmarks prior to the procedure. Do not bounce the needle off any bony surfaces.

The procedure may be difficult in some patients. In the morbidly obese, it may be difficult to identify anatomic landmarks. The standard needle may be too short to enter the joint cavity. A spinal needle may be required to perform an arthrocentesis in an obese patient. Uncooperative patients require sedation and/or restraint prior to performing the procedure.

A prosthetic joint increases the risk of a septic arthritis. Arthrocentesis is technically more difficult secondary to scar formation and alteration of the normal anatomic relationships. **Joints that contain a prosthesis should be aspirated only to rule out a septic arthritis. Arthrocentesis for other reasons, including joint injection, should be referred to a consultant.**

Corticosteroids are instilled into joints for a variety of conditions. If the patient has no response to the injection within a few weeks, it may be repeated. If multiple injections cause no improvement, an alternative form of therapy should be explored.[9] Multiple injections into a joint increase the risk of complications.

EQUIPMENT

- Clean gloves
- Gauze squares
- Povidone iodine or chlorhexidine solution
- Sterile skin marking pen
- Local anesthetic (injectable, vapor coolant, or ice)
- 25 to 27 gauge needle
- 3 mL syringe
- Needles to aspirate fluid (18/20/22 gauge)
- Syringes to aspirate fluid (1/3/5/10/20/30/60 mL)
- Hemostat
- Specimen tubes
- Culturettes or culture tubes

Optional Equipment

- US machine
- US gel
- US transducers (5 to 10 MHz)
- Sterile US probe covers

Arthrocentesis should be performed with a needle of sufficient bore to allow the aspiration of thick fluid, fluid with debris, or purulent fluid. An 18 to 20 gauge needle is recommended for large joints (i.e., shoulder, elbow, ankle, knee, and hip). A 22 to 23 gauge needle is recommended for all other joints. Using too small a needle makes the procedure technically more difficult and more painful for the patient.

A high-frequency (5 to 10 MHz) linear array transducer is preferred for arthrocentesis and should be used whenever possible.[44] If this type of transducer is not available, or if more depth of field is required, a curvilinear array may be used. Cavalier and colleagues reported using color Doppler and a sterile needle guide attached to the transducer when performing US-guided arthrocentesis in children.[52] Doppler was used to localize the blood vessels so that they could be avoided by the needle. While Doppler may occasionally provide additional anatomic information, it is not routinely used when performing an arthrocentesis. The use of a needle guide depends on the personal preference of the sonographer.

PATIENT PREPARATION

A complete history and physical examination should be performed prior to the arthrocentesis. The affected joint should be thoroughly assessed. Inspect the skin overlying the joint for breaks, infection, old scars, prior incisions, superficial lesions, or any wounds. Palpate the joint to identify any warmth, tenderness,

or effusion. Evaluate the joint for any crepitation, deformity, ligamentous instability, or limitations in motion.

As with any nonemergent procedure, consent should be obtained from the patient or their representative. Ideally, the consent should be documented in the medical record and signed by the patient. Some prefer to note on the patient's chart "indications, risks, and benefits were discussed with the patient" rather than having the patient sign a consent form.[4,10] The following is a sample consent for performing an arthrocentesis (which may be written on the medical record and signed by the patient):

Arthrocentesis involves inserting a small needle into your_____joint. The skin is anesthetized prior to the procedure. Ordinarily, the procedure has no significant complications. Occasionally, a patient may experience bleeding into the joint, infection of the joint or skin, pain, bruising, nerve injury, or an allergic reaction to the medications administered. These complications are minimized by the use of sterile technique and proper techniques.

Position the patient based on the specific joint to be aspirated and the approach to be used. Expose the joint and surrounding areas. Identify the anatomic landmarks required for proper needle placement. The landmarks may be difficult to identify on a swollen and tender joint. Compare the "affected" joint to the "normal" joint on the opposite side of the body. Identify the joint and a landmark on the normal joint and transfer this to the affected joint. Clean any dirt and debris from the skin. Scrub the needle insertion site with povidone iodine or chlorhexidine solution and allow it to dry.

Apply anesthesia to the skin and subcutaneous tissue using 1% lidocaine, topical vapor spray, or ice.[11] The administration of some form of local anesthesia is recommended but not required.[4,12] The most common local anesthetic used is a short-acting injectable anesthetic solution of 1% lidocaine. **Do not inject the local anesthetic solution deeper than the subcutaneous tissues**. Deep injections may instill anesthetic solution into the joint cavity, which may interfere with the synovial fluid analysis. There is disagreement if the additional needle stick to administer the anesthesia causes as much discomfort as aspiration without any anesthesia. This decision is specific to each patient and EP.

Alternative methods of anesthesia include ice and topical vapor coolants. A sterile drape may be placed over the prepped skin and a bag of ice water placed over the drape. Remove the ice water bag and drape after 5 minutes and perform the procedure. Ethinyl chloride topical vapor coolant may be used as an anesthetic. Spray the solution onto the area of skin in which the needle will be inserted. Apply the spray from 6 in. above the skin. Spray until the skin turns white and frosty. This usually takes 5 to 10 seconds. Immediately perform the procedure, as the anesthesia lasts only 30 to 60 seconds.

TECHNIQUES

THE BASIC TECHNIQUE

The general procedure preferred by one of the authors and the editor (EFR) will be described. Some may prefer to insert the needle into the joint space and then attach the syringe. Specifics will be addressed with each individual joint.

Apply the needle to the syringe and break the resistance. This avoids any sudden and painful movements of the needle within the joint cavity. Stretch the skin over the site where the needle will be inserted. Penetrate the skin briskly with the needle and enter the joint cavity. Gently aspirate synovial fluid. If bone is encountered, slightly withdraw the needle and re-advance it in a different direction. If no fluid is obtained, reevaluate the joint to determine if an effusion is present, if another site is more appropriate for the procedure, or if another physician may offer a different perspective. For diagnostic aspirations, it is not necessary to aspirate all of the fluid from the joint. Synovial fluid analysis can be performed on 1 to 5 mL of fluid.

If additional fluid is to be removed after the original syringe is filled, or if pharmaceuticals are to be injected into the joint, do not remove the needle from the joint cavity. Grasp the hub of the needle with a hemostat. Remove the syringe and attach the second syringe. Continue to aspirate fluid or inject the desired pharmaceutical. Remove the needle when the procedure has been completed. Apply a bandage to the skin. Transfer the synovial fluid into appropriately labeled tubes or containers. Document the procedure in the medical record. A sample procedure note is described below:

After informed consent, the skin overlying the_____joint was cleaned and prepped with povidone iodine/chlorhexidine solution. The skin was anesthetized with (_____mL of_____% lidocaine, ethyl chloride vapor coolant, ice for_____minutes). Using sterile technique, an_____gauge needle was inserted on the (supero-/infero-,medial/lateral/inferior/superior) surface of the joint. It was directed (supero-/infero-,medially/laterally/inferiorly/superiorly). _____mL of fluid was obtained. It was (thin, thick, yellow, clear, straw-colored, bloody, purulent, with debris, without debris). No complications were noted.

The joint was injected with_____mL of_____% (name of local anesthetic) and/or_____mL of_____%_____(name of corticosteroid). No complications were noted.

THE BASIC US TECHNIQUE

The acoustic windows used for US-guided arthrocentesis are the soft tissues overlying the joint. The transducer is most commonly oriented across a joint so that the bones on each side of the joint are visualized and the joint space between them. Bone is highly reflective of US waves and the cortex is seen as a bright white echogenic line on the US image. Synovial fluid will be seen as an anechoic line or hypoechoic collection within the joint space. When visualized longitudinally, the needle will appear as a narrow, linear hyperechoic structure with a posterior reverberation artifact (**Figure 77-1**). When visualized transversely, the needle appears as a small hyperechoic round object.[45]

The general procedure and technique depend on whether the static or dynamic method is used. Using the static technique, manipulate the US transducer over the joint until the optimal spot for needle entry is found based on fluid accessibility and a needle path that avoids major blood vessels, nerves, and tendons. Mark the skin on the midpoint of each side of the US transducer. Rotate the transducer 90° and repeat the process. Connect the two sets of lines to form an "X" that marks the spot for needle entry (**Figure 77-2**). Set aside the US transducer, prepare the skin in a sterile manner, and proceed with the arthrocentesis using the standard landmark-based technique.

The dynamic or real-time method is slightly more demanding technically but offers the advantage of allowing visualization of the needle and needle tip.[44] Prepare the patient's skin in a sterile manner. Place a sterile probe cover over the US transducer and apply sterile US gel to the skin. Place the transducer over the joint in the appropriate orientation and manipulate it until the synovial fluid is visualized. Inject a local anesthetic agent into the skin and subcutaneous tissue along the projected course of the arthrocentesis needle. In many cases, it is possible to observe the infusion of the anesthetic agent on the US image.[44] Advance the needle through the skin and soft tissue and direct it toward the synovial fluid. The needle can be advanced either longitudinally or transversely to the axis of the US transducer. The longitudinal axis allows visualization of the entire needle along its path and is the technique utilized by most EPs. Visualization in the transverse axis allows only one



FIGURE 77-1. Longitudinal view of a needle approaching a joint effusion.

cross-sectional area of the needle to be seen so it can be difficult to identify the needle and its tip. Regardless of orientation, continue to advance the needle until its tip is visible within the synovial fluid. Aspirate the synovial fluid. It is often possible to watch the synovial fluid diminish in size as it is aspirated.

TEMPOROMANDIBULAR JOINT ARTHROCENTESIS

Landmarks The landmarks for temporomandibular joint (TMJ) arthrocentesis are found by first drawing a line on the patients face from the corner of the eye to the ipsilateral tragus (canthal-tragus line). Mark the point 10 mm from the tragus along the line and 0.5 mm below the line. This marks the superior compartment. Mark a second point 20 mm from the tragus along the line and 1 mm below the line. This marks the superior compartment.

Patient Positioning Place the patient sitting upright with their jaw held slightly open.

Needle Insertion and Direction Use two 21-gauge needles to access the joint space compartments. Insert the first needle at the first mark and advance it into the joint space. Inject 2 to 3 mL of sterile saline to insufflate the joint space. Insert and advance the second needle at the second point and into the joint space. Correct placement is confirmed when the saline flows out the needle.[41]

Remarks Arthrocentesis of this joint is a unique solution to a specialized TMJ disorder called closed lock, in which the patient's jaw is felt to be locked and will not open greater than 20 to 25 mm. It is theorized to be the result of small adhesions and nongliding of the intraarticular disk in the TMJ space. Arthrocentesis and subsequent lavage can relieve the symptoms of closed lock.

Joint Injection Once the two needles are in place in the superior compartment, massive lavage with normal saline or lactated ringers solution can be achieved with the first needle as input and the second needle as output. Continuous fluid can be infused and removed using a 10 mL syringe or attaching IV tubing to each needle.[42]



FIGURE 77-2. The "X" marks the spot for needle entry.

STERNOCLAVICULAR JOINT ARTHROCENTESIS

Landmarks The sternal end of the clavicle and the suprasternal notch are the landmarks for this joint (**Figure 77-3**). The joint can be palpated just medial to the sternal end of the clavicle and just lateral to the suprasternal notch.

Patient Positioning Place the patient supine on a stretcher with their arm hanging over the edge of the table (**Figure 77-3A**). Abduct the arm 90°. Externally rotate the arm so that the palm faces upward. This position maximally opens the sternoclavicular joint to allow easy access.

Needle Insertion and Direction Insert a 23 gauge needle through the anterior joint surface and perpendicular to the skin (**Figure 77-3B**). Advance the needle to a depth of 2 to 5 mm.

Remarks This joint is often involved with degenerative arthritis. Septic arthritis is commonly seen in intravenous drug abusers who inject drugs into the great vessels; also known as "pocket shooting." This joint may only contain 0.25 to 0.50 mL of fluid.

Joint Injection A maximum volume of 1 mL may be instilled into this joint. A maximum dose of 10 mg of corticosteroids may be instilled into this joint.

ACROMIOCLAVICULAR JOINT ARTHROCENTESIS

Landmarks The acromioclavicular (AC) joint is very superficial (**Figure 77-4**). Palpate the clavicle and move laterally until a prominence is felt. This is the AC joint. Have the patient move their arm to confirm the joint location.

Patient Positioning Place the patient sitting upright on a stretcher with the affected arm hanging by their side. A weight may be placed in the patient's hand to distract and open the joint space.

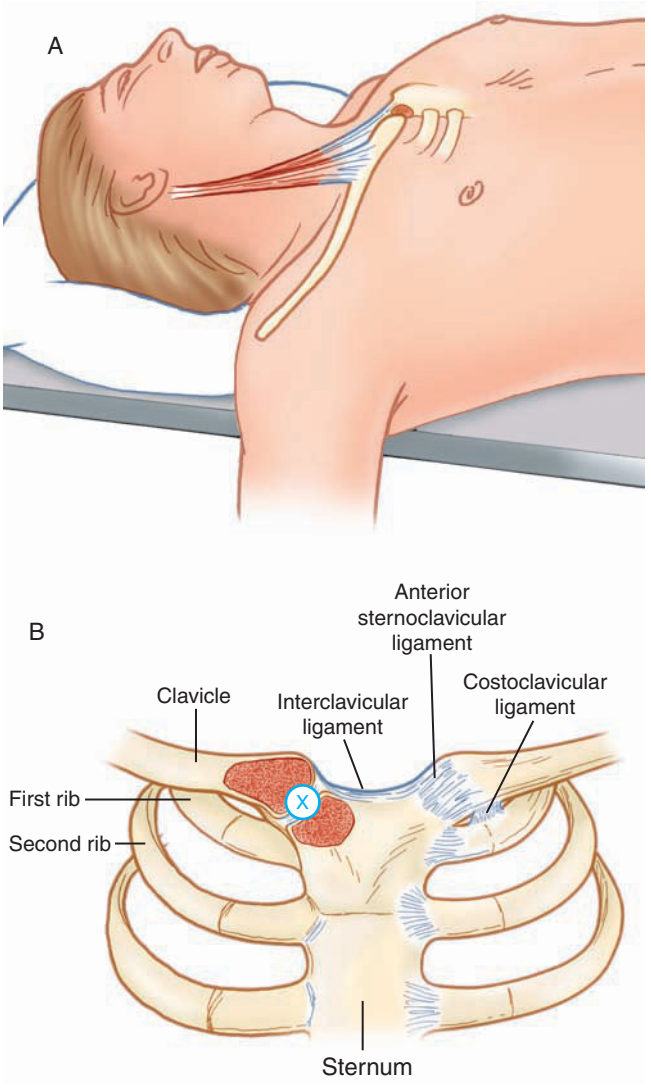


FIGURE 77-3. Sternoclavicular joint arthrocentesis. **A.** Patient positioning. **B.** Anatomy and needle insertion. The site of needle insertion is represented by an "⊗".

Needle Insertion and Direction Insert a 22 gauge needle through the superior surface of the AC joint and perpendicular to the skin (**Figure 77-4**). Advance the needle to a depth of 3 to 5 mm.

Remarks The AC joint is very superficial. It has a dense, thick capsule anteriorly that is lacking on its superior surface. The joint may contain only 0.25 to 0.50 mL of fluid.

Joint Injection A maximum volume of 1.5 mL may be instilled into this joint. A maximum dose of 10 mg of corticosteroids may be instilled into this joint.

GLENOHUMERAL JOINT (SHOULDER) ARTHROCENTESIS, ANTERIOR APPROACH

Landmarks Palpate the coracoid process of the scapula (**Figure 77-5**). It will be found below the lateral third of the clavicle. Internally rotate and adduct the humerus. Palpate the groove between the coracoid process and the humeral head. This groove is the landmark for introduction of the needle.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Flex the elbow 90°. Internally rotate and adduct the arm.

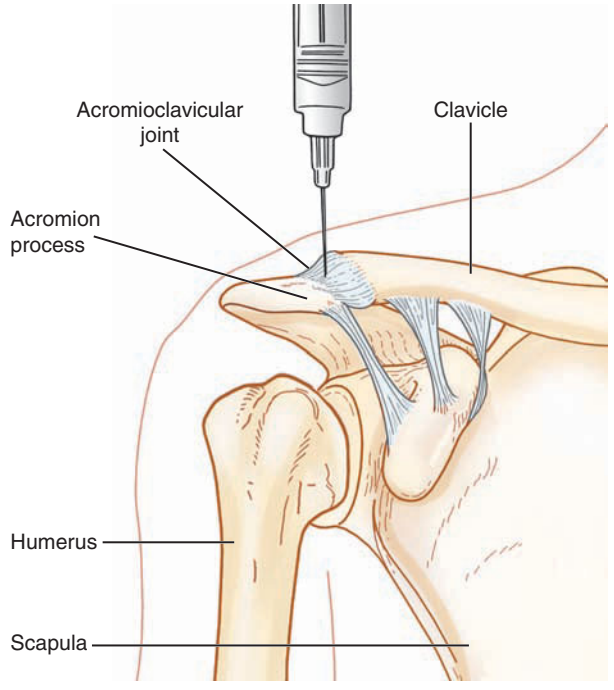


FIGURE 77-4. Acromioclavicular joint arthrocentesis.

In the proper position, the forearm is resting against the patient's abdomen.

Needle Insertion and Direction Insert an 18 gauge needle perpendicular to the skin and into the groove just lateral to the coracoid process (**Figure 77-5B**). Aim the needle directly posterior. Advance the needle until a loss of resistance is felt as the joint cavity is entered.

Ultrasound Probe Placement With the patient positioned as above, place the US probe inferior and lateral to the coracoid process.

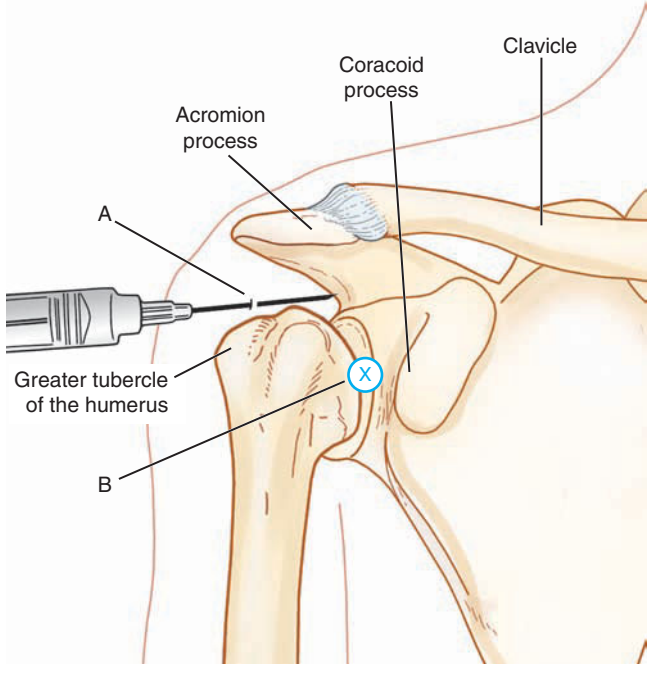


FIGURE 77-5. Shoulder joint arthrocentesis. **A.** Lateral approach. **B.** Anterior approach. The site of needle insertion is represented by an "⊗".

Rotate the probe so that the marker is cephalad and angled medially toward the patient's head. The curve of the humeral head will appear different than the flat portion of the glenoid, and between these hyperechoic surfaces lies the V-shaped hypoechoic joint space.

Remarks This approach is the simplest yet most painful of the three approaches. The needle must penetrate the tendons of the coracobrachialis, subscapularis, biceps, and pectoralis major muscles in addition to the very tough anterior joint capsule. The major disadvantage of this approach is the possible (but rare) penetration of the brachial plexus or the axillary vessels with the needle. The patient can view the large needle as it approaches the skin and this may increase their anxiety level. The posterior approach is preferred when using US guidance.[44]

Joint Injection A maximum volume of 15 mL may be instilled into this joint. A maximum dose of 30 mg of corticosteroids may be instilled into this joint.

GLENOHUMERAL JOINT (SHOULDER) ARTHROCENTESIS, LATERAL APPROACH

Landmarks Identify the acromion process of the scapula (**Figure 77-5**). A groove can be found just inferior to the lateral surface of the acromion and above the greater tubercle of the humerus.

Patient Positioning Place the patient sitting upright on a stretcher with the affected arm hanging by their side. A weight may be placed in the patient's hand to distract and open the joint cavity.

Needle Insertion and Direction Insert an 18 gauge needle into the midpoint of the groove (**Figure 77-5A**). Direct the needle medially and slightly posterior. Advance the needle to a depth of 2.5 to 3 cm.

Remarks Immediately below the deltoid muscle is the subacromial bursa. This bursa does not communicate with the shoulder joint. The needle must be inserted 2.5 to 3 cm to ensure the needle is in the shoulder joint and not in the subacromial bursa. The anterior or posterior approach to shoulder arthrocentesis avoids this potential problem.

Joint Injection A maximum volume of 15 mL may be instilled into this joint. A maximum dose of 30 mg of corticosteroids may be instilled into this joint.

GLENOHUMERAL JOINT (SHOULDER) ARTHROCENTESIS, POSTERIOR APPROACH

Landmarks Identify the spine of the scapula (**Figure 77-6**). Follow the spine laterally until it turns anterior to become the acromion process. This posterior border of the acromion process is the landmark for this technique. Locate the coracoid process of the scapula, just inferior to the lateral third of the clavicle.

Patient Positioning Place the patient sitting upright on a stretcher. Place the palm of the hand of the affected shoulder on the anterior surface of the opposite shoulder. The arm and forearm should be held against the chest. This position maximally opens the posterior joint space.

Needle Insertion and Direction Place the nondominant thumb on the posterior border of the acromion process. Place the nondominant index finger on the coracoid process. Insert an 18 gauge needle 1 to 2 cm below the thumb and parallel to the floor (**Figure 77-6**). Aim the needle toward the tip of the index finger, approximately 30° medially. Advance the needle to a depth of 2 to 3 cm.

US Probe Placement Position the patient as described above. Place the US transducer across the posterior aspect of the shoulder in a transverse orientation (**Figure 77-7**). The marker may be directed medially or laterally. The echogenic cortex of the humeral head is visible along with the adjacent glenoid rim (**Figure 77-8**). The joint fluid is visible as an anechoic area between these two bony structures (**Figure 77-8**). Insert and advance the needle from the lateral edge of the US transducer, oriented along the long axis of the transducer, and into the joint fluid.

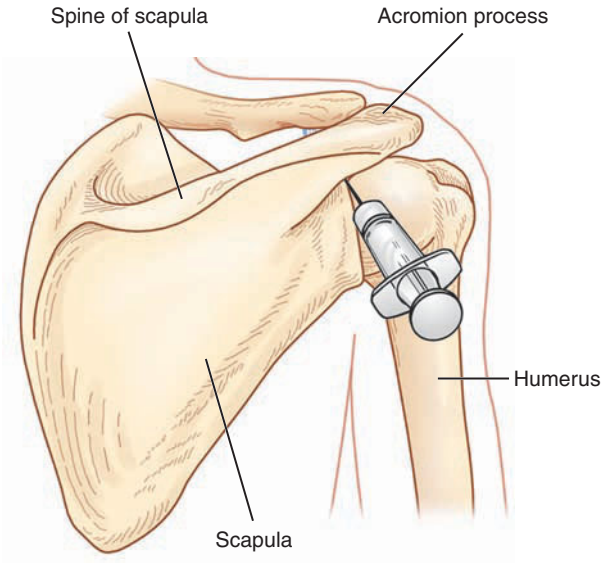


FIGURE 77-6. Posterior approach for shoulder joint arthrocentesis.

Remarks This is felt by some physicians to be the preferred approach to shoulder arthrocentesis. The needle will pierce the deltoid and infraspinatus muscles and avoid the tendons of the rotator cuff. This approach avoids the anxiety associated with the patient observing the large needle and syringe used for the procedure during the anterior or lateral approach. The posterior joint capsule is much thinner and more easily penetrated than the anterior joint capsule. There are no significant neurovascular structures that may be injured from this approach.



FIGURE 77-7. In the posterior approach to the shoulder, the US transducer is placed in a transverse orientation.



FIGURE 77-8. US image of the posterior shoulder. The hypoechoic joint fluid (*asterisk*) is located between the echogenic cortices of the humeral head (*arrow*) and the glenoid rim (*arrowhead*).

Joint Injection A maximum volume of 15 mL may be instilled into this joint. A maximum dose of 30 mg of corticosteroids may be instilled into this joint.

HUMERORADIOULNAR JOINT (ELBOW) ARTHROCENTESIS, LATERAL APPROACH

Landmarks The lateral epicondyle of the humerus, the radial head, and the tip of the olecranon process of the ulna are the landmarks for this joint (**Figure 77-9A**). Flex the elbow 45° and pronate the hand. Pronation of the hand stretches the radial collateral ligament, moves the radial nerve out of the needle's path, and widens the synovial cavity. Identify the depression between the landmarks. The depression is located proximal to the radial head in the area where no bony structures are palpated.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Flex the elbow 45° and pronate the hand. This position widens the joint cavity and avoids any neurovascular structures.

Needle Insertion and Direction Insert a 22 gauge needle perpendicular to the skin and into the depression just proximal to the radial head (**Figure 77-9A**). Advance the needle to a depth of 0.75 to 2.0 cm.

Remarks This is the preferred approach for elbow arthrocentesis. It avoids tendons and neurovascular structures, thereby reducing the risk of complications.[13]

Joint Injection A maximum volume of 5 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.

HUMERORADIOULNAR JOINT (ELBOW) ARTHROCENTESIS, POSTERIOR APPROACH

Landmarks Identify the top of the olecranon process of the ulna and the triceps muscle insertion into the olecranon process (**Figure 77-9B**). Find the point just proximal to the top of the olecranon and just lateral to the triceps insertion. This point is the landmark for insertion of the needle.

Patient Positioning Place the patient sitting upright on a stretcher. Flex the elbow 90° with the hand supinated. The forearm and hand should be resting on a tabletop or on the patient's leg.

Needle Insertion and Direction Approach the joint from the posterolateral surface with the needle parallel to the radial shaft. Insert a 22 gauge needle perpendicular to the skin at the landmark (**Figure 77-9B**). Advance the needle to a depth of 1 cm.

US Probe Placement Position the patient as described above. Place the US transducer along the posterior elbow in a longitudinal orientation, with the marker toward the shoulder (**Figure 77-10**). This produces an image with the humerus located to the left, the olecranon located to the right, the olecranon fossa at the bottom, and the triceps tendon passing from side to side across the top of the screen (**Figure 77-11**). Keep the US transducer in the same orientation and slide it laterally to move off the triceps tendon. The joint effusion will be visualized in or adjacent to the olecranon fossa (**Figure 77-11**). Be sure to avoid the ulnar nerve which passes over the medial epicondyle, by choosing a location as far lateral as possible.[33,34] Advance the needle over the superior edge of the US transducer and into the synovial fluid.

Remarks Potential complications include needle penetration of the triceps tendon or the radial nerve. This approach is reserved for patients in whom the lateral approach is contraindicated.

Joint Injection A maximum volume of 5 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.

HUMERORADIOULNAR JOINT (ELBOW) ARTHROCENTESIS, POSTEROLATERAL APPROACH

Landmarks Identify the lateral surface of the olecranon process of the ulna and the lateral epicondyle of the humerus (**Figure 77-9C**). Find the indentation just lateral to the olecranon and just distal to the lateral epicondyle. This point is the landmark for the insertion of the needle.

Patient Positioning Place the patient sitting upright on a stretcher. Flex the elbow 90° with the hand supinated. The forearm and hand should be resting on a tabletop or on the patient's leg.

Needle Insertion and Direction Approach the joint from the posterolateral surface with the needle parallel to the radial shaft. Insert a 22 gauge needle perpendicular to the skin at the landmark (**Figure 77-9C**). Advance the needle to a depth of 1 cm.

Remarks This approach is an alternative when the lateral approach is contraindicated.

Joint Injection A maximum volume of 5 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.

RADIOCARPAL JOINT (WRIST) ARTHROCENTESIS

Landmarks Identify the lunate bone (**Figure 77-12**). Palpate the middle (third) metacarpal and follow it proximally until a

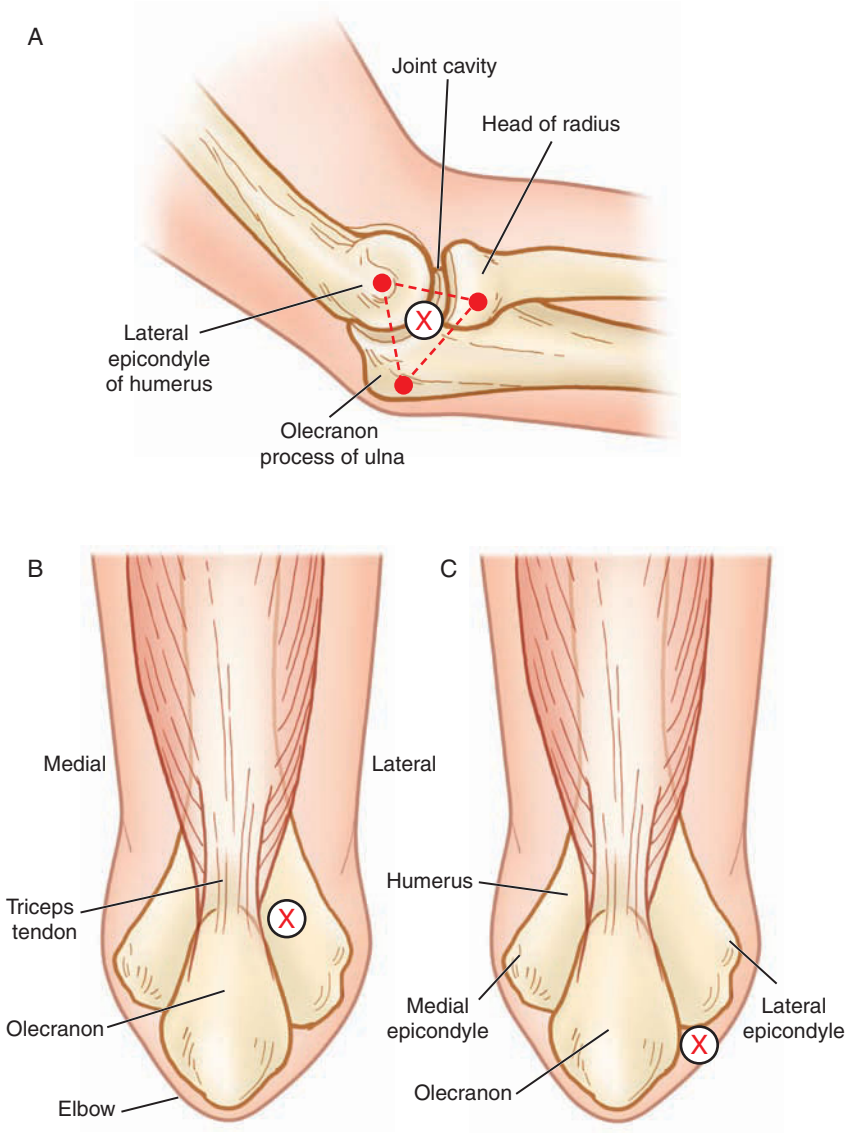


FIGURE 77-9. Elbow joint arthrocentesis. The site of needle insertion is represented by an "⊗". **A.** Lateral approach. **B.** Posterior approach. **C.** Posterolateral approach.



FIGURE 77-10. The US transducer is placed along the posterior elbow in a longitudinal orientation.

rounded bean-like elevation is felt (**Figure 77-12A**). This is the lunate. Palpate the indentations proximal and distal to the lunate. The indentation proximal to the lunate is the landmark for needle insertion.

Alternatively, identify Lister's tubercle and the extensor pollicis longus (EPL) tendon (**Figure 77-12B**). Lister's tubercle is a bony prominence in the center of the dorsal aspect of the distal radius. The EPL tendon can be found lateral (radial) to Lister's tubercle. If the EPL tendon is difficult to find, extend the hand and thumb against resistance and it will become prominent. The lunate is the bony prominence distal to Lister's tubercle. The indentation proximal to the lunate is the landmark for needle insertion.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Pronate the hand with the wrist in slight (e.g., 20°-50°) flexion and ulnar deviation (**Figure 77-12A**). The palm of the physician's nondominant hand should be holding the patient's palm. Reidentify the lunate with the nondominant thumb.

Needle Insertion and Direction Insert a 22 gauge needle perpendicular to the skin in the indentation proximal to the lunate (**Figure 77-12A**). Advance the needle to a depth of 0.75 to 1.25 cm.

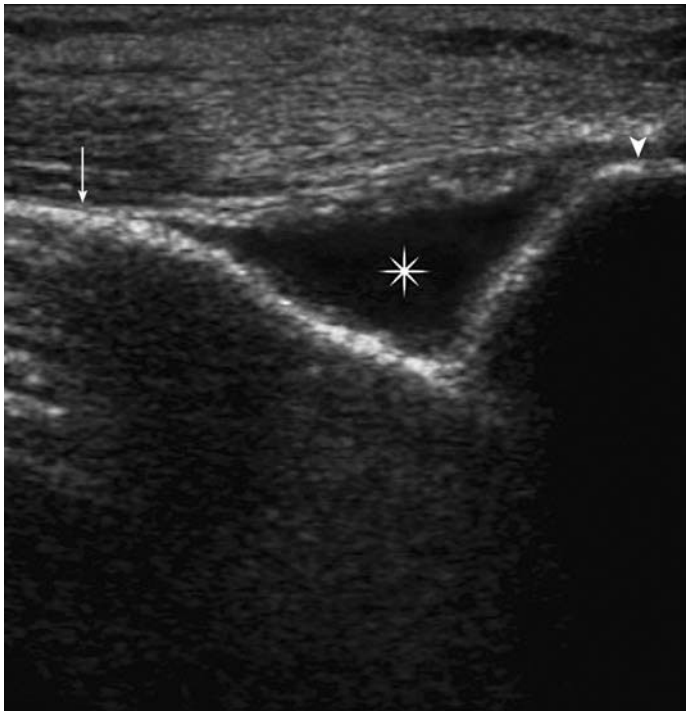


FIGURE 77-11. US image of the longitudinal view of an elbow joint. The hypoechoic joint fluid (*asterisk*) is located between the echogenic cortices of the humerus (*arrow*) and the olecranon (*arrowhead*).

Alternatively, insert the needle in the indentation just distal to Lister's tubercle and ulnar to the EPL tendon (**Figure 77-12B**).

Remarks The preferred, and easiest, method is to identify the lunate and then insert the needle in the indentation just proximal to the lunate.

Joint Injection A maximum volume of 2 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.

INTERCARPAL JOINT ARTHROCENTESIS

Landmarks Identify the lunate bone (**Figure 77-12**). Palpate the middle (third) metacarpal and follow it proximally until a rounded bean-like elevation is felt (**Figure 77-12A**). This is the lunate. Palpate an indentation distal to the lunate and proximal to the base of the third metacarpal. This indentation is the landmark for insertion of the needle.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Pronate the hand with the wrist in slight (e.g., 20°-50°) flexion and ulnar deviation (**Figure 77-12A**). The palm of the physician's nondominant hand should be holding the patient's palm. Reidentify the landmarks with the nondominant thumb.

Needle Insertion and Direction Insert a 22 gauge needle perpendicular to the skin in the indentation distal to the lunate. Advance the needle to a depth of 0.5 to 1.0 cm.

Remarks The joints between the carpal bones are all connected to each other (**Figure 77-13**). Fluid aspirated from one of these joints is representative of all the joints. Likewise, injection of one joint allows the pharmaceutical to be distributed to all the joints.

Joint Injection A maximum volume of 1.5 mL may be instilled into this joint. A maximum dose of 15 mg of corticosteroids may be instilled into this joint.

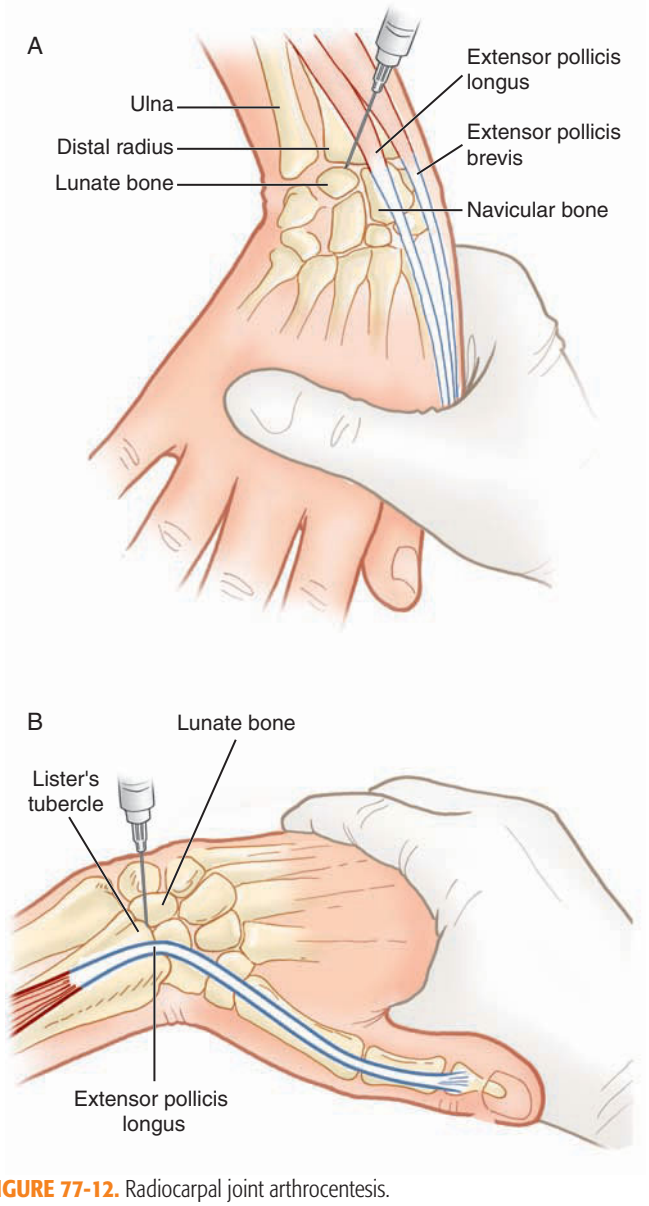


FIGURE 77-12. Radiocarpal joint arthrocentesis.

CARPOMETACARPAL JOINT OF THE THUMB ARTHROCENTESIS

Landmarks The base of the first metacarpal and the abductor pollicis longus (APL) tendon are the landmarks for this joint (**Figure 77-14**). Identify the radial aspect of the base of the first metacarpal. Have the patient rotate the affected thumb to help identify the joint. Identify the APL tendon by extending the patient's thumb against resistance.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Flex the thumb into the palm with the tip of the thumb touching the fifth metacarpal head. Clench the remaining fingers into a fist (**Figure 77-14A**).

Needle Insertion and Direction Insert a 22 gauge needle into the joint space at the radial aspect of the base of the first metacarpal and just lateral (radial) to the APL tendon (**Figure 77-14A**). Direct the tip of the needle toward the base of the fourth metacarpal. Advance the needle to a depth of 0.5 to 1.0 cm.

Remarks If difficulty is encountered when inserting the needle, try an alternative thumb position (**Figure 77-14B**). Flex the first

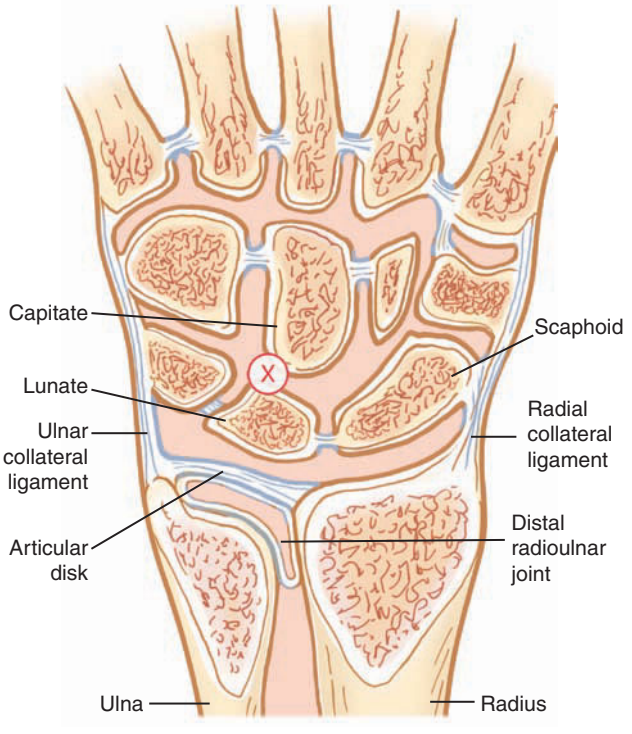


FIGURE 77-13. Intercarpal joint arthrocentesis. Coronal section through the wrist and hand demonstrating that the joints between the carpal bones are all interconnected. The site of needle insertion is represented by an "⊗".

carpometacarpal joint 45° and apply traction to the distal thumb. This in-line traction will enlarge the joint cavity and allow easier access.

Joint Injection A maximum volume of 1.5 mL may be instilled into this joint. A maximum dose of 10 mg of corticosteroids may be instilled into this joint.

METACARPOPHALANGEAL JOINT ARTHROCENTESIS

Landmarks Identify the metacarpophalangeal (MCP) joint and the extensor digitorum tendon (**Figure 77-15A**). The MCP joint can be located just proximal to the prominence at the base of the proximal phalanx of the finger. Identify the extensor tendon by having the patient extend the finger against resistance.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Pronate the hand and abduct the fingers. Grasp the finger and apply distal traction.

Needle Insertion and Direction Insert a 22 gauge needle into the dorsal joint space just medial or lateral to the extensor tendon (**Figure 77-15B**). Direct the tip of the needle toward the center of the joint. Advance the needle to a depth of 0.3 to 0.5 cm.

Remarks The application of distal traction often causes a depression to appear on both sides of the extensor tendon (**Figure 77-15B**). These depressions can be used as landmarks for the site of needle insertion into the joint cavity.

Joint Injection A maximum volume of 1 mL may be instilled into this joint. A maximum dose of 5 mg of corticosteroids may be instilled into this joint.

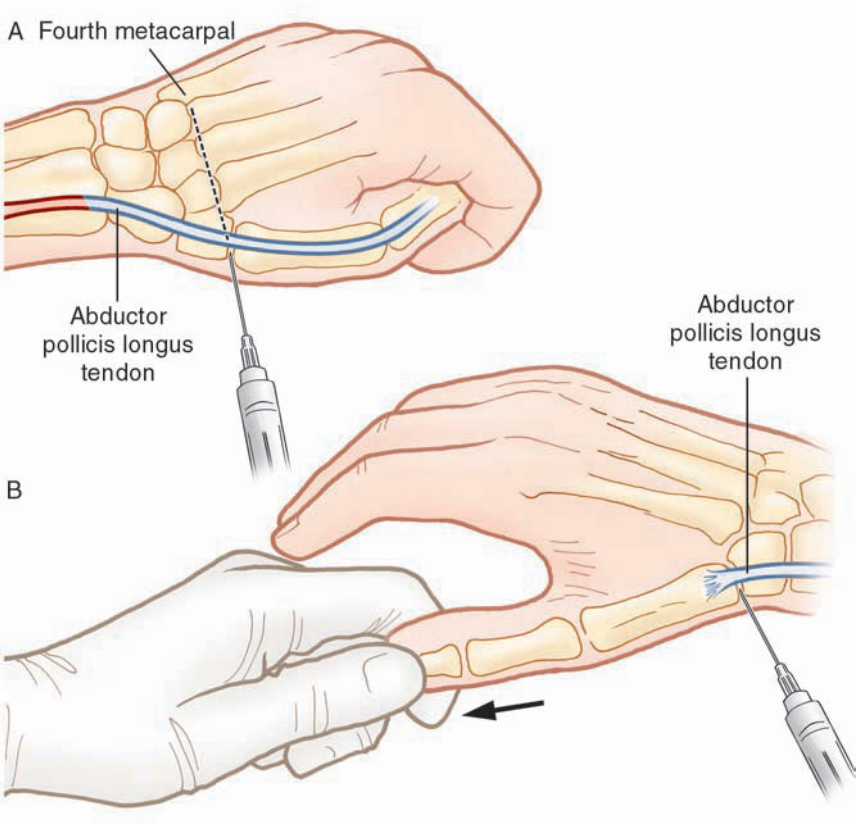


FIGURE 77-14. Carpometacarpal joint of the thumb arthrocentesis. **A.** Recommended approach. The *dotted line* represents the proper direction for needle insertion, toward the base of the fourth metacarpal. **B.** An alternative technique. The arrow represents the application of distal traction.

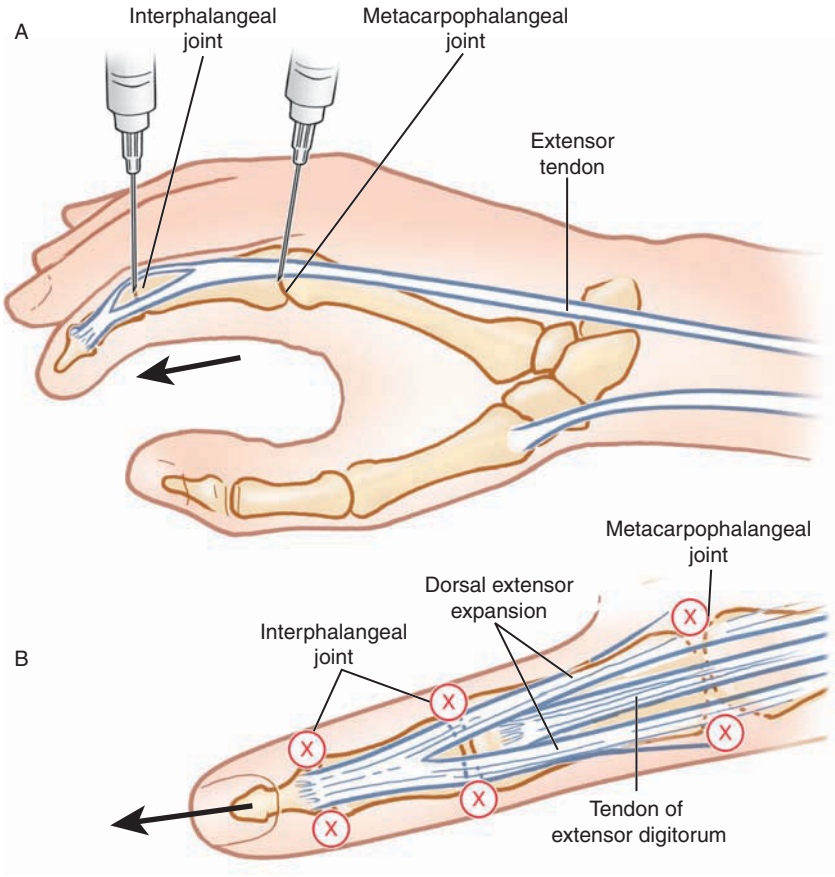


FIGURE 77-15. Arthrocentesis of the metacarpophalangeal and interphalangeal joints. **A.** Proper needle placement. **B.** Distal traction will cause dimpling of the skin in the areas noted by the "⊗". These areas of skin dimpling are the landmarks for needle insertion. The *arrow* represents the application of distal traction.

INTERPHALANGEAL JOINT OF THE FINGER ARTHROCENTESIS

Landmarks Identify the interphalangeal (IP) joint and the extensor tendon (**Figure 77-15A**). The IP joint can be located just proximal to the prominence at the base of the middle or distal phalanx of the finger. Identify the extensor tendon by having the patient extend the finger against resistance.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Pronate the hand and abduct the fingers. Grasp the finger and apply distal traction.

Needle Insertion and Direction Insert a 22 gauge needle into the dorsal joint space just medial or lateral to the extensor tendon (**Figure 77-15B**). Direct the tip of the needle toward the center of the joint. Advance the needle to a depth of 0.3 to 0.5 cm.

Remarks The application of distal traction often causes a depression to appear on both sides of the extensor tendon (**Figure 77-15B**). These depressions can be used as landmarks for the site of needle insertion into the joint cavity. The joints are small and normally contain almost no synovial fluid. When inflamed or infected, the joint cavity may contain up to 2 mL of synovial fluid.

Joint Injection A maximum volume of 1 mL may be instilled into this joint. A maximum dose of 5 mg of corticosteroids may be instilled into this joint.

HIP JOINT ARTHROCENTESIS, ANTERIOR APPROACH

Landmarks Identify the anterior superior iliac spine (ASIS) and the femoral pulse (**Figure 77-16**). The landmark for insertion of the needle is 2 to 3 cm below the ASIS and 2 to 3 cm lateral to the femoral artery pulse.

Patient Positioning Place the patient supine on a stretcher with the affected leg internally rotated and the knee slightly flexed.

Needle Insertion and Direction Insert a 3.5 in., 18 gauge needle at the landmark (**Figure 77-16**). Direct the tip of the needle posteromedially. Insert the needle at a 60° angle to the skin of the thigh. Advance the needle until bone is encountered. Slightly withdraw the needle and begin aspirating the synovial fluid.

US Probe Placement Position the patient as described above.[49] Place the US transducer over the anterior hip and aligned with the long axis of the femoral neck, with the marker in a superior-medial direction and aimed toward the umbilicus (**Figure 77-17**).[44] The echogenic cortex of the femoral head is visible to the left of the image and the femoral neck to the right. The concave transition between these two areas is the anterior synovial recess.[44,49] Synovial fluid will be seen in this recess and tends to displace the joint capsule anteriorly (**Figure 77-18**).[43] Insert the needle from the inferolateral edge of the US transducer and advance it into the synovial fluid.

Remarks This approach is technically easier and recommended by many authors. A long spinal needle is usually required for this procedure. Use caution as the needle may injure the articular cartilage. This procedure should be performed by an Orthopedist, a Rheumatologist, or a Radiologist under fluoroscopic guidance if US is not available in the ED.

Joint Injection A maximum volume of 10 mL may be instilled into this joint. A maximum dose of 40 mg of corticosteroids may be instilled into this joint.

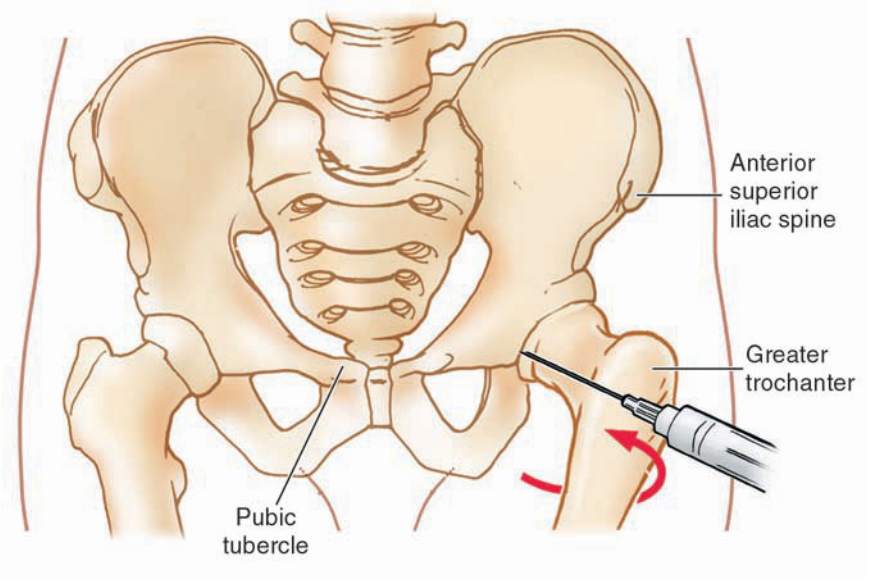


FIGURE 77-16. Anterior approach for hip joint arthrocentesis. The *curved arrow* represents internal rotation of the femur.

HIP JOINT ARTHROCENTESIS, LATERAL APPROACH

Landmarks The greater trochanter is the landmark for this technique (**Figure 77-19**). Place the patient supine with the affected leg internally rotated. Palpate the greater trochanter.

Patient Positioning Place the patient supine on a stretcher with the affected leg internally rotated (**Figure 77-19A**). Identify the greater trochanter and hold it between the thumb and index finger. A second patient position may be used for the alternative approach (**Figure 77-19B**). Place the patient lying on the unaffected side. Flex



FIGURE 77-17. The US transducer is placed anteriorly over the hip joint and aligned with the long axis of the femoral neck.



FIGURE 77-18. US image of a hip effusion. The hypoechoic effusion (*asterisk*) is located in the anterior synovial recess between the echogenic cortices of the femoral neck (*arrowhead*) and the femoral head (*arrow*).

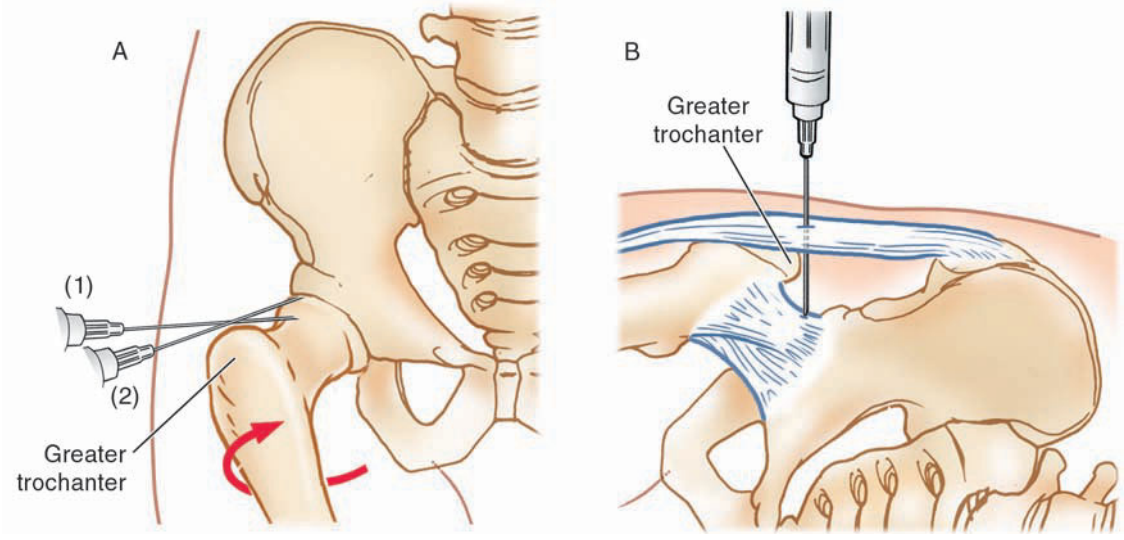


FIGURE 77-19. Lateral approach for hip joint arthrocentesis. **A.** The patient is supine with the leg internally rotated (*curved arrow*). A needle is inserted above the greater trochanter and advanced until the femoral neck is encountered (1). The needle has been withdrawn slightly, redirected cephalad, then readvanced into the joint cavity (2). **B.** An alternative approach.

the unaffected, lower leg 90°. Fully extend the upper, affected, leg with a pillow supporting the ankle.

Needle Insertion and Direction Insert a 3.5 in., 18 gauge needle just superior to the superior margin of the greater trochanter (**Figure 77-19A**). Advance the needle horizontally, parallel to the stretcher, until it contacts the femoral neck. Withdraw the needle 2 to 4 mm and redirect it slightly cephalad. Advance the needle while applying negative pressure to the syringe until synovial fluid enters the syringe. Stop advancing the needle and continue to aspirate the synovial fluid. The alternative technique requires the insertion of the needle perpendicular to the skin and 1 cm proximal to the greater trochanter (**Figure 77-19B**). Advance the needle until the femoral neck is contacted. Withdraw the needle 2 mm and begin aspirating synovial fluid.

Remarks In the morbidly obese, the greater trochanter may not be palpable. This approach is technically more difficult than the anterior approach. The advantage of this approach is that the articular cartilage will not be in the needle's path and so avoids injury. This procedure should be performed by an Orthopedist, a Rheumatologist, or a Radiologist under fluoroscopic guidance.

Joint Injection A maximum volume of 10 mL may be instilled into this joint. A maximum dose of 40 mg of corticosteroids may be instilled into this joint.

PATELLOFEMOROTIBIAL JOINT (KNEE) ARTHROCENTESIS, SUPRAPATELLAR APPROACH

Landmarks Identify the midpoint of the superolateral or superomedial border of the patella (**Figure 77-20A**). Either of these landmarks may be used as the site for needle insertion.

Patient Positioning Place the patient supine on a stretcher with the affected knee fully extended.

Needle Insertion and Direction Insert an 18 gauge needle through the midpoint of the superolateral or superomedial border of the patella (**Figure 77-20A**). Direct the tip of the needle toward the intercondylar notch of the femur. Advance the needle to a depth of 1.5 to 3.0 cm.

US Probe Placement Position the patient as described above. A small roll or towel can be used behind the knee to provide slight flexion. Place the US transducer in a longitudinal orientation superior to the patella, with the probe marker directed toward the patient's head. The cortex of the distal femur is visible as a bright echogenic line to the right of the image and the synovial fluid is visible deep to the quadriceps tendon (**Figure 77-21**). Keep the US transducer in oriented longitudinally and slowly slide it medially or laterally to move off the quadriceps tendon. Insert the needle from the superior edge of the US transducer in a longitudinal orientation and direct it toward the synovial fluid. Advance the needle into the synovial fluid.

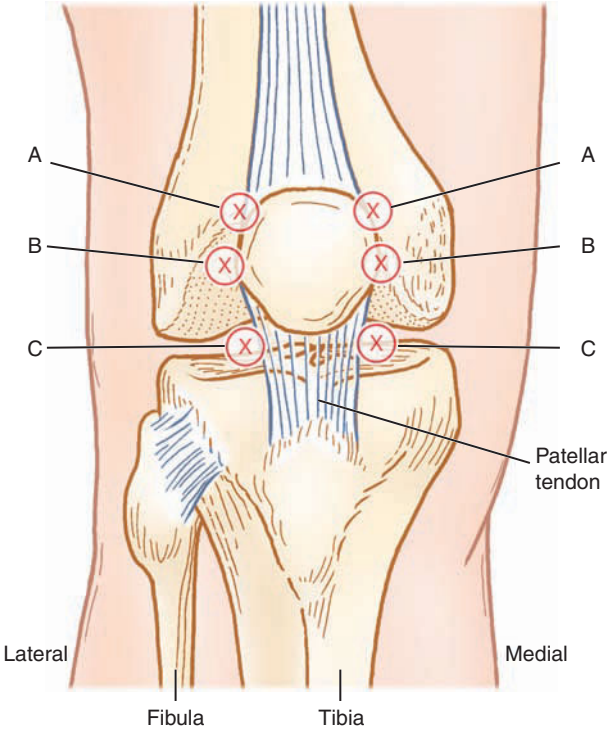


FIGURE 77-20. Knee joint arthrocentesis. The site of needle insertion is represented by an "⊗". **A.** Medial and lateral suprapatellar approach. **B.** Medial and lateral parapatellar approach. **C.** Medial and lateral infrapatellar approach.



FIGURE 77-21. US image of a knee effusion. The hypoechoic joint fluid (*asterisk*) is located above the echogenic cortex of the distal femur (*arrow*).

Remarks The needle enters the suprapatellar bursa and avoids any potential damage to the articular cartilage. The bursa is a direct continuation of the synovial cavity.[44] There are no neurovascular structures of significance to injure with this approach. If the knee effusion is minimal, synovial fluid may not be able to be aspirated from this approach. Approximately 10% of the population has a plica completely separating the suprapatellar bursa from the knee joint. If this variation exists in the patient, the bursa fluid will not represent synovial fluid.

Joint Injection A maximum volume of 10 mL may be instilled into this joint. A maximum dose of 40 mg of corticosteroids may be instilled into this joint.

PATELLOFEMOROTIBIAL JOINT (KNEE) ARTHROCENTESIS, PARAPATELLAR APPROACH

Landmarks Identify the midpoint of the lateral or medial border of the patella (**Figure 77-20B**). Either of these landmarks may be used as the site for needle insertion.

Patient Positioning Place the patient supine on a stretcher with the affected knee fully extended.

Needle Insertion and Direction Insert an 18 gauge needle just below the midpoint of the lateral or medial border of the patella (**Figure 77-20B**). Direct the needle perpendicular to the long axis of the leg and aimed toward the intercondylar notch of the femur. Advance the needle to a depth of 1 to 2 cm.

Ultrasound Probe Placement Place the US transducer oriented longitudinally, and either lateral or medial to the patella, with the marker directed toward the patients head. Identify the joint fluid. Slowly rotate the US transducer to a horizontal orientation to identify the area with the largest anechoic fluid collection.[44] Insert and advance the needle along the superior edge of the US transducer and into the joint fluid.

Remarks The easiest site for arthrocentesis is the medial parapatellar region. There are no disadvantages to using the medial parapatellar site.

Joint Injection A maximum volume of 10 mL may be instilled into this joint. A maximum dose of 40 mg of corticosteroids may be instilled into this joint.

PATELLOFEMOROTIBIAL JOINT (KNEE) ARTHROCENTESIS, INFRAPATELLAR APPROACH

Landmarks Identify the inferior border of the patella and the patellar tendon (**Figure 77-20C**). The tendon is a thick band that passes from the inferior border of the patella to the tibial tuberosity.

Patient Positioning Place the patient sitting upright on a stretcher with the affected knee bent 90° over the edge of the bed and the leg hanging freely and unsupported.

Needle Insertion and Direction Insert an 18 gauge needle 0.5 cm below the inferior border of the patella at the level of the joint line and just medial or lateral to the patellar tendon (**Figure 77-20C**). Direct the needle perpendicular to the long axis of the leg and aimed toward the intercondylar notch of the femur. Advance the needle to a depth of 1.5 to 2.0 cm.

Remarks The weight of the leg helps to open the joint cavity. The risk of injury to the articular cartilage is minimal. This approach was popular in the past but is not often used today. Do not pierce the patellar tendon with the needle.

Joint Injection A maximum volume of 10 mL may be instilled into this joint. A maximum dose of 40 mg of corticosteroids may be instilled into this joint.

TIBIOTALAR JOINT (ANKLE) ARTHROCENTESIS, ANTEROLATERAL APPROACH

Landmarks Identify the joint cavity, the lateral malleolus, and the extensor digitorum longus (EDL) tendons (**Figure 77-22**). The joint cavity is located below the distal edge of the fibula and between the bases of the malleoli. Extend the toes against resistance to identify the EDL tendons. Palpate the base of the lateral malleolus.

Patient Positioning Place the patient sitting upright or supine on a stretcher. The patient can also be placed sitting upright on a stretcher with affected knee bent 90° over the edge of the bed and the foot hanging freely and unsupported. Plantar flex the ankle.

Needle Insertion and Direction Insert a 22 gauge needle perpendicular to the fibular shaft at the level of the base of the lateral malleolus; midway between the malleolus and the lateral border of the EDL tendon (**Figure 77-22A**). Advance the needle to a depth of 0.5 to 1.0 cm.

US Probe Placement Position the patient as described above. Place the US transducer over the anterior tibiotalar joint in a longitudinal orientation, with the marker of the US transducer toward the patient's head (**Figure 77-23**).[44,46] Manipulate the US transducer with a slight rotation until the echogenic cortex of the tibia and talus bones are both visible (**Figure 77-24**). The tibia is visible to the left of the image and the talus to the right. During the rotation of the US transducer, note the location of the dorsalis pedis artery and the extensor tendons so that they may be avoided when inserting the needle.[44] The joint fluid is visible as a hypoechoic area in the V-shaped recess between the tibia and talus (**Figure 77-24**). Insert the needle at the inferior end of the transducer and advance it into the joint fluid.

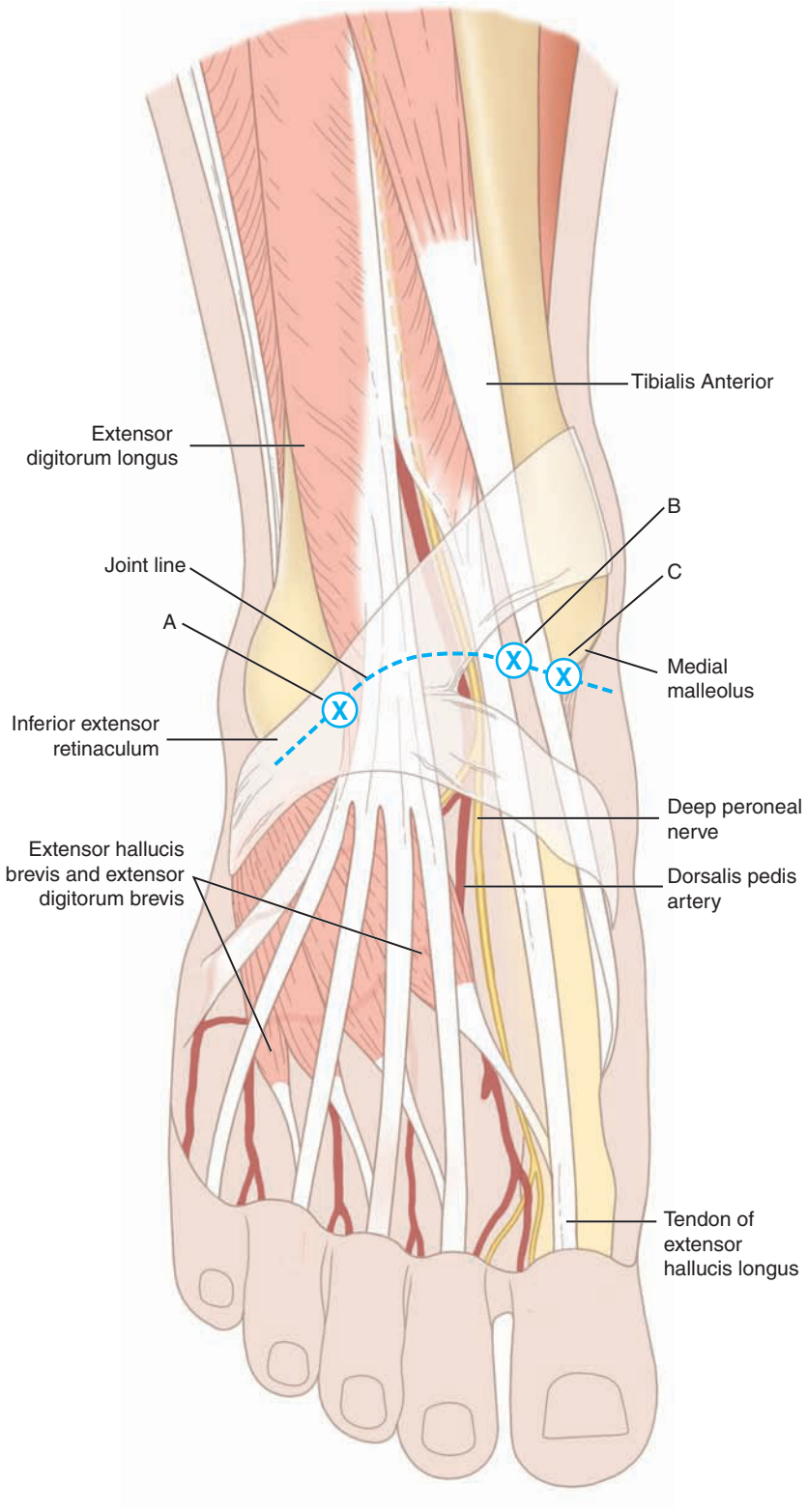


FIGURE 77-22. Arthrocentesis of the ankle joint. The site of needle insertion is represented by an "⊗". **A.** Anterolateral approach. **B.** Anteromedial approach. **C.** An alternative technique for the anteromedial approach.

Remarks This approach avoids potential injury to the dorsalis pedis vessels and the deep peroneal nerve.

Joint Injection A maximum volume of 3 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.

TIBIOTALAR JOINT (ANKLE) ARTHROCENTESIS, ANTEROMEDIAL APPROACH

Landmarks Identify the joint cavity, the medial malleolus, and the tendons of the tibialis anterior (TA) and the extensor hallucis longus



FIGURE 77-23. The US transducer is placed over the anterior tibiotalar joint in a longitudinal orientation.

(EHL) muscles (**Figure 77-22**). The joint cavity is located below the distal edge of the tibia and between the bases of the malleoli. Extend the great toe against resistance to identify the EHL tendon. Plantar flex the ankle against resistance to identify the TA tendon. Palpate the base of the medial malleolus.

Patient Positioning Place the patient sitting upright or supine on a stretcher. The patient can also be placed sitting upright on a stretcher with the affected knee bent 90° over the edge of the bed and the foot hanging freely and unsupported. Plantar flex the ankle to use the EHL tendon as the landmark for the procedure. Alternatively, plantar flex the ankle and invert the subtalar joint to use the TA tendon as the landmark for the procedure.

Needle Insertion and Direction Insert a 22 gauge needle perpendicular to the tibial shaft at the level of the base of the malleolus and medial to the EHL tendon (**Figure 77-22B**). Alternatively, insert the needle medial to the TA tendon (**Figure 77-22C**).

Ultrasound Probe Placement The procedure is exactly as described above for the anterolateral approach.

Remarks If using the EHL tendon as the landmark, use caution to avoid the dorsalis pedis vessels and the deep peroneal nerve that usually lie immediately lateral to the EHL tendon.

Joint Injection A maximum volume of 3 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.



FIGURE 77-24. US image of the longitudinal view of the anterior tibiotalar joint. The hypoechoic joint fluid (*asterisk*) is located in the recess between the echogenic cortices of the tibia (*arrow*) and talus (*arrowhead*).

SUBTALAR JOINT ARTHROCENTESIS

Landmarks Identify the tip of the medial malleolus. Palpate the sustentaculum tali of the calcaneus (**Figure 77-25**). It is approximately 1.5 to 2.0 cm below the tip of the medial malleolus.

Patient Positioning Place the patient supine on a stretcher with the foot held at a right angle to the leg. Externally rotate the hip until the medial malleolus is pointing upward.

Needle Insertion and Direction Insert a 22 gauge needle immediately above and slightly posterior to the sustentaculum tali (**Figure 77-25**). Advance the needle to a depth of 1.5 to 2.0 cm.

Remarks This is a difficult procedure because the joint space is very small. Fluoroscopy may be required to gain entry into the joint cavity. This procedure is seldom performed in the ED. US is not very helpful due to the small joint space and irregular body surfaces.

Joint Injection A maximum volume of 1.5 mL may be instilled into this joint. A maximum dose of 20 mg of corticosteroids may be instilled into this joint.

INTERTARSAL JOINT ARTHROCENTESIS

There are no specific landmarks for the many intertarsal joints. Radiographs are required to identify the location of a specific joint. Plain radiographs are often not helpful and fluoroscopic guidance is required. For these reasons, arthrocentesis of these joints is not routinely performed in the ED. Some authors

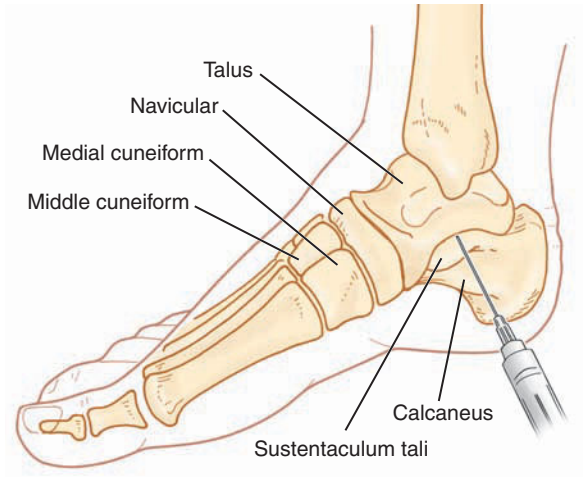


FIGURE 77-25. Subtalar joint arthrocentesis.

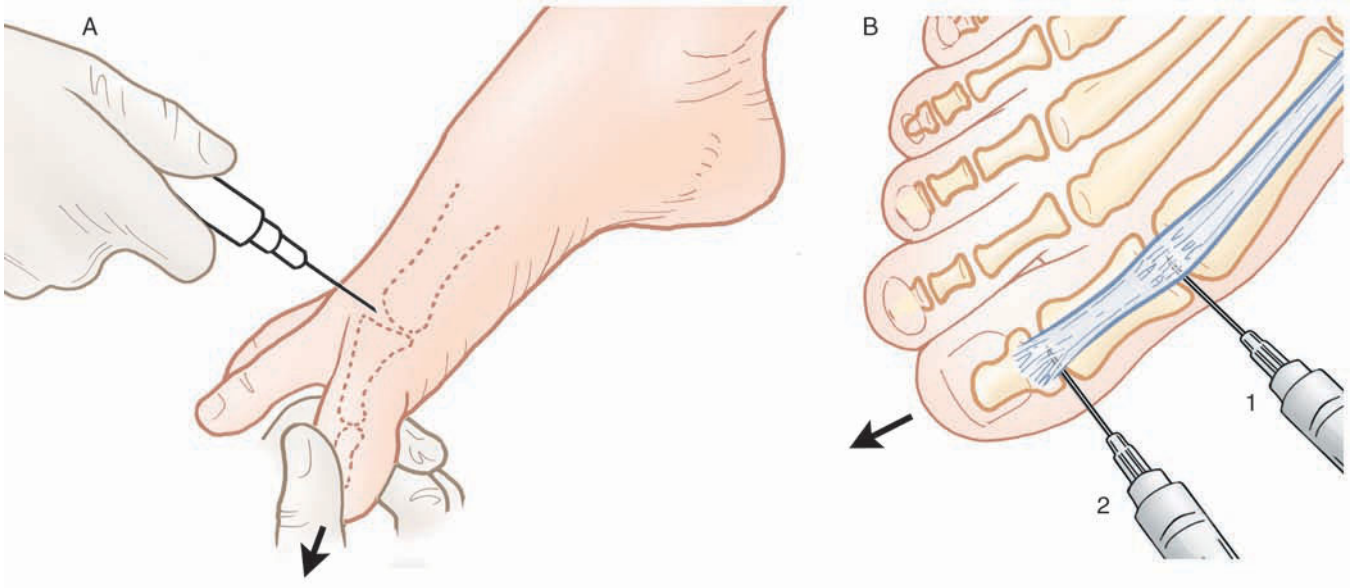


FIGURE 77-26. Arthrocentesis of the metatarsophalangeal and interphalangeal joints of the foot. **A.** The ankle is plantar flexed. The affected toe is flexed 15° to 20° at the metatarsophalangeal joint and distal traction is applied (*arrow*). **B.** The needle is inserted just inferomedial or inferolateral to the extensor tendon at the level of the metatarsophalangeal joint (1) or the interphalangeal joint (2).

recommend probing the general area of the joint with a needle until it enters the joint cavity. This is extremely painful for the patient and risks injury to the articular cartilage. Therefore, this technique cannot be recommended.

METATARSOPHALANGEAL JOINT ARTHROCENTESIS

Landmarks Identify the metatarsophalangeal (MTP) joint and the extensor tendon. The MTP joint can be located just proximal to the prominence at the base of the proximal phalanx of the toe. Identify the extensor tendon by having the patient extend the toe against resistance.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Plantar flex the foot. Grasp and plantar flex the toe 15° to 20° and apply distal traction (**Figure 77-26A**).

Needle Insertion and Direction Insert a 22 gauge needle into the dorsal joint space and just medial or lateral to the extensor tendon (**Figure 77-26B**). Direct the tip of the needle toward the center of the MTP joint. Advance the needle to a depth of 0.3 to 0.5 cm.

Remarks The application of distal traction often causes a depression to appear on both sides of the extensor tendon. These depressions can be used as landmarks for the site of needle insertion into the joint cavity.

Joint Injection A maximum volume of 1.5 mL may be instilled into this joint. A maximum dose of 10 mg of corticosteroids may be instilled into this joint.

INTERPHALANGEAL JOINT OF THE TOE ARTHROCENTESIS

Landmarks Identify the IP joint and the extensor tendon. The IP joint can be located just proximal to the prominence at the base of the middle or distal phalanx of the toe. Identify the extensor tendon by having the patient extend their toes against resistance.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Plantar flex the foot. Grasp and plantar flex the toe 15° to 20° and apply distal traction (**Figure 77-26A**).

Needle Insertion and Direction Insert a 23 gauge needle into the dorsal joint space and just medial or lateral to the extensor tendon (**Figure 77-26B**). The needle should be aimed toward the center of the joint. Advance the needle to a depth of 0.3 to 0.5 cm.

Remarks The application of distal traction often causes a depression to appear on both sides of the extensor tendon. These depressions can be used as landmarks for the site of needle insertion into the joint cavity. These joints are small and normally contain almost no synovial fluid. When inflamed or infected, the joint cavity may contain up to 1.5 mL of synovial fluid.

Joint Injection A maximum volume of 1 mL may be instilled into this joint. A maximum dose of 5 mg of corticosteroids may be instilled into this joint.

JOINT INJECTION TECHNIQUE

A joint may be injected with corticosteroids and/or local anesthetic solution to relieve pain and inflammation. Identify the anatomic landmarks, prepare the patient, and insert the needle as if performing an arthrocentesis. Inject the pharmaceutical(s), remove the needle, and apply a bandage.

Occasionally, synovial fluid may be required for analysis prior to the injection of pharmaceuticals. A prospective randomized study in rheumatoid arthritis patients found that aspirating all the synovial fluid prior to therapeutic steroid injection reduced the risk of relapse, led to better outcomes, and increased symptom relief.[40] Identify the anatomic landmarks, prepare the patient, and insert the needle as if performing an arthrocentesis. Aspirate the synovial fluid into the syringe. With the needle still in the joint, grasp the hub of the needle with a hemostat. Remove the original syringe containing the aspirated synovial fluid. Attach a second syringe containing the pharmaceutical(s) to be injected into the synovial cavity. Reaspirate to confirm that the needle tip remained within the synovial cavity. Inject the pharmaceutical(s). While injecting, no resistance should be felt. If resistance is encountered, the needle may have dislodged from the joint cavity. Remove the needle, reinsert it into the synovial cavity, aspirate to confirm proper positioning, and then inject the pharmaceutical(s). After injection, remove the needle and apply a bandage.

ULTRASOUND AND PEDIATRIC HIP EFFUSIONS

The evaluation of a suspected pediatric hip joint effusion requires the consideration of septic arthritis versus a toxic synovitis. Toxic synovitis is the most common cause of hip pain in children and occurs most frequently in ages 3 to 6 years old. It is a nonpyogenic, inflammatory condition of the joint synovium with an unknown etiology. It occurs most commonly in the hip joint and occasionally in the knee joint.

In contrast, septic arthritis is an acute pyogenic inflammation that occurs most commonly in children below the age of 4 years, with a peak incidence between 6 and 24 months of age. Useful studies include serum WBC, ESR, blood cultures, plain films, CT, MRI, and US. The aspiration and analysis of joint fluid being most critical.

US has been shown to be as accurate as MRI in detecting effusions. It is most easily performed using an anterior approach with the US transducer oriented in the sagittal plane and parallel to the femoral neck. An effusion is visible as a convex rather than concave joint capsule that is greater than 5 mm in thickness. Transudates are more often hypoechoic whereas exudates and hemorrhage are usually more hyperechoic.[35]

Many imaging techniques such as plain film, scintigraphy, MRI or CT are useful to help differentiate these two clinical entities. MRI and CT provide the highest quality information. However, these studies usually require sedation or even general anesthesia in young children due to the long exam times and requirement for no motion. US-guided hip joint arthrocentesis is a useful bedside imaging technique to help solve this problem. **US can only detect the presence of a joint effusion. It cannot reliably differentiate between the two entities without further joint fluid aspiration and analysis. US should not be used as a primary means to rule out a suspected septic arthritis.**[35]

AFTERCARE

There is no special care or precautions required after performing an arthrocentesis. Pain can be relieved with the use of ice, elevation, and nonsteroidal anti-inflammatory drugs. Joint injection, on the other hand, often requires some precautions. Some recommend limiting joint activity for 4 to 8 hours if an anesthetic solution is injected into a joint. An anesthetized joint, especially weight-bearing joints, may be susceptible to further injury when the joint has decreased sensation. Injection of corticosteroids into a joint cavity often requires a period of immobilization. This discussion is beyond the scope of this chapter. The readers should refer to a rheumatology or orthopedic textbook, or the medical literature, for this information.

COMPLICATIONS

Complications can occur with joint aspiration and/or injection (**Table 77-3**). Most of the complications are minor. Significant complications are rare; but they do occur.

TABLE 77-3 Complications Associated with the Aspiration and/or Injection of Joints

Allergic reactions
Bleeding
Cartilage injury
Dry tap
Infection
Joint instability
Needle-associated complications
Corticosteroid-induced complications
Vasovagal reactions

ALLERGIC REACTIONS

Allergic reactions can occur from hypersensitivity to the local anesthetic solution. Symptoms can range from mild itching and urticaria to circulatory collapse and death. Severe allergic reactions are extremely rare but may occur. Taking a thorough history can prevent many allergic reactions. The preservative in the local anesthetic solution is often the cause of the allergic reaction. Local anesthetic solutions containing no preservatives are an alternative. Some authors believe local anesthesia is not required, as the pain of anesthetic injection is equal to performing the procedure without injectable anesthesia.[4,12] If one is concerned about a potential allergic reaction associated with local anesthetic solutions, topical ice, or vapor coolant is an acceptable alternative to nothing. A solution of 1% to 2% diphenhydramine can also be used as an injectable local anesthetic agent for the skin and soft tissues. Do not inject diphenhydramine into the joint cavity as this can result in a significant inflammatory reaction and possible crystal deposition.

CARTILAGE INJURY

The articular cartilage can be damaged from improper needle insertion or needle movement within the joint cavity. The actual incidence of cartilage injury is unknown. The cartilage is avascular and injuries do not heal. Damaged cartilage can lead to focal degenerative changes and be a nidus for future infection. Injury to the articular cartilage can be prevented with a few simple steps. Select a site for the procedure and a needle path that avoids the articular cartilage. Aspirate as you slowly enter the joint cavity and stop inserting the needle when synovial fluid enters the syringe. There is no advantage to plunging the needle into the middle of the joint cavity. Avoid needle movement once the joint cavity has been entered. Finally, do not try to completely aspirate all the fluid within the joint cavity.

DRY TAP

A needle inserted into a joint does not always guarantee fluid will be aspirated.[14] A dry tap can occur due to improper needle placement, small or absent effusion, mechanical obstruction, or chronic inflammation.

A dry tap can result from improper needle placement. If the needle is not within the joint cavity, no fluid will be aspirated. Slightly withdraw the needle and reinsert it at a different angle. Alternatively, remove the needle, re-identify the anatomic landmarks, and then reinsert the needle.

One of the most common reasons for a dry tap is the lack of an effusion or a small one. It may be difficult on physical examination to determine if an effusion is present. This is especially true if the patient is obese or if a large amount of subcutaneous edema is present. Try using the non-syringe-bearing hand to "milk" fluid toward the needle while aspirating. Alternatively, if a small effusion is suspected, inject a small amount of sterile saline into the joint cavity. Allow the saline to remain for 30 to 60 seconds, then aspirate the fluid.

Synovial fluid may be loculated or inaccessible by the chosen site of needle entry if the joint has been previously injured. Choose an alternate approach or site to enter the joint cavity. This may facilitate synovial fluid aspiration.

Mechanical obstruction can result in a dry tap. Gently move the needle tip to determine if it can move freely. If it does not, it may be caught or embedded in cartilage, periosteum, or synovium. Withdraw the needle 1 to 2 mm and reaspirate. The needle may also be within the intraarticular fat pad. Slightly withdraw the needle and reaspirate. A plica may be obstructing the lumen of the needle. Rotate the needle and reaspirate. If no fluid is aspirated, slightly advance the needle and reaspirate. If still no fluid is obtained, attempt an alternate approach or reconsider if an effusion is present and if the procedure is actually required.[31]

The synovial fluid itself may be the cause of a dry tap. The presence of purulent fluid or fluid with debris may clog the needle. Remove the needle and repeat the procedure with a larger gauge needle. If the needle clogs during the aspiration, try reinjecting a small amount of the synovial fluid to dislodge the obstruction and then reaspirate. A larger gauge needle may be required to complete the procedure.

Aspiration of synovial fluid from a chronically inflamed joint may be problematic. The synovium may undergo fatty replacement known as lipoma arborescens. Long-standing inflammatory fluid may be resorbed, leaving a thick gelatinous material that is difficult to aspirate. In these cases, arthrocentesis should be referred to the experienced clinician or a consultant.

HEMORRHAGE

Significant bleeding is extremely rare. External hemorrhage can be controlled with direct pressure over the puncture site. Hemarthroses are usually small, self-limited, and only require observation. If a significant hemarthrosis or external hemorrhage occurs, treatment may be required to reverse the anticoagulant or replace clotting factors. The readers should refer to another source for management of these complications, as a detailed discussion is beyond the scope of this chapter.

Arthrocentesis can be safely performed in patients who are anticoagulated or have a bleeding disorder. The most experienced EP should perform the procedure to limit any potential complications and bleeding. Also reconsider if the procedure must be done immediately in the ED. The only true indication to perform an arthrocentesis in a coagulopathic patient in the ED is to rule-out a septic joint.

INFECTION

Infection of a sterile joint can occur when the needle penetrates unclean skin, cellulitic skin, infected subcutaneous tissues, or skin lesions. If proper aseptic technique is used, the risk of infecting a sterile joint occurs in less than 1:10,000 arthrocenteses.[4] The risk of infection is negligible when the skin is properly cleansed, aseptic technique is used, and the skin is not punctured through an obvious infection or through a skin lesion that may harbor microorganisms.

HYPODERMIC NEEDLE-ASSOCIATED COMPLICATIONS

The hypodermic needle can be the source of complications in rare circumstances. The needle may separate from the hub during the procedure and require a minor surgical procedure to recover it.[15] The needle tip may be advanced too deep and become embedded in the bony skeleton surrounding the joint. Upon withdrawing the syringe, the needle tip may break off and remain embedded in the bone or the needle may separate from the hub.

CORTICOSTEROID-INDUCED COMPLICATIONS

Corticosteroid-induced complications can be acute or chronic.[3,4,16–18] **The most severe acute complication is injection of corticosteroids into an infected joint. A septic arthritis must be ruled out prior to instillation of corticosteroids into a joint cavity.** Other local complications include steroid arthropathy, Charcot arthropathy, osteonecrosis, aseptic necrosis, tissue atrophy, tendon rupture, fat necrosis, formation of calcifications, joint instability, intraneural injection, and postinjection flare. Systemic complications include flushing, pancreatitis, posterior subcapsular cataracts, and hyperglycemia. Due to the potential for complications, many clinicians defer corticosteroid injections to the Orthopedist, Rheumatologist, or Sports Medicine consultant.

VASOVAGAL REACTIONS

The patient may experience an increase in vagal tone from apprehension, needle phobias, and/or pain. Vasovagal reactions are relatively common and may be associated with light-headedness and/or fainting. To prevent secondary injury to the patient, arthrocentesis should be performed with the patient on a stretcher or in a chair that reclines. These vasovagal reactions are self-limited and only require reassurance.

SYNOVIAL FLUID ANALYSIS

Hailed as the most valuable test in rheumatology, synovial fluid analysis provides essential diagnostic information for the appropriate management and treatment of urgent and emergent arthritic conditions.[4,30] It has been established as a fundamental component to the complete and appropriate work-up of arthritic diseases. With the possibility of potential joint destruction and chronic disability, **the role of synovial fluid analysis in the expedient diagnosis and treatment of acute joint disease cannot be overemphasized.**

Controversy exists concerning what constitutes the appropriate guidelines for a "routine" synovial fluid analysis.[4,19–21,23,24] This controversy arises from multiple issues that include the clinical scenario, physician competency with appropriate arthrocentesis techniques, the sensitivity and specificity of individual tests, the availability and proficiency of laboratories, and cost. Classification schemes have been established based upon gross, microscopic, biochemical, and microbiological analyses. The most traditional and cited classification for synovial fluid is normal, noninflammatory, inflammatory, septic, or hemorrhagic (**Table 77-4**).[4,19,20,24] Despite the controversy that exists with guidelines and classification schemes, **it is critical to differentiate between an inflammatory and noninflammatory process, with the intent of expediting the diagnosis and treatment of a possible infectious etiology**.[4]

A detailed discussion of synovial fluid analysis is beyond the scope of this book. A brief discussion of the most essential components that can be performed in the ED will be presented.

PATHOPHYSIOLOGY OF SYNOVIAL FLUID

Synovium refers to the 1 to 3 cell thick structure that lines the joint space and terminates at the articular cartilage margin.[19] This structure overlies a highly vascularized subsynovium, both of which are supported by the dense fibrous joint capsule.[19] The synovium produces synovia, an ultrafiltrate of plasma that includes hyaluronate. The synovia serves to lubricate, nourish, and clear the metabolic waste of the avascular articular cartilage.[20] Synovial fluid has been demonstrated to possess potent bactericidal activity against the most common gram-positive organisms responsible for septic arthritis.[28]

TABLE 77-4 Synovial Fluid Analysis

	Normal	Noninflammatory	Inflammatory	Septic	Hemorrhagic
Gross analysis					
Color	Clear/yellow/straw	Straw/xanthochromic	Xanthochromic/cloudy/white	White/variable	Red
Clarity	Transparent	Transparent	Translucent/opaque	Opaque	Opaque
Viscosity	Very high	High	Low	Very low/variable	
Mucin clot	Good/firm	Fair-to-good/firm	Fair-to-poor/friable	Poor/friable	
Microscopic analysis					
Total leukocyte count (WBC/mm^3)	<150	<3000	3000–50,000	>50,000	
Polymorphonuclear leukocytes (%)	<25	<25	>70	>90	
Biochemical analysis					
Glucose (mg/dL)*	Normal	Normal	70–90	>90	
Protein (mg/dL)†	1.3–1.8	3–3.5	>4.0	>4.0	
Microbiological analysis					
Gram's stain	Negative	Negative	Negative	Positive‡	Negative
Culture	Negative	Negative	Negative	Positive‡	Negative
Differential diagnosis					
		Osteoarthritis	Rheumatoid arthritis	Bacterial infections	Trauma coagulopathy
		Traumatic arthritis	Acute crystal		Anticoagulant therapy
		Early rheumatoid arthritis	Synovitis		Tumor
			Viral arthritis		Charcot's arthropathy
		Avascular necrosis	Psoriatic arthritis		Hemangioma
		Crystal synovitis§	Reiter's syndrome		A-V malformation
		Osteochondritis dissecans	Arthritis of IBD**		Sickle cell disease
			SLE		Postsurgical
		SLE	Polyarteritis		Joint prosthesis
		Polyarteritis	Scleroderma		
		Scleroderma	Amyloidosis		
		Amyloidosis			

WBC, white blood cells; * and † variable interpretation (refer to the text); ‡ variable results depending on organism (refer to the text); § chronic or subsiding; SLE, systemic lupus erythematosus; **IBD, inflammatory bowel disease.

The synovium has been described as a double barrier in which molecules must pass through the endothelial microvasculature as well as the synovium and its matrix.[20] This double barrier is responsible for the retention of plasma protein. In the presence of an inflammatory process, the barrier is disrupted and protein can leak through the synovium. Difficulty arises in the diagnostic interpretation of protein and smaller molecules (i.e., sodium, chloride, urea, urate, and lactate) found in synovial fluid secondary to the effects of damaged endothelial permeability and variable lymphatic drainage.[20,23,24]

GROSS ANALYSIS OF SYNOVIAL FLUID

The color of synovial fluid varies depending on the amount of protein, blood, and breakdown products of hemoglobin. Normal synovial fluid usually appears clear to a straw or yellow color. Inflammatory and purulent synovial fluid may appear xanthochromic to white. Hemorrhagic synovial fluid is red and must be distinguished from a traumatic arthrocentesis. A traumatic aspiration usually clots and is more than often nonhomogenous.[19,20] A hematocrit may be sent on a bloody aspirate to distinguish between a traumatic tap and hemorrhagic fluid. A vein was pierced by the needle (i.e., traumatic tap) if the synovial fluid hematocrit is equal to the serum hematocrit.[20]

The following synovial fluid properties observed during bedside gross analysis were found to better predict a potentially septic joint when compared to synovial fluid cell count alone.[30]

The clarity of synovial fluid refers to the amount and type of particles within the fluid. Normal synovial fluid is usually transparent and newspaper print can be easily read through a glass tube containing this fluid.[19] Inflammatory and purulent synovial fluid is translucent to opaque secondary to the presence of leukocytes. Opaque fluid can also represent crystals and other particulate matter. Infected synovial fluid cannot be differentiated from noninfected synovial fluid based on gross appearance alone.[4]

Synovial fluid viscosity is determined by the intactness and concentration of hyaluronate. Viscosity can grossly be assessed by observing a drop of fluid fall from the tip of the needle. The "string" formed will normally be 5 to 10 cm in length.[22] In inflammatory and septic synovial fluid, the hyaluronidase is depolymerized and degraded.[20] The string formed in these conditions is shorter, or not formed at all, and the fluid falls as a drop. Processes resulting in a significant effusion without inflammation may also dilute hyaluronate without degrading it and result in decreased viscosity. Clotted white blood cells may enhance viscosity in the presence of inflammation.[20] EPs must be cautious with their interpretations of viscosity because even quantitative measures often fail to distinguish between inflammatory and noninflammatory states.[4]

The mucin clot test evaluates the degree of polymerization of hyaluronate.[4,19] The mucin clot test is performed by one of two methods. The first method involves mixing the supernatant of a centrifuged specimen with a few drops of glacial acetic acid. The second method involves mixing 1 mL of synovial fluid to 4 mL of 2% acetic acid. A "good" clot consists of a dense white precipitant that indicates a high degree of polymerization and a high viscosity.[19] A "poor" clot consists of little to no precipitate and suggests an inflammatory process that has depolymerized the hyaluronate. Controversy exists concerning the subjectiveness of the clot's endpoint.[4]

MICROSCOPIC ANALYSIS OF SYNOVIAL FLUID

The total leukocyte count, more than any other test, aids in distinguishing between an inflammatory, noninflammatory, and septic process.[20] Although a significant overlap may exist, the total leukocyte count can be used to identify synovial fluid as normal, noninflammatory, inflammatory, or septic (**Table 77-4**). Using this classification scheme, a total leukocyte count of less than 3000 cells/L is considered noninflammatory. A count between 3000 and 20,000 cells/L is considered inflammatory. The range of 20,000 to 50,000 cells/L may be inflammatory or septic. A count greater than 50,000 cells/L is considered septic until proven otherwise. **The overlap between categories is considerable and clinicians must be cautious of basing a diagnosis solely on the total leukocyte count.** Depending on the acuteness of the inflammation, several arthritic conditions such as gout, pseudogout, and rheumatoid arthritis may yield a significantly elevated total leukocyte count approaching 100,000 cells/L.[21] Immunocompromised hosts and some infectious diseases, such as tuberculosis and *Neisseria gonorrhoeae*, may have lower absolute counts than expected.[4]

The differential leukocyte count may further aid in distinguishing between inflammatory, noninflammatory, and septic synovial fluid. The cell count and differential (WBC) of the joint fluid is the best diagnostic test for septic arthritis, while the serum ESR and WBC perform poorer in the identification of infection.[37] However, using the traditional cut-off value of 50,000 WBC/mm^3 lacks sensitivity enough to safely rule-out a septic arthritis.[39] Inflammatory processes generally have greater than 70% neutrophils while septic synovial fluid has greater than 90% neutrophils.[19] Again, the overlap can be significant depending on the arthritic process and its acuteness. Crystal-induced processes may present with high neutrophil counts, while immunocompromised hosts, fungal infections, and tuberculosis may present with lower neutrophil counts.[4,21] **In general, a synovial fluid containing greater than 90% neutrophils in the presence of an elevated total leukocyte count should be highly suspicious of a septic process.** High eosinophil counts may suggest parasitic infection, allergic reactions, tumor, or Lyme disease.[20,23] High monocyte counts may suggest viral infection (e.g., rubella and hepatitis B) or serum sickness.[22]

Crystal identification is an essential component of synovial fluid analysis. Crystal identification requires the use of a polarized light microscope with higher-powered lenses and oil immersion capabilities. Crystals can be identified based on their shape, size, and birefringence. Birefringence is defined as the crystals' ability to bend the light passing through it into two distinct directions, negative or positive. The light's ability to bend negatively or positively is transformed into a specific color (yellow or blue) under the polarized microscope.[19,20] Caution must be taken as artifact and tissue debris can often imitate birefringent material.

Crystal analysis requires an experienced technician and is rarely if ever performed in the ED. Monosodium urate crystals are commonly seen in gout. These crystals are needle-shaped, 2 to 25 μm in length, and have strong negative birefringence. They may clump together in sheets.[22,25] Local anesthetic solutions have the ability to dissolve monosodium urate crystals. Therefore, the joint cavity should not be penetrated with the needle when anesthetizing the skin and subcutaneous tissue.[21] Calcium pyrophosphate dihydrate crystals are seen in pseudogout. These crystals are rhomboidal or rectangular, 2 to 10 μm in length, and have weak positive birefringence.[22,25] These crystals may be more difficult to detect than monosodium urate crystals because of the weaker birefringence. Cholesterol crystals may present in multiple forms and sizes. They are typically flat rhomboidal plates, 5 to 50 μm in length, and have both negative and positive birefringence.[22] Artifact "crystals" can be produced by a variety of substances. Corticosteroids can be detected weeks after injection and have variable shapes but no regular geometric form. Maltese crosses are strong birefringent particles that are secondary to multiple compounds such as talc powder, lipids, calcium oxalate, and dust.[22]

BIOCHEMICAL ANALYSIS OF SYNOVIAL FLUID

As discussed previously under the pathophysiology section, difficulty arises with the interpretation of total protein secondary to the effects of damaged endothelial permeability and variable lymphatic drainage.[20] In theory, the damage caused by an inflammatory process should increase the permeability of proteins into the synovial fluid. Multiple studies have shown that protein samples were only able to classify synovial fluid into an inflammatory or noninflammatory process in approximately 50% of the cases.[23] Furthermore, the total protein count was unable to differentiate among various groups of arthritides, including rheumatoid arthritis and osteoarthritis.[4]

Theoretically, inflammatory and infectious processes consume glucose and thus lower the level present in synovial fluid. One study has shown that glucose levels were able to classify synovial fluid into an inflammatory or noninflammatory process in less than 50% of cases.[23] In 50% of the septic joints analyzed, the glucose level was not significantly decreased. Another study reports glucose analysis having a sensitivity of 20% and specificity of 84% in detecting inflammatory joint disease.[24] Synovial fluid glucose levels can vary from serum glucose levels when taken less than 6 hours after oral intake.[24] **These studies are just a few of many that confirm synovial fluid glucose levels are not reliable to diagnose or rule out a septic joint.**

Other biochemical markers have been studied to elicit a marker to differentiate a septic from a nonseptic joint. These include lactate, lactic dehydrogenase, and numerous immunologic and inflammatory mediators. These biochemical markers, at present, are not sensitive or specific to rule out a septic joint. They are not recommended for routine synovial fluid analysis. Bacterial polymerase chain reaction (PCR) techniques with aspirated joint fluid are currently being studied and are theoretically superior tests, able to identify difficult to culture organisms. However, many drawbacks including high false positives due to contamination limit usage until further studies are done.[38]

MICROBIOLOGICAL ANALYSIS OF SYNOVIAL FLUID

The Gram's stain is an easily performed test that yields rapid results and can lead to the expedient diagnosis and treatment of a septic joint. The Gram's stain has a sensitivity of 50% to 70% for nongonococcal infections and less than 10% for gonococcal joint infections.[24] Although the sensitivity of this test is low, the specificity of the Gram's stain approaches 100%. This makes it an essential component of routine synovial analysis. *N. gonorrhoeae* is identified as a gram-negative intracellular diplococci. *Staphylococcus aureus* and *Streptococcus* are responsible for approximately 70% of nongonococcal septic arthritis and can be identified as gram-positive cocci in clusters and gram-positive cocci in chains, respectively.[27] Recent studies have identified an increased prevalence of MRSA-associated osteoarticular pathology such as septic arthritis and subperiosteal abscesses.[36] These diagnoses should be considered in patients with and without risk factors for community-acquired MRSA infection.[36]

Bacterial identification is essential when confronted with the possibility of a septic joint. Synovial fluid cultures have a sensitivity of 75% to 95% for nongonococcal bacteria and 10% to 50% for gonococcal bacteria in the absence of previous antibiotic treatment. Difficulty arises from the low sensitivity of cultures for some organisms, culture methods, specimen preparation, and the length of time for some bacteria to grow.[24] Recent advances with the use

of polymerase chain reaction techniques have shown increased sensitivity and specificity for detecting *N. gonorrhoeae*.[19,26]

SPECIMEN COLLECTION

Minimal quantities of synovial fluid can yield valuable information. Analysis can be performed with as little as two drops of synovial fluid.[21] The total leukocyte count, differential leukocyte count, crystal analysis, and Gram's stain can be obtained from the first drop while the second drop can be sent for cultures.[21] Unfortunately, few institutions or laboratories can perform synovial fluid analysis with only two drops of fluid.

The specimen may be transported for analysis by one of two methods. First, the syringe with the synovial fluid may be capped and sent to the laboratory. The laboratory technicians will then divide the specimen for analysis. Alternatively, the synovial fluid may be placed into tubes. A new sterile needle, different from the arthrocentesis needle, should be used to place fluid in the test tubes. A needle used for steroid injection should never be used secondary to the formation of a crystal-like substance.[4] Synovial fluid for microscopic analysis should be collected in test tubes with and without preservatives. Fluid should be placed in a Culturette or culture bottle for microbiological analysis. Synovial fluid for crystal analysis should be sent in a test tube with liquid heparin (green-topped tube) because EDTA and powdered anticoagulants interfere with crystal identification.[21] A red-topped tube containing no preservatives should be used to test for chemistries, serology, and viscosity. A tube with an anticoagulant (purple-topped tube) is used for the cell count, cell differential, and cytology. Prompt examination of fluid specimens is urgent to avoid the following problems: misdiagnosing borderline inflammatory fluids because of decreased WBC counts, not identifying crystals that dissolve with time, or over interpreting findings because of new, artifactual crystals.[29]

SUMMARY

Arthrocentesis is used to diagnose and make treatment decisions regarding a joint. It is a safe, easy, and simple procedure. Arthrocentesis is relatively painless and extremely beneficial to the patient. It may be performed for diagnostic information and/or therapeutic treatment. Analysis of the synovial fluid provides unique and valuable information about a joint. It is the only method to accurately and definitively diagnose or rule out a septic arthritis. Arthrocentesis is indicated to evaluate the cause of an arthritis or a joint effusion. All patients presenting with an acute monoarthritis or an acute, nontraumatic effusion should undergo arthrocentesis when the diagnosis is not clear based upon the history and physical examination.

78 Methylene Blue Joint Injection

Joseph E. Tonna, Heather H. Bohn, and Matthew R. Lewin

INTRODUCTION

Trauma can breach the integrity of the joint capsule and result in infection, long-term arthritis, and other serious and potentially permanent morbidity. Synovial joint fluid provides nutrition to the articular cartilage. Loss of synovial fluid without prompt joint capsule closure can lead to cartilage wasting. Additionally, any breach of the joint capsule, especially through dirty skin, can introduce environmental contaminants and risk septic inoculation of the joint. The injection of joints with methylene blue dye is a simple, rapid, and definitive way to assess joint capsule integrity in cases of periarticular trauma where the clinical examination is inconclusive.

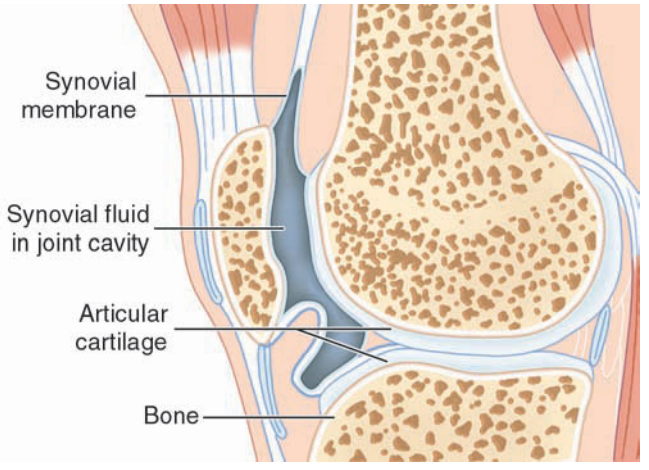


FIGURE 78-1. The anatomy of the knee joint.

ANATOMY AND PATHOPHYSIOLOGY

Synovial joints, such as those of the fingers, wrist, shoulder, and knee, consist of a fibrous capsule that overlies a thin, delicate synovial membrane (**Figure 78-1**). The synovial membrane is a highly vascular structure and the site of synovial fluid production. The synovial fluid provides nutritional support to the relatively avascular articular cartilage. Joint capsules contain varying volumes of fluid, and can be greatly expanded under conditions of inflammation or injection.

Methylene blue is a relatively safe and stable deep blue dye used in both chemistry and medicine. It has most frequently been used to treat methemoglobinemia and for marking skin and lymphatic tracts for oncologic surgery. It is readily oxidized, which has been the proposed basis for its vasoconstrictive effects.[1] Methylene blue can cause local necrosis without an immune sensitization when injected at full strength directly into tissues.[2]

The literature regarding the safety of methylene blue, even during direct intradermal injection, is supportive of its use. When used for lymph node mapping (i.e., direct intradermal and intraparenchymal injection), there is consistent evidence of local inflammatory reactions ranging from local wheal and flare (0.5% of patients) to focal erythema with induration (5% of patients).[3,4] Superficial tissue toxicity occurred in only 1.25% of patients.[4] These reactions were proportional to the concentration of methylene blue dye (ranging from a dilution of 1:1 to 1:7) and the superficiality of the injection.[4] Emergency Physicians (EPs) need to be aware of the potential complications arising from its use just as with any drug or dye introduced parenterally or intradermally. The tissue toxic effects are believed to be much less for intra-articular injections than direct intradermal injection.

INDICATIONS

The primary indication for injecting a joint with methylene blue dye is to assess the integrity of the articular joint capsule (**Figure 78-2**). This includes any of the following injuries in close proximity to a joint: skin laceration, a visible joint capsule through a wound, an open fracture, extravasation of serous or serosanguineous fluid

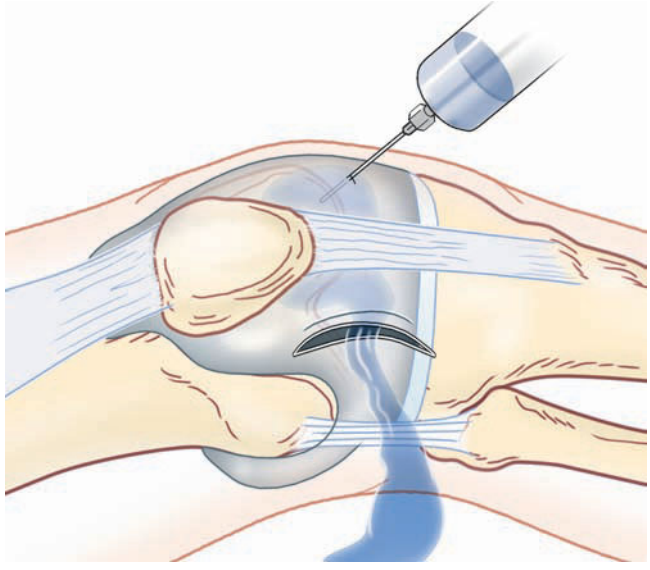


FIGURE 78-2. Methylene blue dye injection into a knee joint. The loss of capsule integrity allows the dye to flow out of the joint cavity.

from a wound, or a traumatic loading of the joint with evidence of a deformity or an acute effusion. The finger, wrist, elbow, shoulder, toe, ankle, knee, and hip (with varying success) joints can all be injected with methylene blue.

CONTRAINDICATIONS

There are few contraindications to injecting methylene blue dye into a joint. It should be avoided in patients with a known allergy to methylene blue. Patients with glucose-6-phosphate dehydrogenase (G6PD) deficiency can develop acute reactions as they do not generate sufficient NADPH to efficiently reduce methylene blue to leukomethylene blue. These individuals are prone to methylene blue-induced hemolysis, oxidative hemolysis, and hemolytic anemia. Methylene blue can itself initiate methemoglobin formation. It should not be injected intraspinally or intrathecally.

There are a few relative contraindications to the injection of methylene blue. It should be used cautiously in a patient with a known coagulopathy, especially a factor deficiency, to prevent intra-articular hemorrhage. Consider reversing the coagulopathy before the injection. Methylene blue should not be used if there is a lack of procedural knowledge or skill by the EP. Not all synovial joints can be injected due to structural instability.

Joint injection is not contraindicated, but often unnecessary, when definitive operative treatment of the joint is indicated. This includes a visibly open joint capsule, a fracture with obvious joint involvement, intra-articular air on radiographs, and an intra-articular foreign body. In many injuries, the articular capsule will be breached but not externally open to the environment if there is no wound tracking to the skin surface. These injuries may present with an acute joint effusion or radiographic evidence of a periarticular fracture with or without intra-articular air. Despite capsular rupture, methylene blue is not helpful in such cases.

EQUIPMENT

- Sterile drapes
- Sterile gloves
- Sterile gown
- Face mask
- Eye protection
- Povidone iodine or chlorhexidine solution
- Sterile gauze
- Sterile dressing or tape
- Sterile saline
- Sterile basin
- Local anesthetic solution (lidocaine 1% or 2%, etc.)
- 25 g or 27 g needles for infiltrating local anesthetic
- 18 g or 21 g needles for joint injection
- 5 mL syringes for local anesthetic injection
- 10 mL syringes for fingers or toe injection
- 30 mL syringes for wrist or elbow injection
- 60 mL syringes for hip, knee, or shoulder injection
- 1% methylene blue dye

PATIENT PREPARATION

A complete history and physical examination should be performed prior to the injection of methylene blue dye. The affected joint should be thoroughly assessed. Inspect the skin overlying the joint for breaks, infection, old scars, prior incisions, superficial lesions, or any wounds. Palpate the joint to identify any warmth, tenderness, or effusion. Evaluate the joint for any crepitation, deformity, ligamentous instability, or limitations in motion.

As with any nonemergent procedure, consent should be obtained from the patient or their representative. Ideally, the consent should be documented in the medical record and signed by the patient. The patient should be consented for both the arthrocentesis procedure (joint injection) as well as for the use of methylene blue.

Position the patient based on the specific joint to be injected and the approach to be used. Expose the joint and surrounding areas. Identify the anatomic landmarks required for proper needle placement. The landmarks may be difficult to identify on a swollen and tender joint. Compare the "affected" joint to the "normal" joint on the opposite side of the body. Identify the joint and a landmark on the normal joint and transfer this to the affected joint. Clean any dirt and debris from the skin. Scrub the needle insertion site with povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes or a clear sterile dressing to maintain sterility of the injection site (**Figure 78-3**). The rate of infection resulting from intra-articular injections is very low if sterile technique is used.[5]

A comfortable, relaxed patient will facilitate arthrocentesis, as tense muscles distort the anatomy of the joint and make anatomic palpation more difficult. Oral analgesics for the precipitating injury along with adequate local anesthesia for the procedure are often sufficient. The articular cartilage has no intrinsic pain fibers, but the synovial membrane, joint capsule, and skin are richly innervated. Adequate time should be taken for the infiltration of local anesthetic solution. The subcutaneous injection of local anesthetic solution is often most practical for larger joints such as the knee, shoulder, and hip. A regional block is often easier for small and more distal joints such as the finger and ankle.

Apply anesthesia to the skin and subcutaneous tissue using 1% lidocaine, topical vapor spray, or ice. The administration of some form of local anesthesia is recommended but not required. The most common local anesthetic used is a short-acting injectable anesthetic solution of 1% lidocaine. There is disagreement if the additional needle stick to administer the anesthesia causes as much discomfort as performing the procedure without any anesthesia. This decision is specific to each EP and patient.





FIGURE 78-3. An injury at the level of the knee joint. The patient is prepared by draping the lateral joint where the needle will be inserted (**A**) or by dressing the area with a sterile clear dressing (**B**).

Alternative methods of anesthesia include ice and topical vapor coolants. A sterile drape may be placed over the prepped skin and a bag of ice water placed over the drape. Remove the ice water bag and drape after 5 minutes and perform the procedure. Ethinyl chloride topical vapor coolant may be used as an anesthetic. Spray the solution onto the area of skin in which the needle will be inserted. Apply the spray from 6 in. above the skin. Spray until the skin turns white and frosty. This usually takes 5 to 10 seconds. Immediately perform the procedure, as the anesthesia lasts only 30 to 60 seconds.

Because of the aforementioned effects of methylene blue dye, it is common, though not universal, to dilute the dye in normal saline before the injection. Draw up one to two drops of 1% methylene blue dye into an appropriately sized syringe. Fill the remainder of the syringe with sterile saline to dilute the dye. Apply an appropriately sized needle for the joint to be injected onto the syringe.

TECHNIQUES

THE BASIC TECHNIQUE

The use of musculoskeletal ultrasound is useful to assist in arthrocentesis and has been shown to have many benefits including greater fluid aspiration and greater novice physician confidence. It does not result in more pain for the patient and takes minimal additional time to perform at the bedside. The reader is referred to an ultrasound technique text for full instruction, but a few important points are included here. Bone will appear hyperechoic and easily differentiated from muscle and subcutaneous tissue. Tendons will appear fibrillar in nature, like a bundle of drinking straws. Joint fluid will appear hypoechoic and dark. The "seagull sign" is a shape that can be seen on most joint images and represents the joint space between the articular surfaces of two opposing bones. It is a V-shaped hypoechoic area surrounded by hyperechoic bone. Once the landmarks are identified, the needle can be inserted with or without ultrasound guidance.

Apply the needle to the syringe and break the resistance. This avoids any sudden and painful movements of the needle within the joint cavity. Stretch the skin over the site where the needle will be inserted. Penetrate the skin briskly with the needle and enter the joint cavity. Gently aspirate synovial fluid to confirm proper needle position within the joint cavity. If bone is encountered, slightly withdraw the needle and re-advance it in a different direction. Grasp the hub of the needle with your finger or a hemostat. Remove the syringe while leaving the needle in place. Attach the syringe filled with the diluted methylene blue onto the needle.

Inject the methylene blue slowly into the joint cavity. There should be no resistance to flow if the needle is within the joint capsule. The injection should not be painful if the needle is within the synovial capsule. Observe the skin wound for extravasation of blue dye while it is being injected into the joint cavity. Remove the needle when the procedure has been completed. Apply a bandage to the skin.

Different joints will accommodate various amounts of injected volume. The knee may allow for 30 mL or more, whereas the finger may accommodate only 1 mL. It is only necessary to inject a minimal amount of dye before extravasation is seen. If the joint capsule is ruptured, a greater amount of fluid can be injected, as it will escape through the breach. In intact joints, the capsule will expand, increasing pressure and resistance to continued injection. There is often visibly swelling of the skin around the injected joint if there is no breach.

Complete a procedure note in the medical record. A sample procedure note is described below:

After informed consent, the skin overlying the_____joint was cleaned and prepped with povidone iodine solution. The skin was anesthetized with (_____mL of_____% lidocaine, ethyl chloride vapor coolant, ice for_____minutes). Using sterile technique, an_____gauge needle was inserted on the (supero-/infero-,medial/lateral/inferior/superior) surface of the joint. It was directed (supero-/infero-,medially/laterally/inferiorly/superiorly). _____mL of fluid was obtained. It was (thin, thick, yellow, clear, straw-colored, bloody, purulent, with debris, without debris). No complications were noted.

The joint was injected with_____mL of sterile saline containing less than 0.2 mL of 1% methylene blue dye. No complications were noted.

SPECIFIC SITES

Methylene blue joint injection can be reasonably accomplished at any joint. The concern for joint capsule rupture without concomitant obvious need for operative exploration and fixation is rare

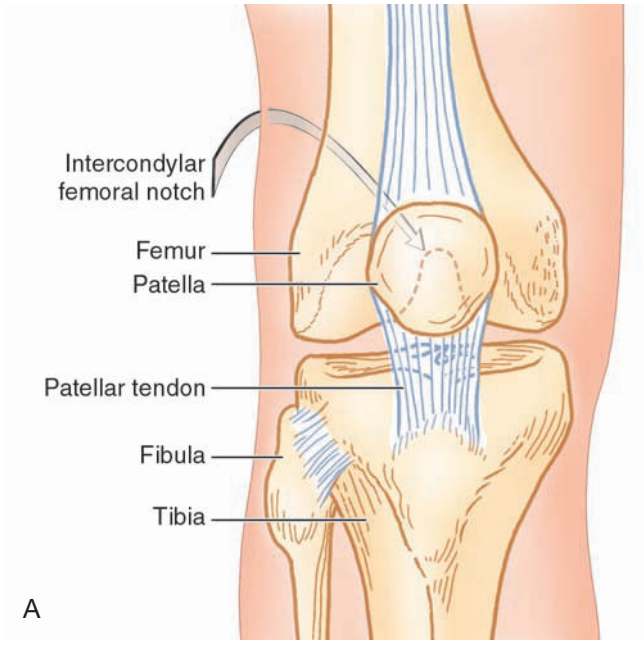






FIGURE 78-4. Methylene blue dye injection of the knee. **A.** Anatomy of the region. **B.** Palpating the boundaries of the patella. **C.** Injection of methylene blue using the medial parapatellar approach.

in joints other than the knee and fingers. The knee is relatively easy to inject while the fingers are more difficult. Arthrocentesis with methylene blue injection in the knee and finger is discussed below. The principles and techniques described below can be used on any synovial joint for which there is concern of a capsule breach and for which the EP feels competent to perform arthrocentesis. Please refer to Chapter 77 for the complete details of joint arthrocentesis.

PATELLOFEMOROTIBIAL JOINT (KNEE) ARTHROCENTESIS, PARAPATELLAR APPROACH

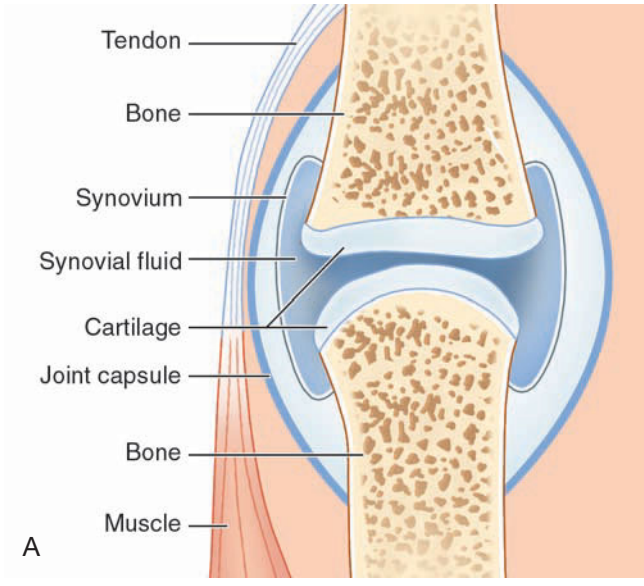
Landmarks The knee joint can be injected in a variety of locations and with the knee extended or flexed. Palpate the borders of the patella (superior, lateral, and inferior) and the patellar tendon (**Figures 78-4A & B**). Identify the midpoint of the lateral or medial border of the patella (**Figure 78-4B**). Either of these landmarks may be used as the site for needle insertion.

Patient Positioning Place the patient supine on a stretcher with the affected knee fully extended.

Needle Insertion and Direction Insert an 18 gauge needle just below the midpoint of the lateral or medial border of the patella (**Figure 78-4C**). Direct the needle perpendicular to the long axis of the leg and aimed toward the intercondylar notch of the femur. Advance the needle to a depth of 1 to 2 cm. Inject the methylene blue dye.

Ultrasound Probe Placement Start with probe placement longitudinally lateral or medial to the patella for a first view of the possible fluid collection. Then change the probe to a horizontal orientation, and rotate the probe like the hand of a clock around the patella 360° to discover the area with the largest anechoic fluid collection.

Remarks The easiest site for arthrocentesis is the medial parapatellar region. There are no disadvantages to using the medial parapatellar site. The lateral and medial parapatellar approaches are used with high relative success, most likely due to the large joint space and minimal accessory structures. Studies have demonstrated decreased success of the medial midpatellar approach (56%), relative to the lateral midpatellar (76%-93%) or the infrapatellar (71%-85% lateral and 73%-75% medial) approaches.[6,7]



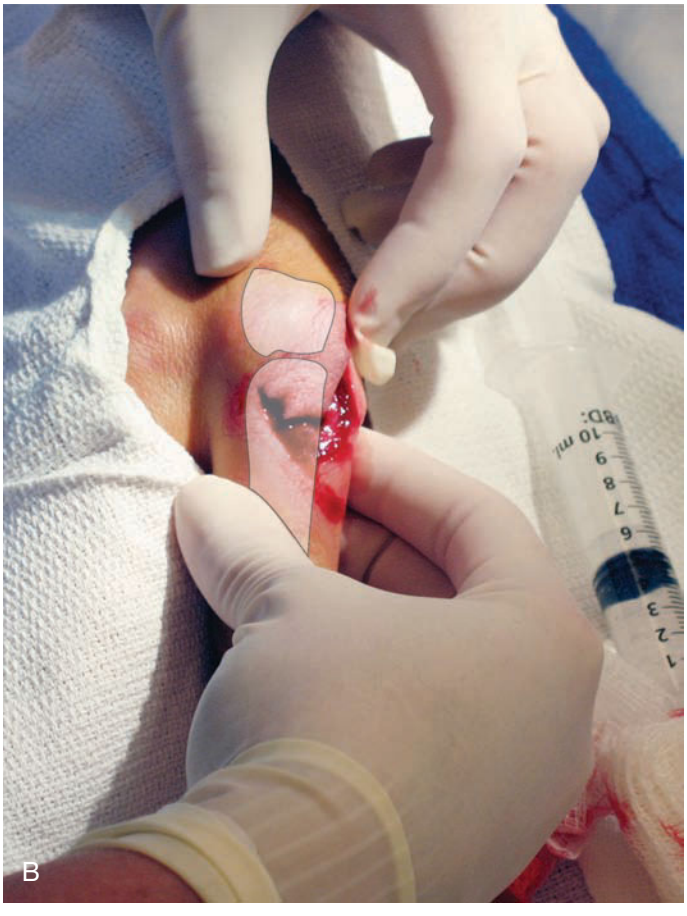




FIGURE 78-5. Methylene blue dye injection of the metacarpophalangeal (MCP) joint. **A.** Anatomy of the region. **B.** Palpation of the MCP joint. **C.** Injection of methylene blue.

METACARPOPHALANGEAL JOINT ARTHROCENTESIS

The relatively thin dermal and subcuticular layers over the phalanges often make one wonder about deep soft tissue avulsions or lacerations and the potential involvement of the joint capsule. Injection with methylene blue dye is an ideal method to assess joint capsule integrity. The success rate of arthrocentesis is much lower in the phalangeal joints than larger joints. The overlying ligaments and tendons are more prominent and the synovial capsule is smaller. A failure rate of 15% for finger arthrocentesis was found among skilled surgeons, and as high as 32% among first year residents.[8] Successful arthrocentesis was highest in the proximal interphalangeal joint compared to the distal interphalangeal joint or carpometacarpal joint of the thumb.

Landmarks Identify the metacarpophalangeal (MCP) joint and the extensor digitorum tendon (**Figures 78-5A & B**). The MCP joint can be located just proximal to the prominence at the base of the proximal phalanx of the finger. Identify the extensor tendon by having the patient extend the finger against resistance.

Patient Positioning Place the patient sitting upright or supine on a stretcher. Pronate the hand and abduct the fingers. Grasp the finger and apply distal traction.

Needle Insertion and Direction Insert a 22 gauge needle into the dorsal joint space just medial or lateral to the extensor tendon

(**Figure 78-5C**). Direct the tip of the needle toward the center of the joint. Advance the needle to a depth of 0.3 to 0.5 cm. Inject the methylene blue dye.

Remarks The application of distal traction often causes a depression to appear on both sides of the extensor tendon. These depressions can be used as landmarks for the site of needle insertion into the joint cavity.

Joint Injection A maximum volume of 1 mL may be instilled into this joint.

ASSESSMENT

The lack of methylene blue extravasation reassures the EP of an intact joint capsule. Extravasation of dye through the injury site is indicative of a ruptured joint capsule. These require exploration, high volume irrigation, and adjunctive medical treatment such as antibiotics. Although some wounds can be closed primarily in the Emergency Department after consultation with an Orthopedic or Hand Surgeon, open joints require management in the operating room.

A minimal amount of methylene blue dye needs to be injected before visible extravasation will occur. Upon injection, if no extravasation occurs, attempt to aspirate fluid. This may be difficult in small joints. Aspiration of blue fluid provides additional confirmation of intracapsular needle placement.

Given the not insignificant rate of ectopic needle placements (i.e., extrasynovial, intraligamentous, or intratendinous), a high index of clinical suspicion should be maintained for a joint capsule rupture, even in the face of a negative study. Clinical intuition and judgment should guide all decisions.

AFTERCARE

Arthrocentesis with methylene blue dye is a relatively benign procedure. The postprocedural care consists of monitoring for external bleeding and swelling. Musculoskeletal and neurovascular checks should be performed at the area and distal to the joint. Apply a bandage to the injection site. Pain should be minimal and analgesia can be achieved with oral nonnarcotic analgesics alone. In the setting of a significant traumatic injury, the patient may already be receiving opioid analgesics.

COMPLICATIONS

Complications are rare and include hemarthrosis, nerve injury, tendon injury, cartilage damage, and infection. External bleeding and nerve damage should be immediately apparent. A hemarthrosis may be insidious and appear with progressive swelling, pain with joint motion, and often without joint warmth. Tendon and cartilage damage may not be apparent for some time and present with joint stiffness or arthritis. Septic arthritis is the most concerning complication, evidenced by swelling, erythema, warmth, pain with range of motion, and systemic symptoms. Cellulitis may also complicate the procedure, appearing some time later with local warmth, erythema, and induration over the site. Please refer to Chapter 77 for a more complete discussion regarding the complications of arthrocentesis.

SUMMARY

Synovial joint injection with methylene blue dye provides the EP with a simple, rapid, and definitive method of assessing joint capsule integrity in cases of periarticular trauma. This procedure can determine between repairing a wound and sending a patient home or admitting a patient to the hospital for joint exploration and closure. Joint injection with methylene blue is technically simple with a low rate of complications.

79 Basic Principles of Fracture and Joint Reductions

Scott C. Sherman

INTRODUCTION

Orthopedic injuries are some of the most common presenting complaints facing the Emergency Physician (EP). Forces that cause injury can be large enough to result in fractures, displaced fractures, and joint dislocations. While each injury is different, some general principles can be applied to all displaced fractures and joint dislocations. For specific instructions on the techniques to reduce common fractures and dislocations, please refer to Chapters 80 through 91.

ANATOMY AND PATHOPHYSIOLOGY

The most common reason for a fracture to be displaced or a joint to be dislocated in a particular direction is the mechanism of injury. In the upper extremity, for example, a fall forward on an outstretched arm is the most common mechanism. Therefore, elbow dislocations occur most frequently in a posterior direction, distal radius fractures are most often Colles fractures, and supracondylar fractures are extension type fractures in 95% of cases.[1]

The deforming forces of muscles and ligaments also play an important role in the appearance of a fracture. Injury results in the muscles surrounding a fracture to contract or spasm. This leads to further deformity such as shortening, angulation, and rotation of the bone fragments distal and proximal to the fracture. For example, depending on the location of a humeral shaft fracture, the bone fragments will displace in different directions (**Figure 79-1**). Fractures that occur between the insertions of the pectoralis major and deltoid muscles will result in a proximal humerus that is adducted from contraction of the pectoralis major muscle and a distal humerus that is abducted from contraction of the deltoid muscle (**Figure 79-1A**). Conversely, if the fracture occurs distal to the deltoid insertion, the proximal humerus will be abducted from contraction of the deltoid muscle and the distal humerus will be adducted from contraction of the biceps and triceps muscles (**Figure 79-1B**).

INDICATIONS

The reduction of fractures and joint dislocations in the Emergency Department (ED) is more frequently indicated than it is not. Reduction is more readily achieved if it occurs soon after an injury. No fracture benefits from a prolonged period of angulation or displacement because the reduction becomes more difficult the longer the fracture has been present. No joint benefits from a prolonged dislocation as damage to articular cartilage increases with time.

Reduction should occur on an emergent basis when perfusion to the extremity is absent. A nonperfused extremity has a finite period of time before nerve and muscle death occur. For this reason, reduction should occur as soon as possible. **The earlier perfusion is restored, the better the chance of avoiding tissue necrosis.**

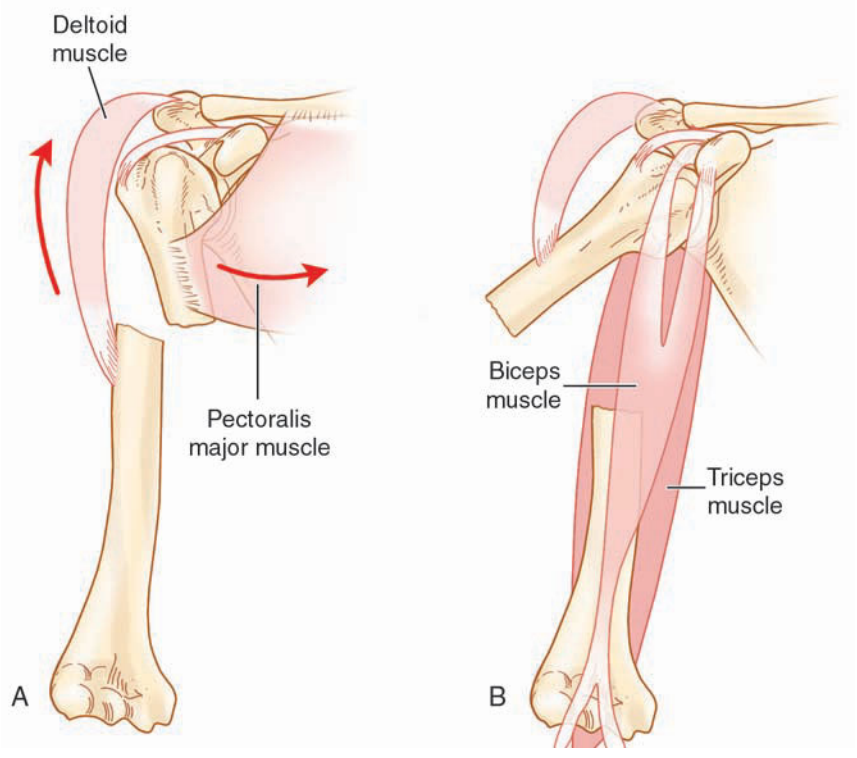


FIGURE 79-1. The direction of fracture displacement is influenced by muscle contraction following the injury. **A.** Humeral shaft fracture between the insertions of the deltoid and pectoralis major muscles. Arrows represent the direction of pull on the fracture fragments. **B.** Humeral shaft fracture distal to the deltoid muscle insertion.

Vascular injury can occur after any displaced fracture or dislocation. The EP should note the presence of an expanding hematoma, absent distal pulses, or delayed capillary refill. Some examples of orthopedic injuries more commonly associated with vascular injury include knee dislocations, posterior sternoclavicular joint dislocations, and supracondylar fractures. The importance of early reduction and repair of vascular injuries is emphasized in the case of a knee dislocation. If surgery is delayed more than 8 hours, up to 86% of patients will require an amputation.[2]

Not all displaced fractures and dislocations suspected of causing vascular injury should be reduced by the EP. When vascular injury is suspected in a patient with a posterior sternoclavicular joint dislocation, for example, reduction is best performed in the operating room with a cardiothoracic surgeon available because the distal clavicle may be tamponading a lacerated subclavian vessel.[3] In a similar manner, supracondylar fractures require immediate reduction only when the extremity is pulseless and perfusion is absent.[4]

Urgent reduction of displaced fractures and joint dislocations is also indicated to reduce the incidence of other potential complications. The incidence of compartment syndrome of the forearm is reduced by early reduction of displaced supracondylar fractures.[5] Likewise, a posterior hip dislocation should be reduced in a timely manner. The likelihood of avascular necrosis rises exponentially from a rate of 5% with less than 6 hours of being dislocated to 50% with greater than 6 hours of being dislocated.[6]

Neurologic injury results from the original injury, traction on a nerve, or compression of a nerve. Patients may experience altered sensation, decreased sensation, and/or paresthesias. **These injuries require urgent reduction to decrease potential long-term complications.**

CONTRAINDICATIONS

Despite the potential advantages of early reduction of fractures and dislocations in the ED, the EP should be aware of potential relative and absolute contraindications. Chronic or previously unrecognized dislocations are difficult to reduce in a closed manner and overly forceful attempts increase the chances of causing a fracture. An example is a surgical neck of the humerus fracture in a patient when attempting to reduce a chronic shoulder dislocation. Reduction in the ED is contraindicated when the patient requires immediate operative treatment. An open fracture in a perfused extremity should be reduced in the operating room where an appropriate surgical washout can occur.

Reduction is unnecessary when the potential for remodeling is such that the fracture angulation will correct without the need of a painful reduction or the risk of procedural sedation. For example, distal radius fractures in children have been shown to heal well even when they are 15° to 20° angulated.[7–10] Other fractures where some degree of displacement or angulation may be acceptable and frequently do not require reduction include the clavicle, humeral shaft, and neck of the fifth metacarpal.[1,11–17]

Reduction may be contraindicated in the ED for numerous other reasons. Adequate analgesia may not be possible due to the patient's medical condition or the inability to appropriately monitor the patient. These cases may require general anesthesia in the operating room. It is prudent to consult and wait for an Orthopedic Surgeon when the potential complications of a reduction attempt are high or the EP is uncomfortable performing the technique. A busy EP in a chaotic ED with single coverage may not have the time or resources to adequately sedate a patient and reduce the fracture or dislocation. This situation may require calling in an additional EP or an Orthopedic Surgeon to assist.

EQUIPMENT

- Procedural sedation equipment and supplies (Chapter 129), if applicable
- Hematoma block supplies (Chapter 125), if applicable
- Regional nerve block supplies (Chapter 126), if applicable
- Stretcher
- Weights for distraction

- Bed sheets for traction–countertraction techniques
- Splinting/casting material or commercially made splints (e.g., knee immobilizer)
- Finger traps for upper extremity reductions
- Fluoroscopy, if available, to assist with the reduction and postreduction radiographs
- Assistants depending on the reduction technique

PATIENT PREPARATION

Reduction techniques require a well-informed patient and a signed consent if possible. Explain the risks, benefits, and alternatives to the patient and/or their representative. Tell the patient what to expect. This knowledge may actually assist in the successful performance of the procedure. Anterior shoulder dislocation reduction, for example, can be performed with minimal or no sedation if the patient is able and willing to relax their musculature while the EP slowly manipulates the humeral head back into position.[18] The patient should also be consented for the anesthesia technique as this is a second procedure with potential complications much different from the reduction.

The physical preparation of a patient for the reduction of a fracture or dislocation is dependent on the type of injury and the clinical setting. In general, the patient should be resting as comfortably as possible on a gurney. The patient should be supine whenever possible. Fully expose the involved extremity. Remove any constricting pieces of clothing or jewelry both proximal and distal to the injury. If fluoroscopy is judged to be useful and it is available it should be moved into position. Frequently splint material is measured and set up prior to the start of the procedure so that it may be immediately applied to the extremity in the setting of an unstable fracture or dislocation.

TECHNIQUE

The basic principles to reduce a displaced fracture or a joint dislocation are similar. The procedure can be divided into four steps.[19] These are distraction, disengagement, reapposition, and release. The four steps can be used to reduce most, but not all, displaced fractures or joint dislocations.

The first step is distraction. It involves creating a longitudinal force to pull the fracture fragments or bones involved with a dislocated joint apart. This step should be performed gradually and sometimes requires time to be most effective in overcoming muscle spasm. Distraction is important when the fractured ends of the bone are overriding. It can be applied manually with the help of an assistant or by using weights.

To reduce a distal radius fracture, for example, one common technique to distract the injury uses finger traps to hold the hand in place while weights are wrapped around the arm (**Figure 79-2**). Saline bags placed in stockinette are equally effective and comfortable for the patient when weights are not available (**Figure 79-3**). Each liter bag of saline is equivalent to 1 kg or 2.2 pounds.

Disengagement is the second step to reduction. It allows for further disimpaction of the fracture fragments than distraction alone. Disengagement can be achieved by rotation of the distal fragment or more classically by "recreating the fracture deformity." It relieves tension on the surrounding soft tissues to allow the interlocking fracture fragments to reposition (**Figure 79-4**).

Disengagement is also important for dislocation reduction. It is most frequently achieved by rotation of the bone distal to the joint. An example is the external rotation technique to reduce an anterior shoulder dislocation.



FIGURE 79-2. Distraction for reduction of a forearm fracture.



FIGURE 79-3. Four 1 L bags of saline in stockinette is the equivalent of 8.8 pounds. This setup is useful when weights are not available to distract a fracture.

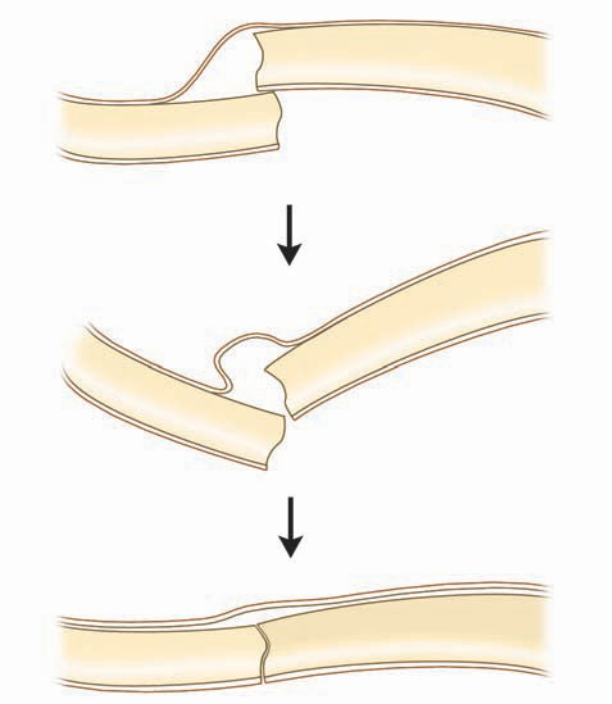


FIGURE 79-4. Disengagement. Recreating the fracture deformity allows the release of interlocking fragments by lengthening and relaxing the soft tissue hinge.

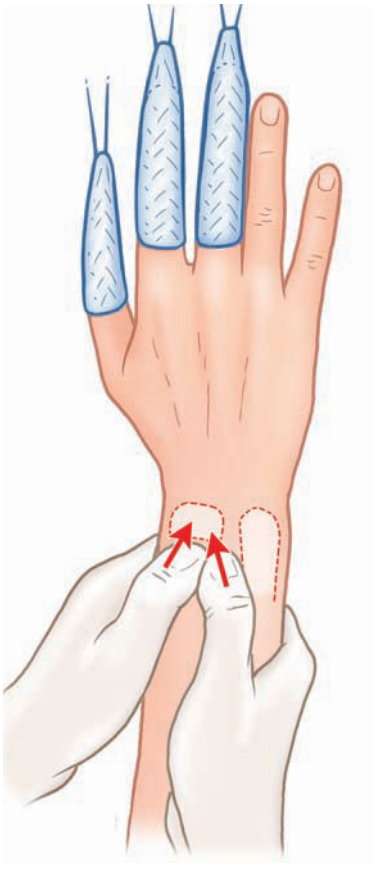


FIGURE 79-5. Reapposition of a forearm fracture.

The third step is reapposition. This is achieved by reversing the forces that caused the injury to bring the bony fragments back into alignment (**Figure 79-5**). While this step seems simple conceptually, it may not be as easy in clinical practice. One important pitfall to avoid is ignoring a rotational deformity that might create functional problems if the bone healed with a rotational deformity. This is especially important when treating fractures of the hand where a 5° rotational deformity of a proximal metacarpal fracture can translate into a distal fingertip that is 1.5 cm out of position[20] (**Figure 79-6**).

Release refers to the removal of the initial distracting force with the intent that alignment will be maintained. It is at this point that forces such as muscle contraction and gravity return and the fracture fragments are at risk for becoming malaligned again. A properly applied splint or cast can protect from loss of fracture alignment. It is advisable to have the splint measured and ready to apply before manual reduction is initiated.

ALTERNATIVE TECHNIQUES

There are frequently alternative techniques or variations of the four steps outlined above that are available to the EP depending upon the circumstance or the success of previous attempts. If the initial technique is unsuccessful, then the next maneuver is attempted and so on. The author uses the following sequence of maneuvers to reduce an anterior shoulder dislocation: scapular manipulation with downward arm traction (disengagement and distraction), then external rotation (disengagement), followed by the Milch technique (disengagement), and finally traction–countertraction (distraction).[18,21–24] The astute EP should also be aware of the limitations of the closed reduction technique. If soft tissue is interposed in an interphalangeal finger dislocation, for example, no amount of distraction or an alternative technique will reduce the dislocation without taking the patient to the operating room.



FIGURE 79-6. Rotational deformity of the fifth digit.

ASSESSMENT

The neurovascular status of the extremity must be assessed to ensure that pulses are present, the extremity is perfusing, and that nerve function has not been compromised before and after any reduction attempt. It should also be assessed after any casting or splinting to the extremity. Postreduction radiographs are taken to assess the success of the reduction, look for any fractures that may have been missed on the prereduction radiographs, and assess any complications from the reduction.

AFTERCARE

Immobilize the extremity as required for the specific fracture or dislocation. A record of the procedure should be placed in the chart including any complications and the method of reduction. The patient should undergo repeat plain radiography in most cases to document the success of the reduction. Patients with reduced fractures and dislocations should be referred to an Orthopedic Surgeon. Occasionally, a fracture that is properly reduced and immobilized will be unstable and become displaced again, frequently necessitating operative fixation.

COMPLICATIONS

When performed properly, complications of fracture and dislocation reduction are uncommon. However, even with proper techniques, complications can occur. These include converting a closed fracture to an open fracture, soft tissue trauma that produces a compartment syndrome, a reduction attempt that causes injury to the soft tissues making the fracture more unstable, producing a fracture during the dislocation reduction attempt by using excessive force, or neurovascular injury/compromise due to bony laceration, or compression of a nerve or blood vessel.

SUMMARY

Displaced fractures and joint dislocations requiring reduction are commonly seen in the ED. As the EP approaches these injuries, the initial step in assessment should be determining the neurovascular status of the extremity. When vascular compromise is present, emergent reduction is the rule with few exceptions. While all dislocations require reduction, not all displaced fractures necessitate reduction. The EP should be familiar with which displaced fractures benefit from reduction. When fracture reduction is indicated, the basic elements of the procedure are distraction, disengagement, reapposition, and release.

80 Sternoclavicular Joint Dislocation Reduction

Eric F. Reichman

INTRODUCTION

Sternoclavicular dislocations are uncommon injuries and account for less than 3% of shoulder girdle dislocations.[1] The medial clavicle may be displaced anteriorly or posteriorly. Anterior dislocations are more common by a ratio of 3:1 to 20:1.[2,3] Case reports of the less common posterior dislocations are more common in the literature due to the higher incidence of associated complications. Posterior sternoclavicular joint dislocations are often seen in younger individuals.[2,4]

Sternoclavicular dislocations are the result of direct trauma to the sternoclavicular joint or to the glenohumeral joint with the force directed toward the sternoclavicular joint. **This injury is usually associated with a tremendous force.** The most commonly reported mechanisms of injury are motor vehicle collisions and contact sports.[2,5] Anterior dislocations are often due to indirect forces transmitted through the anteromedial shoulder. As the shoulder is externally compressed and rolled backward, the lateral clavicle is pulled back and down beyond its limit of motion. The first rib acts as a fulcrum to spring the sternal end of the clavicle anteriorly from its articulation.[2,6]

Posterior dislocations may be due to direct or indirect forces.[3,4,7–13] With indirect trauma, the shoulder is externally compressed and rolled forward from a posterolaterally applied force to the shoulder. The costoclavicular ligament acts as a fulcrum that produces displacement of the sternal end of the clavicle posteriorly from its articulation.[4,9,11,13] Less commonly, a posterior dislocation may be due to a direct blow to the anteromedial clavicle.

There are reports of spontaneous and nontraumatic sternoclavicular subluxations and dislocations.[14] These are usually seen in females less than 20 years of age with sternoclavicular joint laxity. The clavicle dislocates anteriorly during abduction or flexion of the arm to the overhead position. The clavicle reduces spontaneously when the arm is returned to the side. This condition is usually associated with laxity in numerous other joints.

ANATOMY AND PATHOPHYSIOLOGY

The sternoclavicular joint is a diarthrodial joint with both surfaces covered by fibrocartilage (**Figure 80-1**). The intraarticular disk ligament divides the joint into two separate compartments, each of which is lined with synovium.[15] This joint is freely movable and functions almost like a ball-and-socket joint in that it has motion, including rotation, in almost all planes.[3,6,16] This includes 30° to 35° of upward elevation, 35° of combined forward/backward movement, and 40° to 45° of rotation about its long axis.[3,6,16] Less than half of the medial clavicle articulates with the upper angle of the sternum. This gives the sternoclavicular joint the distinction of having the least amount of bony stability of any of the major joints.[3] Given this amount of joint incongruity, it is surprising that sternoclavicular joint dislocations are uncommon. However, its stability comes from strong surrounding ligaments (**Figure 80-1**). These ligaments include the intraarticular disk ligament, the extraarticular costoclavicular ligament (rhomboid ligament), the anterior and posterior sternoclavicular ligaments, and the interclavicular ligament.[15]

The region that lies directly posterior to the sternoclavicular joint contains numerous vital structures (Figure 80-2). Within the confines of the thoracic inlet are the trachea, esophagus, lungs, and great vessels. This proximity, and the small size of the thoracic inlet, accounts for the injuries that may occur to these structures with posterior sternoclavicular joint dislocations.

The medial clavicular epiphysis is the last epiphysis of the long bones to appear. It usually ossifies by the age of 18 to 20 and occasionally not until the age of 25.[3,17] It is also the last to fuse.[3,17] This epiphysis is difficult to see on plain radiographs. Many injuries in patients under 25 years of age that are initially felt to be sternoclavicular joint dislocations are actually Salter I or II epiphyseal injuries.[3,10,18–23]

The diagnosis of a traumatic sternoclavicular joint dislocation may be difficult and delayed. This is particularly true in the patient with multiple injuries.[7,24,25] Symptoms include severe pain that increases with movement of the ipsilateral arm. Physical signs include edema and ecchymosis over the region of the sternoclavicular joint. The

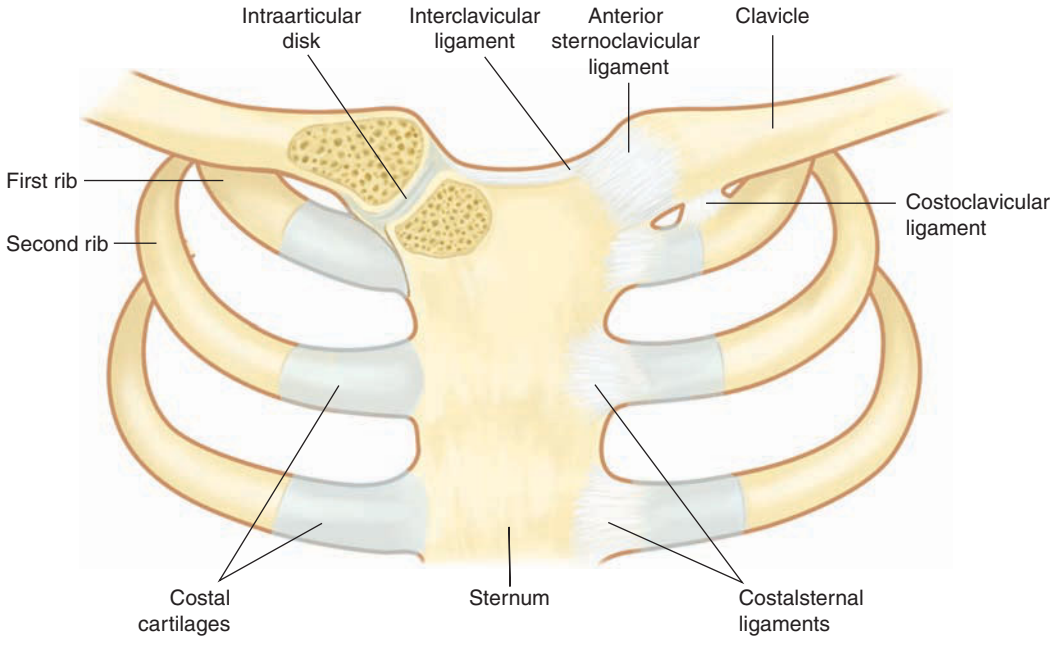


FIGURE 80-1. Anatomy of the sternoclavicular joint and surrounding structures.

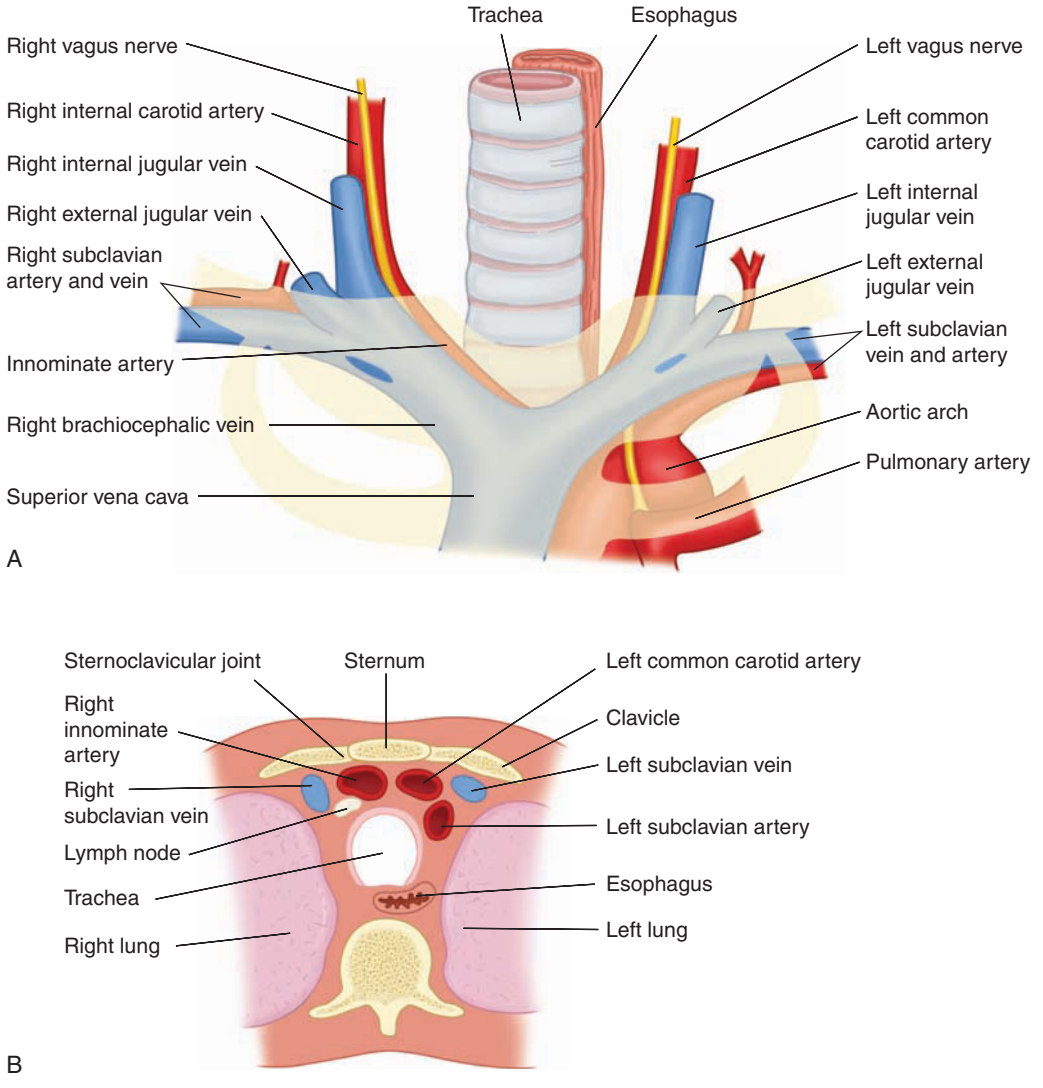


FIGURE 80-2. Anatomic relationships of structures to the sternoclavicular joint. **A.** Anteroposterior view. **B.** Cross section through the level of the sternoclavicular joint.

patient usually holds the injured arm adducted across the trunk. Their head may be tilted toward the affected side to relieve the pain caused by traction of the sternocleidomastoid muscle on the medial clavicle. With anterior dislocations, the medial end of the clavicle may be palpated anterior to the sternum. It may also be fixed or mobile. A visible depression may be noted or a hollow palpated at the location of the sternoclavicular joint with posterior sternoclavicular joint dislocations. However, accompanying edema may obscure these physical findings. The shoulder may be held forward. When the patient is supine, the affected shoulder does not lie flat against the bed.

Additional signs and symptoms associated with a posterior sternoclavicular joint dislocation may also be due to injury or compression of mediastinal structures.[3,4,7,9,11–13,18,25–32] **It is extremely important to perform a careful and complete physical examination, as associated injuries are common.** Compression of the trachea or esophagus may result in cyanosis, dyspnea, or dysphagia. Circulation to the ipsilateral arm may be reduced if the subclavian artery is compressed. Venous congestion of the upper extremity or neck can result from compression of the subclavian or jugular veins. The patient may present in shock due to compression or injury to the retrosternal great vessels. Paresthesias of the upper extremity are due to a brachial plexus injury. Voice changes are due to compression of the recurrent laryngeal nerve. Tracheal or lung injuries can result in pneumothoraces.

The clinician cannot always rely on the clinical findings of observation and palpation to distinguish between anterior and posterior sternoclavicular joint dislocations.[3] Documentation with appropriate radiologic studies is recommended prior to the decision to treat. Routine radiographs of the sternoclavicular joint are often difficult to interpret due to overlapping structures. Several different radiographic projections have been reported to improve the ability to demonstrate asymmetry of the joints.[3,8,9,33] Computed tomography (CT) is the preferred imaging modality to study the sternoclavicular joint. It should always be performed if the diagnosis is uncertain.[9,10] The use of ultrasound to aid in the diagnosis has also been reported.[12,34]

With posterior sternoclavicular joint dislocations, the Emergency Physician should also consider appropriate studies to rule out associated injuries to neighboring structures. This could include a chest radiograph, which may reveal mediastinal widening, a pneumomediastinum, or a pneumothorax. CT will reveal the relationship of the clavicle to the great vessels, esophagus, and trachea. It may also demonstrate compression of these structures, a mediastinal hematoma, or mediastinal emphysema. Angiography, venography, and Doppler studies may be considered to investigate potential vascular injury. Esophagoscopy and/or an esophagram may be employed to evaluate the esophagus. Bronchoscopy is indicated if a tracheal or bronchial injury is suspected.

INDICATIONS

It is generally held that closed reduction should be attempted on all acute traumatic anterior and posterior sternoclavicular joint dislocations.[3,10,27] Anterior sternoclavicular joint dislocations have been reduced via closed techniques up to 10 days postinjury.[9] Successful closed reduction of posterior sternoclavicular joint dislocations has been reported up to 5 days postinjury.[12,27] Posterior sternoclavicular joint dislocations are uncommon injuries. Early consultation with an Orthopedic Surgeon is recommended. Careful evaluation of the patient's airway, breathing, and circulation should be performed prior to the reduction. It is recommended that the reduction be performed where staff and facilities are immediately available to intervene should any thoracic emergency develop.[25] **The dislocation should be reduced emergently if neurologic or vascular compromise exists in the affected extremity.**

Many of these injuries are in fact Salter–Harris I or II epiphyseal injuries in patients less than 25 years of age.[3,10,18–23] Closed reduction should still be attempted after consultation with an Orthopedic Surgeon.

CONTRAINDICATIONS

Reduction may be postponed to attend to more serious injuries unless a posterior sternoclavicular joint dislocation is present and is compromising adjacent structures. Open reduction of posterior sternoclavicular joint dislocations may be preferred if surgery is planned for associated injuries.

Attempted reduction of chronic traumatic anterior dislocations or spontaneous anterior dislocations is not indicated.[41] These patients usually have minimal discomfort, normal range of motion, and can return to normal activity.[3,14] Patients do well without treatment other than nonsteroidal anti-inflammatory drugs, the application of heat, and rest.[2,14,35] The results of operative treatment of such injuries have not been impressive.[3,14]

There is controversy regarding the necessity of reducing chronic posterior sternoclavicular joint dislocations. Some feel that all should be reduced due to the potential compression of adjacent structures or erosion into them.[3,28,36,37] However, there have been reports of patients who have chronic dislocations without sequelae.[6] Treatment decisions for such injuries should be made in consultation with an Orthopedic Surgeon. Reduction would require general anesthesia and operative intervention.[35]

EQUIPMENT

- Sandbags or folded towels
- Povidone iodine or chlorhexidine solution
- Sterile towel clamps
- Sterile gloves
- Local anesthetic solution
- 18 gauge needles
- 25 gauge needles
- 10 mL syringe

PATIENT PREPARATION

Explain the risks, benefits, potential complications, and aftercare of the procedure to the patient and/or their representative. Obtain a signed consent to perform the reduction.

Place the patient supine with the affected side near the edge of the gurney. Place sandbags or towels between the patient's scapulae. They should be thick enough to raise the patient 5 cm off the gurney.[4]

A form of anesthesia and analgesia is required to reduce a sternoclavicular joint dislocation. Closed reduction of anterior sternoclavicular joint dislocations may be performed with local anesthetic solution infiltrated about the medial clavicle and sternoclavicular joint. Consider the administration of supplementary intravenous sedation or procedural sedation. Posterior sternoclavicular joint dislocations have also been reduced using local anesthesia. However, procedural sedation or general anesthesia is recommended. Infiltrate local anesthetic solution about the medial clavicle and sternoclavicular joint if procedural sedation will be performed.

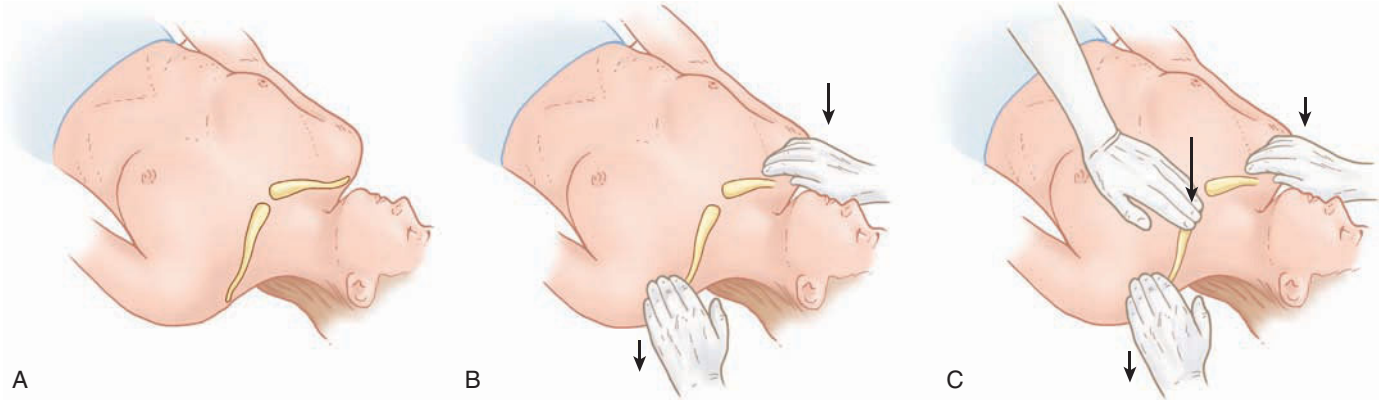


FIGURE 80-3. Reduction of an anterior sternoclavicular joint dislocation. **A.** Patient positioning. **B.** An assistant applies anterior pressure to both shoulders. **C.** The medial clavicle is pushed posteriorly.

TECHNIQUES

ANTERIOR STERNOCLAVICULAR JOINT DISLOCATION REDUCTION

Position the patient as mentioned above. The patient's arms should be at their sides (**Figure 80-3A**). Apply analgesia and sedation. Instruct an assistant to apply downward pressure to the anterior surface of both shoulders (**Figure 80-3B**). Pushing the shoulders posteriorly pulls the clavicles laterally and distracts the dislocated medial clavicle. Push the medial clavicle posteriorly and into anatomic position (**Figure 80-3C**). Relocation of the clavicle usually occurs promptly. Carefully sit the patient upright while the assistant maintains the shoulders in a posterior position. Apply a figure-of-eight splint (**Figure 90-3C**).

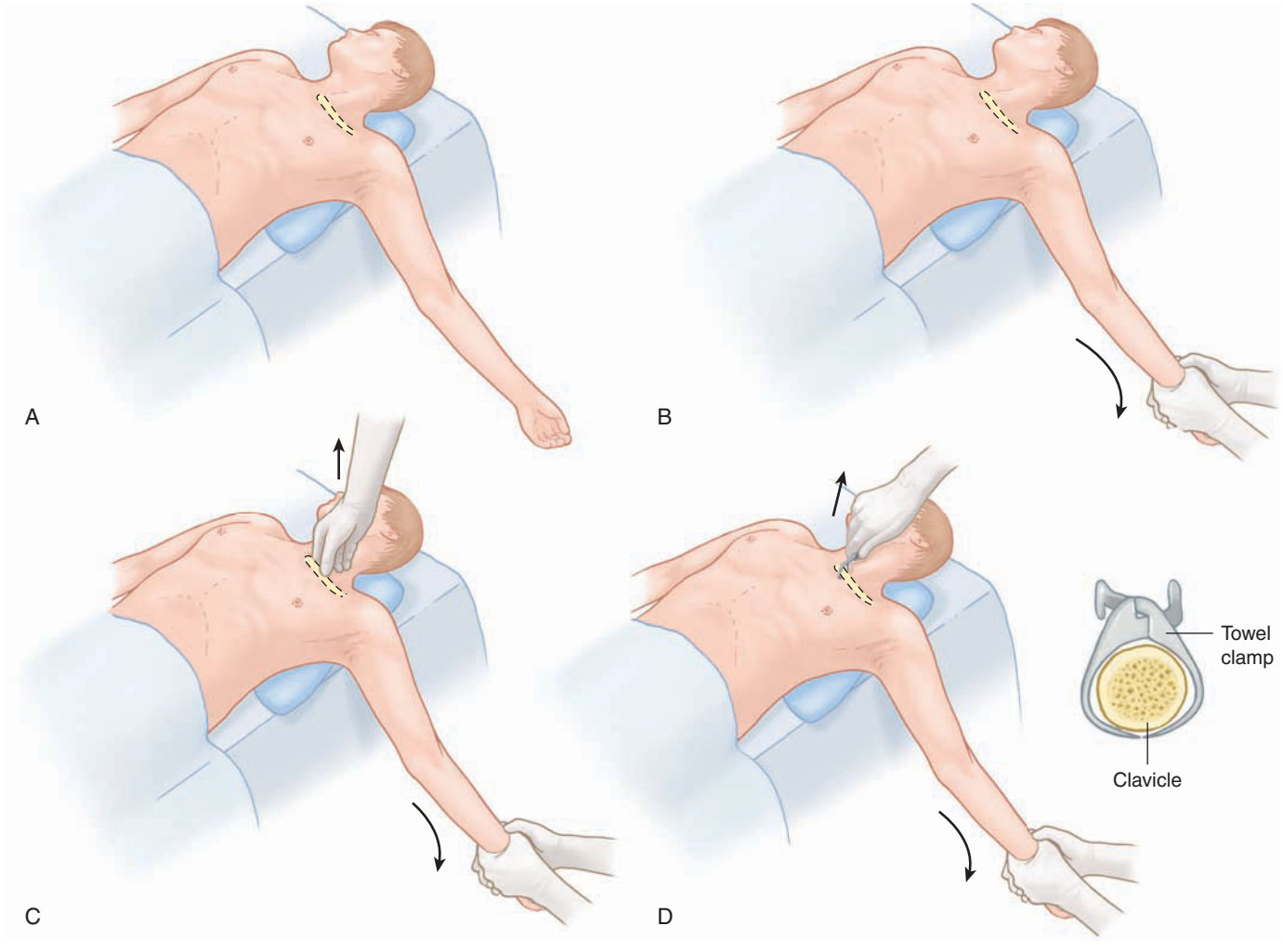


FIGURE 80-4. Reduction of a posterior sternoclavicular joint dislocation. **A.** Patient positioning. **B.** An assistant applies distal in-line traction. **C.** The medial clavicle is grasped and elevated while maintaining distal traction on the extremity. **D.** An alternative technique. A towel clamp is placed around the medial clavicle. The clamp is used to elevate the medial clavicle while maintaining distal traction on the extremity.

POSTERIOR STERNOCLAVICULAR JOINT DISLOCATION REDUCTION

Position the patient as mentioned previously. Apply analgesia and sedation. Abduct the affected extremity 90° and extend it 20° in line with the clavicle (**Figure 80-4A**). Spontaneous reduction may occur at this point. If not, instruct an assistant to apply distal inline traction to the extremity (**Figure 80-4B**). This may be aided by wrapping a sheet about the patient's upper torso to provide countertraction. The clavicle may reduce under traction. Keep the patient's arm abducted, extended, and under traction if the sternoclavicular joint does not reduce. Manually manipulate the clavicle into position. Grasp the medial clavicle and pull it upward into anatomic position (**Figure 80-4C**).

It may be difficult at times to achieve a secure grasp on the medial clavicle. In such cases, clean the skin surrounding the medial clavicle of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Grasp through the skin and around (not through) the shaft of the medial clavicle with a towel clamp (**Figure 80-4D**). The thick cortical bone often prevents purchase of the towel clamp into the clavicle. Ensure that the towel clamp follows the contours of the clavicle when applying it. Grasping too deep can result in injury to the subclavian artery and/or vein. Elevate the medial clavicle into anatomic position while the assistant is maintaining traction on the abducted and extended extremity (**Figure 80-4D**).

ALTERNATIVE TECHNIQUES

An alternative technique may be applied to reduce a posterior sternoclavicular joint dislocation.[4] It uses the first rib as a lever and has been reported to be successful when the previous technique has failed. Position the patient with their arms adducted (**Figure 80-5A**). Apply analgesia and sedation. Instruct an assistant to apply distal in-line traction to the adducted arm (**Figure 80-5B**). This will lever the medial clavicle over the first rib and above the superior sternum (**Figure 80-5B**, inset). Apply downward pressure to the anterior shoulder, forcing it into retraction (**Figure 80-5C**). This will lever the medial clavicle anteriorly and laterally into anatomic position (**Figure 80-5C**, inset). Reduction may occur at this point. If not, elevate the medial clavicle either by manual grasp or using a towel clamp, as described previously. It is postulated that this technique requires less force than the prior technique. A variation of this technique involves applying lateral traction to the upper humerus using a sheet looped around the upper arm.[38]

Other methods of closed reduction for a posterior sternoclavicular joint dislocation have been described but are not often performed. Successful reduction has been described using 4.5 kg

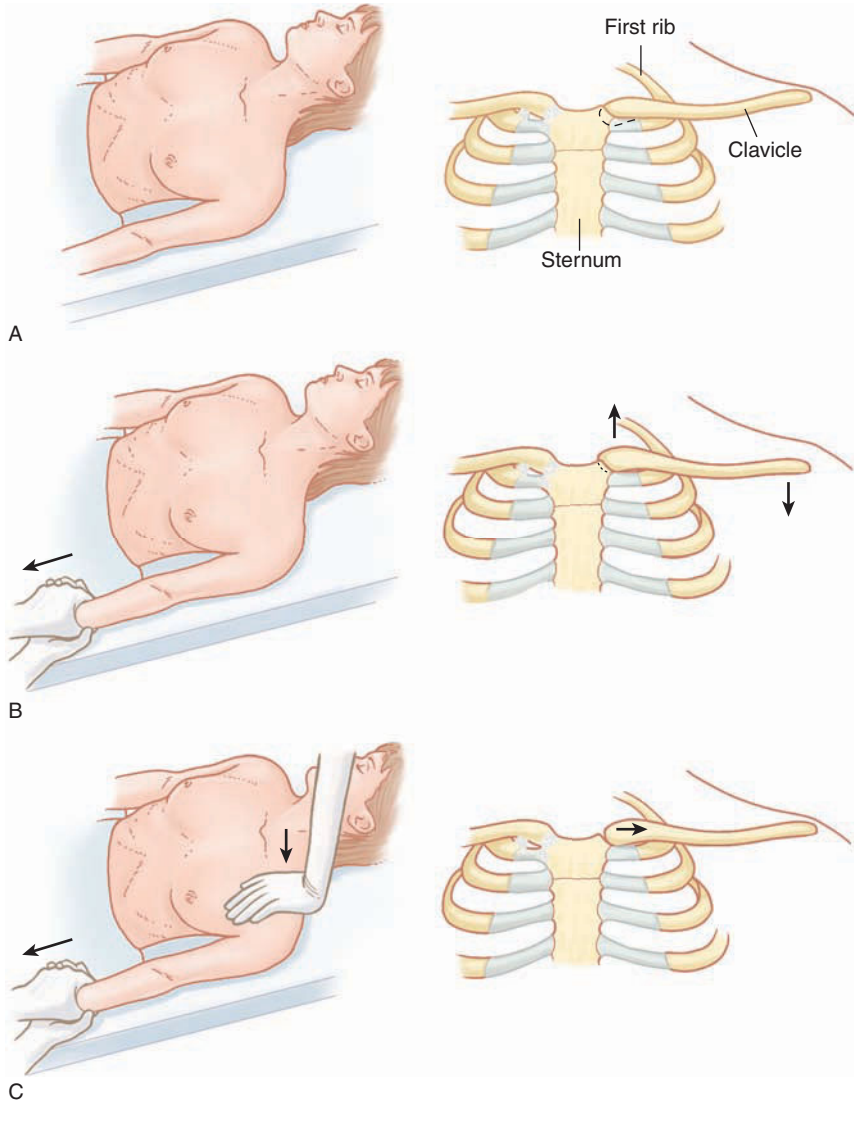


FIGURE 80-5. An alternative technique for reducing a posterior sternoclavicular joint dislocation. (Modified from the study of Buckerfield and Castle.[4]) **A.** Patient positioning. **B.** An assistant applies distal in-line traction (*large arrow*). The medial clavicle will be elevated above the sternum (*small arrows*). **C.** A posteriorly directed force is applied to the shoulder to draw the medial clavicle anteriorly and laterally into its normal anatomic position.

(10 pounds) of lateral skin traction on the abducted arm for 30 minutes.[39] Reduction has also been achieved by simple forced retraction of the lateral clavicle.[8] Reduction has been reported in a sedated patient who was placed for 8 hours on rolled towels between the scapulae.[13]

ASSESSMENT

Assess all patients, both initially and following any reduction attempts, for neurologic and vascular integrity of the upper extremity. Obtain postreduction radiographs to confirm proper bony positioning. The procedure may be repeated if the radiographs show incomplete reduction. **Positioning is not critical if the reduction was performed for neurologic or vascular compromise. The primary consideration is the relief of the compromised nerve and/or artery.** The Orthopedic Surgeon can later reduce the defect that remains.

AFTERCARE

The general principles of orthopedic care should be applied. These include rest, ice, nonsteroidal anti-inflammatory drugs, and supplemental narcotic analgesics.

ANTERIOR STERNOCLAVICULAR JOINT DISLOCATIONS

The sternoclavicular joint is often unstable following reduction. These injuries require splinting to maintain the normal anatomic relationships and allow ligamentous healing. This is best accomplished with a figure-of-eight splint (**Figure 90-3C**). Unfortunately, patients do not often tolerate this splint. Alternatives include a sling, sling and swath, or a sling and Velpeau dressing (**Figures 90-3A & B**). Apply one of the above splints if the medial clavicle will not remain reduced. Orthopedic follow-up should be scheduled within 5 to 7 days of the reduction.

POSTERIOR STERNOCLAVICULAR JOINT DISLOCATIONS

The sternoclavicular joint is usually stable following reduction. The splinting and follow-up are the same as with an anterior sternoclavicular joint dislocation.

COMPLICATIONS

ANTERIOR STERNOCLAVICULAR JOINT DISLOCATIONS

Complications of the reduction are relatively minor. The sternoclavicular joint is usually unstable postreduction and often dislocates spontaneously. This should be explained to the patient prior to attempted reduction. A "cosmetic bump" can remain if reduction is not maintained. Occasionally, these patients will continue to have persistent pain.[3]

POSTERIOR STERNOCLAVICULAR JOINT DISLOCATIONS

Most complications result from the original injury and are due to compression or injury of neighboring structures. The incidence of associated injuries is reported to be 25%.[25] Death secondary to these complications has been reported.[31,40]

Complications of the reduction include pain, incomplete reduction, subclavian vessel injury, and brachial plexus injury. A higher incidence of injury to the subclavian vessels may be seen if a towel clamp is used in the reduction. The reduction of a posterior dislocation can result in an anterior subluxation or dislocation.[42] This conversion of a posterior to anterior dislocation during reduction should not be reduced as it may resolve spontaneously or require open management.

SUMMARY

Sternoclavicular joint dislocations are uncommon injuries. They are usually due to high-impact forces from motor vehicle collisions or contact sports. Anterior sternoclavicular joint dislocations are easily reduced but often do not maintain reduction. However, patients tend to do well with persistent dislocations. Posterior sternoclavicular joint dislocations are even less common. The Emergency Physician should be aware of the high incidence of associated injuries. These dislocations tend to be stable after reduction.

81 Shoulder Joint Dislocation Reduction

Eric F. Reichman

INTRODUCTION

The shoulder joint is the most commonly dislocated of all joints.[1–4] Shoulder dislocations were depicted in Egyptian murals as early as 3000 BC.[1] Despite 5000 years of medical advancements, shoulder dislocations continue to be a major cause of Emergency Department (ED) visits. They account for more than 50% of all joint complications treated by Emergency Physicians (EPs).[2]

The human shoulder is remarkable for its degree of motion. The anatomic features that contribute to this mobility also contribute to its instability.[3] The shallow glenohumeral joint allows the shoulder to be dislocated anteriorly, posteriorly, or inferiorly. The anterior shoulder dislocation is the most common and accounts for 95% of all shoulder dislocations.[1–4] The overall incidence of shoulder dislocations is 17 per 100,000. There is a bimodal age distribution.[1,4] It occurs in males from 20 to 30 years of age most commonly related to athletics and trauma. The other large group is women from 60 to 80 years of age, primarily due to falls.

ANATOMY AND PATHOPHYSIOLOGY

The shoulder (glenohumeral) joint is a multiaxial ball-and-socket type of synovial joint that permits a wide range of motion. Unfortunately, the range of motion is at the expense of stability.[5] The shoulder has greater than 180° of motion in both the sagittal and coronal planes as well as 180° of rotary movement.[6] The spheroidal head of the humerus articulates with the shallow glenoid fossa of the scapula. The glenoid fossa accommodates roughly one-third of the humeral head. The bony landmarks surrounding the shoulder joint are the coracoid and acromion processes of the scapula. A loose, thin fibrous capsule encloses the glenohumeral joint. The muscular component of the shoulder is a fusion of four separate muscles (supraspinatus, infraspinatus, teres minor, and subscapularis) that together form the rotator cuff. These muscles have a tendency to be torn and injured in shoulder dislocations, especially posterior and inferior dislocations.[7] The shoulder receives its blood supply from branches of the axillary artery (the anterior and posterior circumflex humeral arteries).

Innervation of the shoulder is from branches of the suprascapular, axillary, and lateral pectoral nerves. The axillary nerve lies at

the level of the humeral neck. When it is dislocated anteriorly, the humeral head is displaced into the quadrangular space where it may compress and damage the axillary nerve. This can result in a neurapraxia, paralysis of the deltoid muscle, and/or a sensory loss to the skin over the shoulder.

Shoulder dislocations can occur anteriorly, posteriorly, or inferiorly depending on the mechanism of injury. Anterior shoulder dislocations are by far the most common and account for 95% of all dislocations. An anterior dislocation usually results from direct or indirect forces causing abduction, extension, and external rotation of the limb. Anterior dislocations are classified based on the location of the humeral head into subcoracoid, subglenoid, subclavicular, and intrathoracic. Subcoracoid dislocations account for 75% of all anterior shoulder dislocations. The dislocated humeral head can shift between the first three positions but generally remains in one anatomic location.[2] In younger patients, the injury is usually linked to athletics, such as spiking a volleyball or blocking a basketball shot. Older patients may sustain anterior shoulder dislocations from falling on an outstretched arm or from a direct blow on the posterior shoulder.[4] The patient will present in obvious distress, holding the affected arm in slight abduction and internal rotation. Typically, the elbow is flexed and supported by the unaffected arm. The shoulder will have the typical "squared off" appearance, with loss of the normal deltoid contour. The humeral head may be palpable anteriorly.[1]

Posterior shoulder dislocations account for 4% of all shoulder dislocations.[1–4] They have a tendency to be missed, even by experienced EPs. Delayed diagnoses have been made up to a year after the initial injury.[8] The mechanism of injury is usually indirect, with a combination of internal rotation, adduction, and flexion. The most common precipitating mechanism is a seizure. Other etiologies include high voltage electrical injury, direct trauma, and falls.[3] Direct trauma, such as a head-on motor vehicle collision in which the patient braces their hands against the dashboard, can result in bilateral posterior shoulder dislocations in rare instances. Posterior shoulder dislocations are classified based on the location of the humeral head into subacromial, subglenoid, or subspinous. Subacromial dislocations account for 98% of posterior shoulder dislocations.[2,8] The patient usually presents with the arm held in adduction and internal rotation.[9] The shoulder will appear flat anteriorly. The coracoid process of the scapula will be visually prominent and palpable.[1]

Inferior shoulder dislocations are the least common type.[1–4] They represent less than 0.5% of all shoulder dislocations. The inferior shoulder dislocation is also known as luxatio erecta, because the dislocated extremity is extended upward. Inferior shoulder dislocations are usually sustained from indirect forces with the arm hyperabducted, causing the rotator cuff to tear and the arm to rotate 180° externally.[7] Alternatively, a direct axial force applied to the arm above the head, as in a fall or Olympic-style weight lifting, will drive the humeral head inferiorly.[10] The patient will present with the affected arm shortened and fixed above their head, with the hand rotated as if asking a question.[7] The humeral head may be palpable along the lateral chest wall. Inferior shoulder dislocations are often associated with fractures.[1] The fractures can involve the acromion process, coracoid process, clavicle, greater tuberosity, humeral head, and/or glenoid rim.[1,2,6,11] Complete disruption of the rotator cuff often occurs with inferior shoulder dislocations.[1,2,6,11] Dislocations can cause capsular and rotator cuff tears, compression or tears of the axillary artery and its branches, and injury to the subclavian vein. Because of their anatomic proximity, damage to the brachial plexus, suprascapular nerve, and the axillary nerve occur at a rate of 21% to 36% due to traction and compression of these nerves.[8] Prompt reduction of the dislocation may alleviate compression injuries and enable a more thorough examination and evaluation of all components of the shoulder.

Radiographs are required to classify the type of dislocation and diagnose fractures. Associated fractures are detected in up to 24% of anterior shoulder dislocations.[3] They include fractures of the greater tuberosity, humeral head, coracoid process, acromion process, clavicle, and glenoid. Recent evidence suggests that clinically obvious dislocations without a high-energy mechanism can be reduced without prior radiographs.[61–66] There is no consensus at present to eliminate prereduction radiographs versus the current recommendation that all patients have at least two-view prereduction plain radiographs of the affected joint.[12] Postreduction films should be obtained both to document the reduction of the joint and any injury induced by the reduction technique as well as to document bony abnormalities (Hill–Sachs lesions, Bankart lesion) or previously hidden fractures that were not visible on the initial radiographs. There is some evidence that postreduction radiographs may be unnecessary, but further study is required before this can be made the standard of care.[13,14,64–68]

The anteroposterior (AP) view will clearly demonstrate anterior dislocations, inferior dislocations, and almost all humeral fractures. In evaluating radiographs of anterior shoulder dislocations, look for an impaction fracture defect in the posterolateral portion of the humeral head, called a Hill–Sachs deformity. These are found in up to 50% of all anterior shoulder dislocations.[2] A Bankart lesion is an avulsed fragment of the glenoid labrum with contiguous bone.[6] Both lesions tend to get worse the longer the humeral head remains dislocated.

In patients with posterior shoulder dislocations, however, the AP view often shows a "normal" picture, which accounts for the high incidence of missed dislocations. One study showed that up to 50% of posterior shoulder dislocations were missed using only the AP view, whereas lateral views increased the diagnostic accuracy to 100%.[15] There are four features that suggest a posterior dislocation on AP films. First is the loss of the normal elliptical pattern produced by overlap of the humeral head and the posterior glenoid rim. Second, the distance between the anterior glenoid rim and the articular surface of the humeral head will be increased. This is known as the "rim sign." The third is internal rotation of the greater tuberosity to make the humerus take on a "light bulb" or "ice cream cone" appearance.[2,4] Finally, an isolated fracture of the lesser tuberosity on the AP view is suggestive of a posterior shoulder dislocation until proven otherwise.[2] If there is any question, a lateral view (either the Y view or an axillary view) will help delineate the posterior position of the humeral head behind the glenoid fossa.[1]

INDICATIONS

Shoulder dislocations, whether first-time or recurrent, are typically very painful and distressing for the patient. **All attempts should be made to reduce the joint as quickly as possible once the diagnosis is made.** In general, uncomplicated joint dislocations should be reduced within 20 to 30 minutes to alleviate further injury to surrounding neurologic and vascular structures. **A patient with a neurologic deficit or a compromised distal pulse in the setting of a shoulder dislocation should undergo immediate reduction.**

CONTRAINDICATIONS

There are no absolute contraindications to reducing a dislocated shoulder. The patient's airway, breathing, and circulation should be assessed and managed prior to reducing the dislocated shoulder. Any life- or limb-threatening injuries should be managed before the shoulder reduction is attempted.

An Orthopedic Surgeon should be consulted prior to the reduction of a shoulder dislocation in patients with posterior and inferior

dislocations. They are relatively rare, there is a high incidence of complications requiring operative management, dislocations associated with fractures may make the reduction difficult, and other indications for surgical management may exist.[69] The indications for surgical intervention in anterior shoulder dislocations include complete rotator cuff tears, fracture of the greater tuberosity with displacement of more than 1 cm, or fractures of the glenoid rim that are displaced more than 5 mm.[2] Posterior shoulder dislocations with major displacement of a fractured lesser tuberosity or an impression defect greater than 20% of the articular surface necessitate surgical intervention or open reduction.[2,3] Open dislocations require operative management but may be reduced in the ED if there is a delay in getting the patient to the Operating Room. Surgical reduction is indicated in patients with evidence of hemorrhagic shock from a suspected axillary artery injury sustained during a shoulder dislocation.

An Orthopedic Surgeon should be consulted before reducing a dislocated shoulder that presents greater than 7 to 10 days after the acute injury. There is a higher risk of vascular injury when an "old" dislocation is mistaken for an acute injury and subsequently reduced. The axillary artery, which is bound down by the pectoralis major muscle and anterior pericapsular scarring, becomes brittle and may not withstand the traction required to reduce an "old" dislocation. This is especially true in the elderly. A 1941 study reported a 50% hemorrhage-related mortality in patients who had shoulder reductions performed several weeks after initial injury.[11]

Shoulder dislocations in children present unique problems. Pediatric patients whose ossification centers have not yet fused tend to have Salter-Harris type fractures of the epiphyseal plate. **An Orthopedic Surgeon should be consulted prior to the reduction of a pediatric shoulder dislocation unless neurologic or vascular compromise is present in the affected extremity.** Otherwise, the same techniques for reduction can be applied to both adult and pediatric patients.

EQUIPMENT

General Supplies

- Equipment and supplies for procedural sedation (Chapter 129)
- Assistants
- Sheets
- 10 to 15 pounds of weights
- Sling and swath or shoulder immobilizer
- Splinting material (plaster, fiberglass, and prepackaged casting material)

Intraarticular Analgesia

- Povidone iodine or chlorhexidine solution
- 20 mL syringe
- 25 gauge, 2.5 in. needle
- Local anesthetic solution (Carbocaine, lidocaine, and bupivacaine)

Miscellaneous

- Equipment and supplies for nitrous oxide anesthesia (Chapter 128)
- Equipment and supplies for regional anesthesia (Chapter 126)

PATIENT PREPARATION

The risks, benefits, potential complications, and aftercare of the procedure should be explained to the patient and/or their representative. Obtain an informed consent for the reduction procedure. An informed consent should be obtained for procedural sedation and/or an intraarticular injection if they are performed in addition to the reduction procedure.

Place the patient in a position of maximal comfort, usually sitting upright or at a 45° angle, with the affected extremity supported and its motion limited. Placing the patient supine or prone is difficult, painful, and often requires analgesia before being attempted. The patient presenting in spinal immobilization should remain supine. If the spine cannot be cleared, shoulder reduction can be performed without changing the patient's position. Intravenous access should be obtained if indicated. Pain should be addressed quickly and aggressively.

ANALGESIA

There are several methods to control pain for patient comfort before and during the joint reduction procedure. Intravenous or intramuscular narcotics should not be withheld pending prolonged radiographic studies. Commonly administered medications include morphine, meperidine, hydromorphone, and fentanyl.

An alternative to intramuscular or intravenous narcotics is the intraarticular instillation of local anesthetic solution.[16,70–73] This was formally introduced in 1991 as an effective method of analgesia for anterior shoulder dislocations. It is often used in addition to procedural sedation. It can also be used as the only method of analgesia when procedural sedation is contraindicated. Clean the anterolateral shoulder of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the shoulder area and allow it to dry. Identify the hollow 2 cm inferior to the lateral border of the acromion process (**Figure 81-1**). Using sterile technique, insert a 25 gauge needle perpendicular to the skin and into the hollow to a depth of 2 cm (**Figure 81-1**). Inject 10 to 20 mL of a 50:50 mixture of sterile saline and local anesthetic solution. This technique is

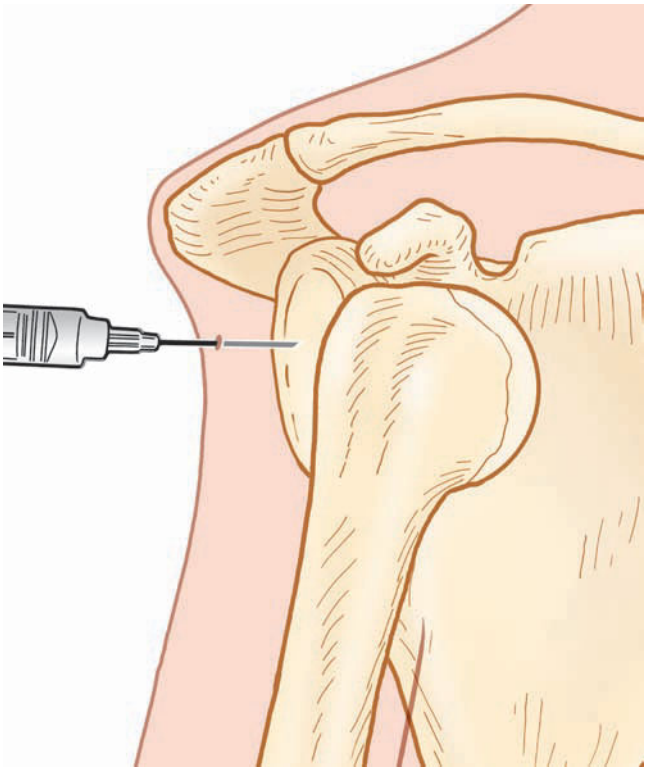


FIGURE 81-1. Local anesthesia for a shoulder dislocation. The needle is introduced in the hollow under the lateral surface of the acromion process.

effective in controlling muscle spasm and pain. The book editor and chapter author believes this should be performed on every dislocated shoulder before attempts at reduction.

Alternative methods for providing analgesia include the use of nitrous oxide, procedural sedation, and regional nerve blocks. Nitrous oxide has numerous advantages including a short onset, it wears off quickly, self-administration by the patient as needed, and a decreased ED length of stay.[74] Unfortunately, the use of nitrous oxide produces a quite variable analgesic response. Please refer to Chapter 128 for a discussion regarding the use of nitrous oxide anesthesia. Procedural sedation is commonly used us aid in the reduction of a dislocated shoulder. Please refer to Chapter 129 for a discussion regarding the use of procedural sedation. Ultrasound-guided brachial plexus blocks provide excellent analgesia but require equipment and training on the part of the EP.[75–79] Please refer to Chapter 126 regarding the details of this technique.

Several sources suggest that patients with an anterior shoulder dislocation without a significant trauma history may actually accept some degree of discomfort as a tradeoff for the prompt resolution of pain by reduction without anesthesia.[17–19] Patient comfort should not be sacrificed for expediency. Anterior shoulder dislocations may require procedural sedation prior to reduction, depending on the patient's level of discomfort and the reduction method chosen. Posterior and inferior shoulder dislocations definitely require procedural sedation prior to reduction.

ANTERIOR SHOULDER DISLOCATION REDUCTION TECHNIQUES

The methods for treating a closed shoulder dislocation depend on overcoming muscular spasm to relocate the humeral head into the glenoid fossa. Reduction techniques are classified into traction techniques, leverage techniques, scapular manipulation, and combinations of the three previous techniques. A study evaluating the various reduction techniques found similar success rates of 70% to 90% regardless of the technique.[20] However, postreduction complication rates are variable.[20] The major considerations in deciding which technique to use are physician experience, familiarity with the technique, availability of time, and the presence or absence of an assistant.[20]

HENNEPIN TECHNIQUE

The Hennepin technique, popularized at Hennepin County Medical Center, is often the preferred method to reduce anterior shoulder dislocations (**Figure 81-2**). This technique can

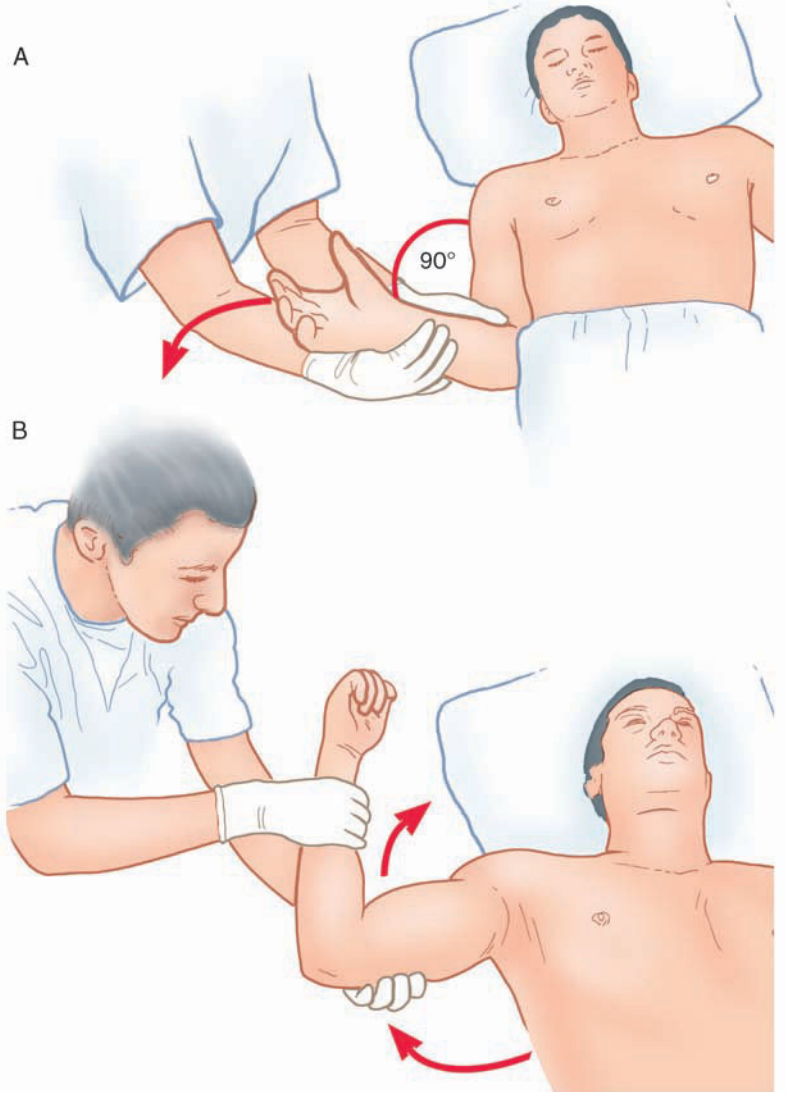


FIGURE 81-2. The Hennepin technique to reduce an anterior shoulder dislocation. **A.** Patient positioning and external rotation of the humerus. **B.** Abduction of the arm with the elbow flexed 90°.

be accomplished with no anesthesia or with the intraarticular instillation of local anesthetic solution. Procedural sedation is not required but may be used if the patient has severe pain and muscle spasms.

Place the patient seated, supine, or reclined 45° on a gurney (**Figure 81-2A**). Place the affected arm in adduction. Flex the elbow 90°. Support the patient's flexed elbow against their torso with the nondominant hand. Grasp the patient's forearm with the dominant hand. Slowly rotate the arm externally. **If pain becomes severe, typically as a result of rotator cuff spasm, stop the motion and wait until the spasm subsides. Do not release the arm or return it to its original position.** Continue to rotate the arm externally until the humeral head reduces or the arm reaches the coronal plane (90° of external rotation). This can take up to 10 minutes to accomplish. If the humeral head is still dislocated, slowly abduct the arm until the humeral head reduces or full abduction is obtained[2] (**Figure 81-2B**). Full abduction occurs when the patient's hand crosses over their head and is able to touch the contralateral ear. Adduct the arm until it is against the patient's torso. Another technique should be attempted if the humeral head is still dislocated.

The advantages of this technique include little to no patient manipulation or positioning, the relative ease of reduction, minimal equipment, the requirement of only a single operator, and the ability to perform the reduction without analgesia. The success rate when performed by EPs is approximately 80%, with 36% of patients not requiring analgesia.[3] The major disadvantage is that patients are often too apprehensive and experiencing too much discomfort to relax their arms sufficiently to allow for reduction to occur. This problem can be eliminated by the intraarticular instillation of local anesthetic solution. Occasionally, patients will require procedural sedation.

EXTERNAL ROTATION TECHNIQUE

This is a modified version of the Hennepin technique.[21–24,98] The technique is identical to the Hennepin technique except that the procedure is terminated when the arm reaches 90° of external rotation. The step of abduction is not performed. The advantages and disadvantages are as listed for the Hennepin technique.

STIMSON TECHNIQUE

The Stimson technique is a safe first-line technique that uses gravity and weights to overcome muscle spasm and reduce the dislocated shoulder[25–28] (**Figure 81-3**). Instill intraarticular local anesthetic solution into the shoulder joint prior to attempting the reduction. Procedural sedation is usually not necessary. **The patient must be under constant observation to monitor their pulse oximetry and respiratory status if procedural sedation is used because of the patient's prone positioning.**

Place the patient prone with the dislocated arm hanging over the side of the gurney (**Figure 81-3**). Flex the shoulder 90°. A pillow or folded sheets may be placed beneath the affected shoulder for patient comfort. Tie a sheet around the patient's hips and the gurney to prevent them from falling off the bed (**Figure 81-3**). Apply 3 to 5 pounds of weight to the wrist or forearm. The weights can be attached by a commercially available device, hung off a padded wrist restraint, or hung off gauze wrapped circumferentially around the wrist. Raise the gurney so that the weights are suspended off the ground (**Figure 81-3**). Every few minutes, add an additional 3 to 5 pounds of weights until a total of 10 to 15 pounds is achieved. The weights will provide traction in a position of forward flexion and are usually sufficient for reduction to take place within 15 to 30 minutes.[4] If the reduction is unsuccessful after 30 minutes, grasp the patient's forearm and twist it to gently rotate the humerus externally and then internally while the patient is prone and the arm is maintained under traction. This maneuver will often reduce the dislocation if the weights alone are unsuccessful.

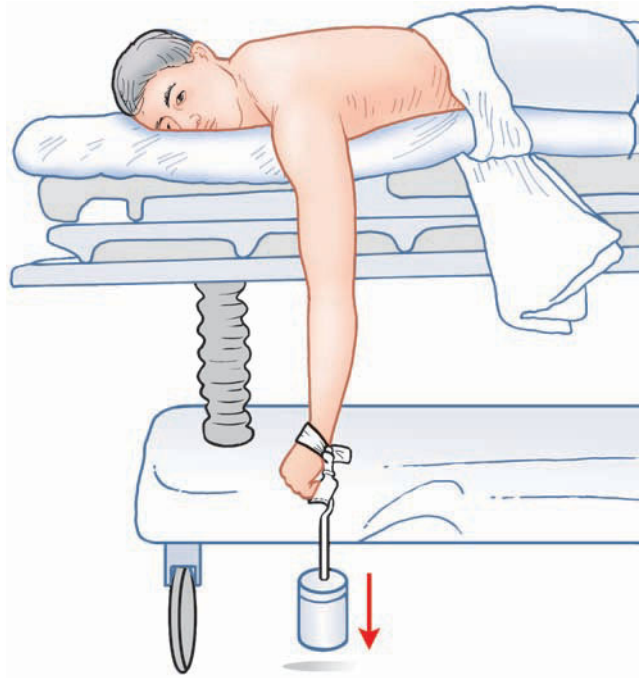


FIGURE 81-3. The Stimson technique to reduce an anterior shoulder dislocation. Weights are progressively added to the wrist to distract the humerus.

An alternative method is to have the patient grip a bucket approximately half full of water. This will provide the necessary traction weight to reduce the joint. The disadvantage of the bucket technique is that the patient will have to grip the bucket for a considerable length of time without releasing it.

The advantage of the Stimson technique is that it is safe and does not require the presence of an assistant. A 96% success rate has been reported with this technique.[3] The disadvantage of the procedure is that the patient must be placed in a prone position that may be painful, uncomfortable, or impossible because of other injuries. There is a small risk of the patient slipping off the elevated gurney. A strap or sheet tied around the patient and the gurney is recommended in order to prevent this. Procedural sedation is not recommended due to the prolonged prone positioning required, which may interfere with the patient's respiration. Additionally, procedural sedation for 15 to 30 minutes is relatively contraindicated and difficult to maintain without potential complications.

SCAPULAR MANIPULATION TECHNIQUE

Scapular manipulation accomplishes reduction by repositioning the glenoid fossa rather than manipulating the humeral head[4,29–33] (**Figure 81-4**). This is a popular technique due to its low complication rate and high patient satisfaction. This technique can be accomplished with no anesthesia or with the intraarticular instillation of local anesthetic solution. Procedural sedation is usually not required.

Place the patient prone with the dislocated extremity hanging over the side of the gurney (**Figures 81-4A & B**). Flex the shoulder 90°. A pillow or folded sheets may be placed below the affected shoulder for patient comfort. Place 5 to 15 pounds of weights suspended from the patient's wrist or in their hand. If weights are not available, an assistant may apply downward traction on the

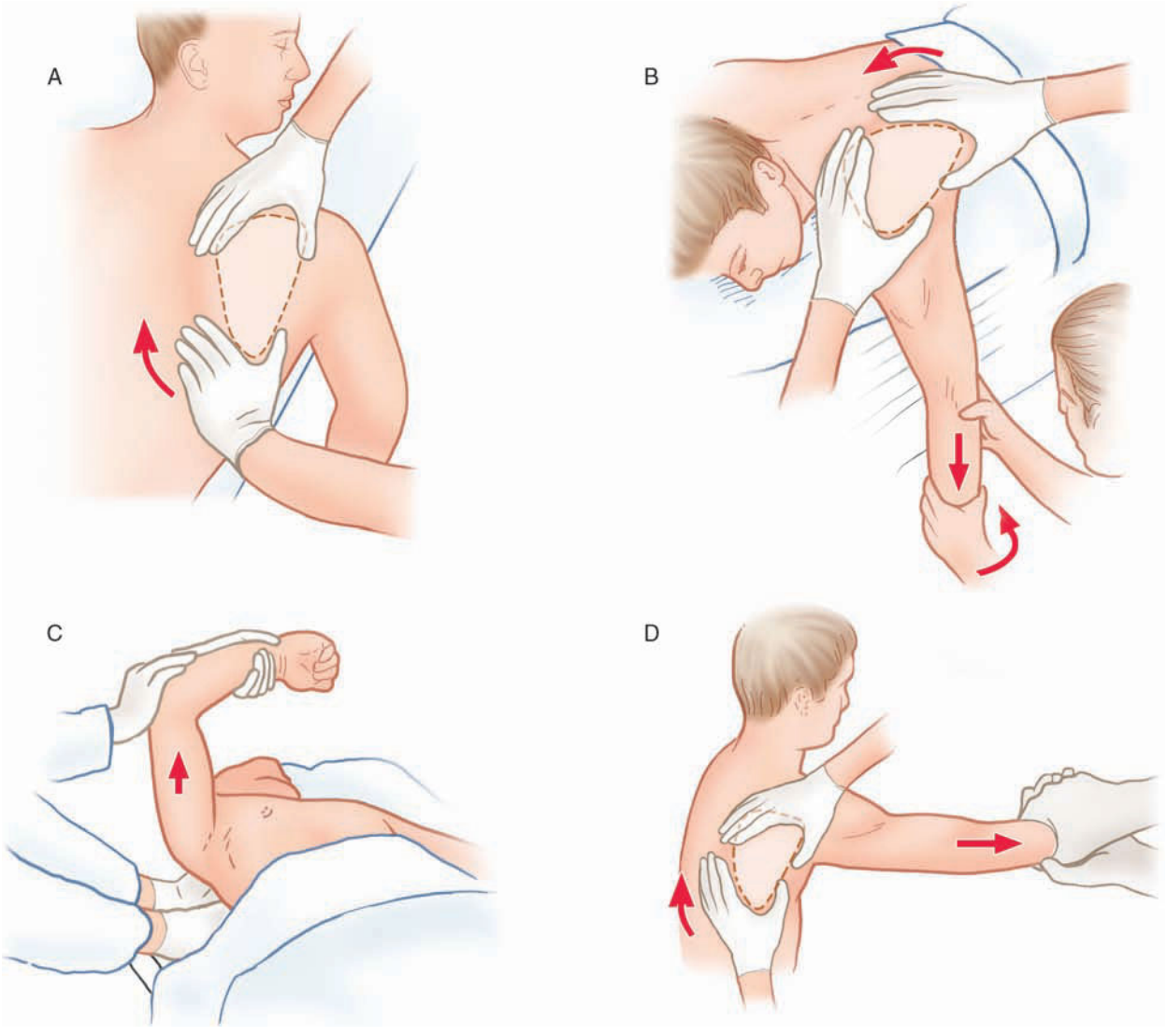


FIGURE 81-4. The scapular manipulation technique to reduce an anterior shoulder dislocation. **A.** Proper hand positioning. The upper hand stabilizes the base of the scapula while the lower hand applies medial and upward pressure on the tip of the scapula (*curved arrow*). **B.** Reduction with the patient prone. Traction is applied by an assistant (*straight arrow*). Occasionally, external rotation is also required (*curved arrow*). **C.** Reduction with the patient supine. Traction is applied on the humerus to elevate the shoulder off the bed (*arrow*). **D.** Reduction with the patient sitting. Traction is applied on the humerus (*arrow*).

extremity (**Figure 81-4B**). The weights or the assistant will provide in-line traction to the arm.

Identify the scapula and its borders. The scapular tip will "wing" laterally. Stabilize the superior portion of the scapula with one hand (**Figure 81-4A**). Place the thumb of the stabilization hand along the superolateral border of the scapula. Apply constant and firm medial and upward pressure to the inferior tip of the scapula using the other hand or thumb (**Figure 81-4B**). The thumb of the stabilizing hand can also be used to apply medially directed pressure to the tip of the scapula. Push the tip of the scapula as far medially as possible. The shoulder should reduce within 1 to 3 minutes. A small degree of dorsal displacement of the scapular tip has also been recommended.[3,33] If the reduction is unsuccessful, slight external rotation of the humerus (by an assistant) while the scapula is being manipulated and the arm is under traction may facilitate reduction (**Figure 81-4B**). This maneuver releases the superior glenohumeral ligament and presents a favorable profile of the humeral head to the glenoid fossa.[31,33]

The scapular manipulation technique may be performed with the patient supine (**Figure 81-4C**). This is particularly helpful when other injuries or conditions preclude using the prone position. Flex the affected shoulder 90°. Instruct an assistant to grasp the forearm and apply upward traction to elevate the shoulder off the bed. Apply your hands to stabilize and manipulate the scapula as described in the previous paragraph.

This technique may also be performed with the patient sitting (**Figure 81-4D**). This is particularly helpful when other injuries or conditions preclude using the prone or the supine position. Flex the affected shoulder 90°. Instruct an assistant to grasp the forearm and apply horizontal traction. Apply your hands to stabilize and manipulate the scapula as described in the previous paragraphs. This method is technically a more difficult version of the scapular manipulation technique because the patient's torso is not stabilized and moves during the traction and scapular manipulation.[3,31,33]

The reduction of an anterior shoulder dislocation by the scapular manipulation technique is usually quite subtle and may be missed by both the patient and the physician. In a few rare cases, the act of lying prone will be sufficient to relocate the shoulder. Success rates of over 90% have been reported with this technique.[3,30–33] The procedure is well tolerated.[3,29–33] In addition, there is a very low incidence

of complications with this procedure and it can be performed without analgesia and monitoring.[97] Disadvantages include the prone position and the need for an assistant to apply traction on the arm.

TRACTION-COUNTERTRACTION TECHNIQUE

The traction-countertraction technique is commonly performed in the ED, mostly out of tradition (**Figure 81-5**). It may be used as a first-line technique or a backup for patients who have failed the Stimson technique.[2] This technique requires anesthesia and analgesia. Instill local anesthetic solution intra-articularly. This may be sufficient, but most patients will require procedural sedation. This technique can cause significant patient discomfort.

Place the patient supine. Pass a sheet around the chest and axilla of the affected arm (**Figure 81-5A**). Abduct the affected arm 45°. Instruct an assistant to grasp the loose ends of the sheet firmly. Grasp the patient's wrist and apply slow and steady traction. Instruct the assistant to apply countertraction. The assistant and EP should be exerting equal and opposite forces. **If pain becomes severe, typically as a result of rotator cuff spasm, stop the motion and wait until the spasm subsides. Do not release the arm or return it to its original position.** After the spasm subsides, continue applying traction and countertraction until the shoulder reduces.

Direct traction on the extended arm may result in rapid EP fatigue. This is especially true if the EP is creating most of the force of traction through contraction of their biceps (**Figure 81-5A**). A less strenuous alternative is available and preferred (**Figure 81-5B**). Position the patient as above. Flex the elbow of the affected arm 90°. Place a looped sheet over the proximal forearm and the EP's hips. Do not loop the sheet around your back, as this can cause low back strain. This method allows the EP to lean back slowly and use their body weight to supply the traction force. The EP's arms should be extended with the hands grasping the patient's distal forearm. When leaning back to apply traction, the EP's hands should maintain the patient's forearm upright with the elbow flexed 90° (**Figure 81-5B**).

Traction may have to be applied for several minutes. The application of gentle and limited external rotation to the affected arm while under traction may speed up the reduction. Alternatively, a second assistant can apply lateral pressure (lateral traction) on the humeral head with their hands. A variation of this technique involves a second assistant with a looped sheet placed high in the patient's axilla (**Figure 81-5C**). This second assistant is used to create lateral traction at the proximal humerus that is perpendicular (90°) to the traction-countertraction axis.[2] As lateral traction is applied, the EP continues in-line traction and can simultaneously adduct the patient's arm to maneuver the humeral head back into position (**Figure 81-5C**). The second assistant may also be used with the technique demonstrated in **Figure 81-5A or B**.

Successful reduction is noted by a lengthening of the arm, a noticeable "clunk," and/or a brief fasciculation of the deltoid muscle. Disadvantages of the traction-countertraction technique include the need for more than one person, the significant degree of force required, the prolonged time and endurance required of the EP and assistant, and the need for procedural sedation. **This technique should not be used to reduce shoulder dislocations associated with significant fractures. The force required for this technique can displace fracture fragments,** necessitating an open reduction or operative management of the displaced fragments.

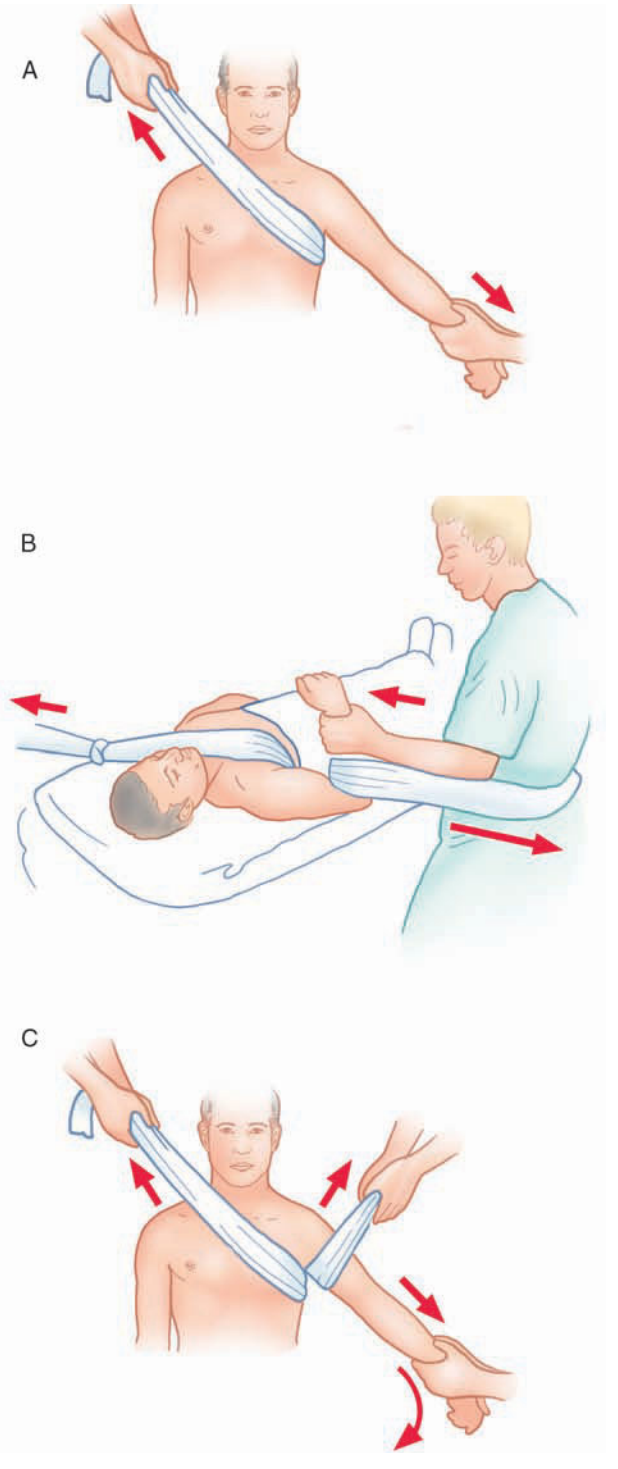


FIGURE 81-5. The traction-countertraction technique to reduce an anterior or posterior shoulder dislocation. **A.** In-line traction is applied to the affected extremity after it is abducted 45°. An assistant provides equal and opposite countertraction with a sheet. **B.** An alternative method. A sheet is looped around the flexed forearm and the EP's hips. The EP leans back (*arrow*) to allow their body to do the work of reduction while their hand maintains the patient's elbow in 90° of flexion. **C.** An additional assistant is applying traction 90° to the traction-countertraction axis with a sheet in the axilla. Simultaneous adduction (*curved arrow*) and in-line traction by the EP may aid in the reduction.

SNOWBIRD TECHNIQUE

The Snowbird technique was named after a ski area in Utah where this technique originated.[34] It was developed in order to reduce the large number of ski-related glenohumeral dislocations quickly while also conserving time and resources. This is an effective alternative reduction technique as compared with the more traditional methods. While this technique can be accomplished with no anesthesia, the intraarticular instillation of local anesthetic solution is highly



FIGURE 81-6. The Snowbird technique to reduce an anterior shoulder dislocation. Downward traction is applied to the humerus (*arrow*) while the humeral head is manipulated back into the glenoid fossa.

recommended. Procedural sedation is usually not required for this reduction technique.

Place the patient in a sitting position on a chair with a back (**Figure 81-6**). Completely adduct the affected arm. Flex the elbow to greater than 90°. Support the affected arm with the other arm or a pillow. Make a 3 foot long loop of 4 in wide cast stockinette. Place the stockinette around the proximal forearm. Instruct the patient to sit as straight as possible. Instruct an assistant to maintain the patient in an upright position by standing adjacent to the unaffected shoulder and clasping their hands around the chest, in the axilla, of the affected shoulder. The EP then places one foot in the stockinette loop and applies firm downward traction with the foot while the patient tries to keep the shoulder relaxed and the affected elbow flexed. Instruct the assistant to provide countertraction to keep the patient from moving. The shoulder may reduce. If not, with continued downward traction on the stockinette, the EP will have both hands free to apply gentle rotation and pressure on the humeral head until the shoulder is reduced.[34]

The Snowbird physicians had a 97% success rate and were able to reduce 93% of anterior shoulder dislocations without any form of analgesia.[34] The advantages of this technique include the relative ease of setup, the rapid nature of the technique, limited use of analgesia, and limited patient positioning. Potential disadvantages include the use of an assistant and the fact that this technique was used and developed on a limited patient population of young healthy skiers.

MILCH TECHNIQUE

Milch, in describing this technique, wrote that a fully abducted arm is in a natural and neutral position in which there is little tension on the muscles of the shoulder girdle.[35–37] Accordingly, the technique that Milch developed relies on gentle manipulation through abduction, external rotation, and traction on the arm.[19,35–40] The patient's affected arm moves in a gradual arc, assisted by the EP, to reduce the dislocation without extensive or forceful manipulation (**Figure 81-7**). While this technique can be accomplished with no anesthesia,[95] the intraarticular instillation of local anesthetic solution is highly recommended. Procedural sedation is not usually required for this reduction technique.

Place the patient supine. Position one hand with the thumb under the dislocated humeral head (**Figure 81-7A**). Slowly abduct the affected arm 180° to an overhead position (**Figure 81-7B**). This can be accomplished by having the patient lift the affected arm. Many patients are unable to do this due to pain, muscle spasm, or apprehension. Gently grip the elbow or wrist and slowly abduct the arm to 180° (**Figure 81-7B**). Once the arm is fully abducted, grasp the patient's distal arm or proximal forearm with one hand. Apply gentle longitudinal traction with slight external rotation to the arm (**Figure 81-7C**). The humeral head may reduce. If not, while maintaining traction with external rotation, apply upward pressure under the humeral head with the other hand to guide it into the glenoid fossa (**Figure 81-7C**).

Successful reduction is attained in 70% to 90% of the cases with no requirement for assistance, other equipment, or medications.[19,35–40] Advantages of the Milch technique include its gentleness, high success rate, limited complications, and good patient tolerance. Disadvantages include positioning the arm in full abduction with or without analgesia, as many patients cannot attain the optimal position due to severe pain, muscle spasm, and/or apprehension. This technique can be modified slightly so that the patient can perform a self-reduction under the instruction of the EP.[96]

ALTERNATIVE ANTERIOR SHOULDER DISLOCATION REDUCTION TECHNIQUES

Numerous alternative and less commonly used techniques are available to reduce an anterior shoulder dislocation. Some of these are modifications of existing methods. Others are original techniques that had too many associated complications and were modified with time and experience. Some are well known and effective techniques that have been used for many years. There is very little research regarding many of these techniques. Some of these techniques may prove to be useful in the reduction of an anterior shoulder reduction. **None of these techniques are advocated as first-line treatments for the reduction of shoulder dislocations. Their inclusion here is for the sake of completeness; it does not necessarily constitute an endorsement for their use.** Only a select few of these techniques are discussed.

HIPPOCRATIC TECHNIQUE

The Hippocratic technique is the original traction-countertraction technique[41] (**Figure 81-8**). It is one of the oldest documented techniques to reduce a shoulder dislocation.[2,11,26,41] This technique has the advantage that it can be performed by one person in any setting. While effective, the Hippocratic technique is not recommended due to the great force required to achieve reduction. Common complications of the technique include fractures, brachial plexus injury, vascular injury, and poor patient tolerability.[2,6,11]

Place the patient supine (**Figure 81-8**). Grasp the wrist of the affected arm and abduct the arm 20° to 30°. Place one foot into the axilla of the affected arm. Firmly grasp the patient's wrist and apply traction to the arm while extending the foot in the axilla to provide countertraction.

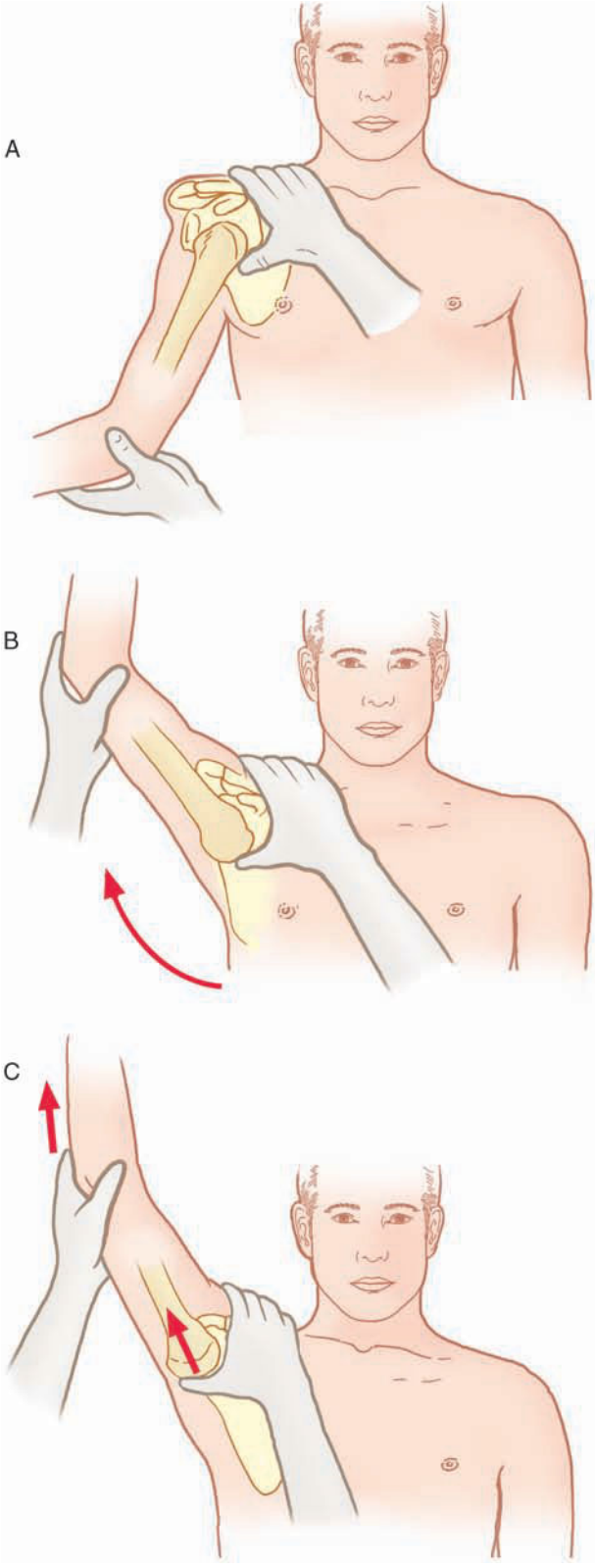


FIGURE 81-7. The Milch technique to reduce an anterior shoulder dislocation. **A.** The distal humerus is grasped with one hand while the thumb of the other hand is placed under the dislocated humeral head. **B.** The arm is abducted to 180°. **C.** In-line traction is applied to the humerus while the thumb pushes the humeral head into the glenoid fossa.

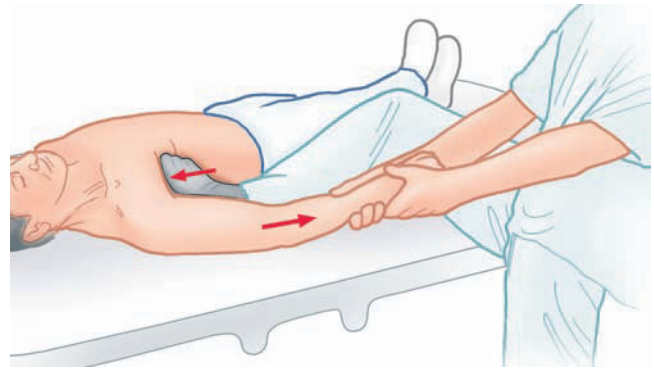


FIGURE 81-8. The Hippocratic technique to reduce an anterior shoulder dislocation. Traction is applied to the arm while countertraction is applied using a foot in the axilla.

KOCHER TECHNIQUE

The Kocher technique was first recorded on an Egyptian mural dated 1200 BC.[42] It is another traditional method that has come into disfavor. This maneuver relies upon leverage and humeral manipulation to reduce the shoulder (**Figure 81-9**). The humeral head is levered on the anterior glenoid while the humeral shaft is levered against the anterior thoracic wall until reduction is achieved.[11,42,43] A substantial amount of force must be applied while adducting and externally rotating the arm in order to reduce the joint.

Place the patient sitting at a 45° incline or supine. Abduct the affected arm 45° and flex the elbow 90° (**Figure 81-9A**). Grasp the patient's distal humerus with the dominant hand and the patient's wrist with the nondominant hand (**Figure 81-9A**). Apply in-line traction to the distal humerus. Rotate the arm externally to its maximum extent while maintaining in-line traction (**Figure 81-9B**). Move the patient's elbow across their chest and to the midline while maintaining in-line traction and external rotation (**Figure 81-9C**) while the elbow is held tightly against the patient's chest. Finally, internally rotate the arm while in-line traction is maintained and until the patient's hand touches their opposite shoulder (**Figure 81-9D**).

The main advantage of this method is that it is a one person technique that has withstood the test of time. However, studies have shown that the forces generated are sufficient to cause fractures of the humeral neck, spiral humeral fractures, vascular trauma, and brachial plexus injury.[11]

ESKIMO TECHNIQUE

The Eskimo technique uses the patient's body weight and gravity as a traction mechanism to reduce an anterior shoulder dislocation.[44] It can be performed in the field, where access to a healthcare facility may be limited. Disadvantages of this technique include the strength and stamina required to lift the patient, EP injury due to heavy lifting, poor patient tolerability, and increased stress on the brachial plexus and axillary vessels.

Place the patient on the floor and lying on the unaffected side (**Figure 81-10**). Instruct the patient to place the affected arm tightly adducted with the elbow flexed 45° (**Figure 81-10A**). Grasp the injured arm and slowly lift the patient 6 to 12 in. off the ground (**Figure 81-10A**) so that the patient's body weight produces enough traction to reduce the joint. Poulsen initially described this technique and reported a 74% success rate.[44]

Alternatively, the patient can be positioned on the unaffected side with the affected arm abducted 90° (**Figure 81-10B**). One or two

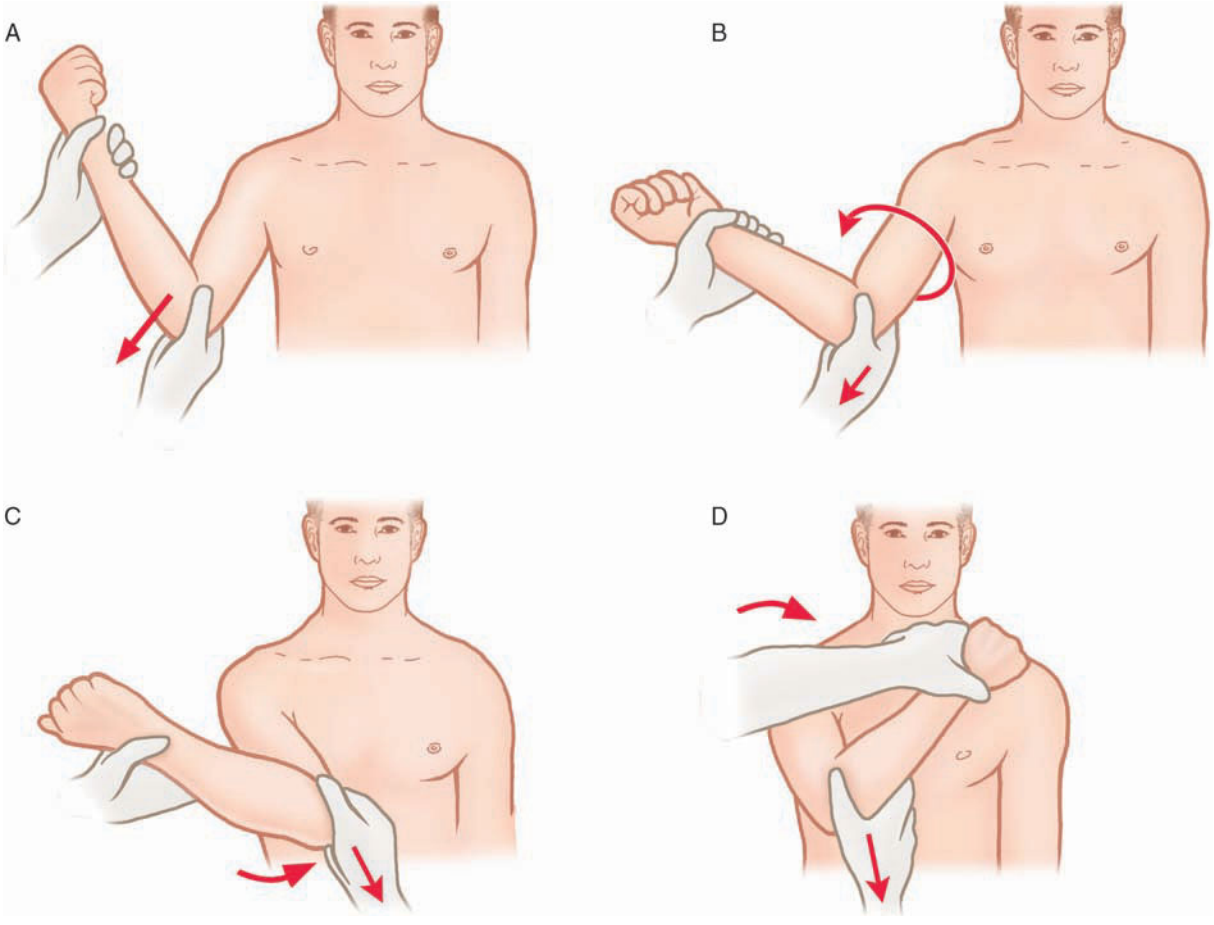


FIGURE 81-9. The Kocher technique to reduce an anterior shoulder dislocation. **A.** The arm is abducted 45° with the elbow flexed 90°. In-line traction is applied to the humerus (*arrow*). **B.** The arm is rotated externally (*curved arrow*) while traction is maintained (*straight arrow*). **C.** The elbow is brought across the chest to the midline while the arm is still rotated externally and traction on the arm is maintained (*straight arrow*). **D.** Traction is maintained while the arm is rotated internally until the patient's hand touches their opposite shoulder.

people can then grasp the patient's wrist and forearm and lift the patient 6 to 12 in. off the ground (**Figure 81-10B**).

CHAIR TECHNIQUE

The chair technique is a simple method to reduce an anterior shoulder dislocation.[45–47,80] It is a variation of the traction-countertraction technique. Place the patient sitting sideways or backwards in a chair with the affected arm draped over the back rest (**Figure 81-11**). Supinate the patient's wrist and apply downward traction while the patient attempts to stand and provide countertraction (**Figure 81-11**).

This technique has a 72% success rate.[3] The advantages include the simplicity of the technique and the fact that analgesia is not required. Unfortunately, a large amount of force is required to reduce the shoulder. These forces can cause injury to the brachial plexus and axillary vessels as the axilla is impinged on the back of the chair.

WRESTLING TECHNIQUE

Zahiri et al. recently described a new technique based on optimal anatomic positioning with limited complications.[48] Place the patient supine with the elbow of the affected shoulder flexed 120°. Grasp the dislocated arm just above the humeral condyles and apply distal traction to the arm. Grasp the distal forearm overhanded with the opposite hand and move the hand from the condyles through the acute angle of the arm, grasping the wrist of the hand holding the forearm. The wrestling hold is now established (**Figure 81-12**). With the hold in place, the patient's forearm will be used as a fulcrum. Abduct the patient's shoulder 45° while maintaining constant traction. Externally rotate the arm in a slow, smooth motion. While maintaining traction and external rotation, move the patient's arm over their chest wall and rotate it internally.[1] The shoulder should then reduce.

This technique has the advantages of requiring no equipment, no analgesia, and no assistants. It may be used in the field where a healthcare facility is not readily available. The main disadvantage is the amount of force applied to the shoulder and surrounding structures. The twisting of the forearm as a lever can displace fracture fragments or cause fractures. This technique also requires the EP to have a significant amount of upper body strength and arms long enough to accomplish the wrestling hold, especially if the patient has large arms. The series of movements is difficult to accomplish while always maintaining distal traction.

PNEUMATIC STRETCHER TECHNIQUE

This technique was developed to reduce a shoulder dislocation when assistants were not available or if the physician did not have the physical strength required to use other techniques.[49] It is a modification of the traction-countertraction technique.

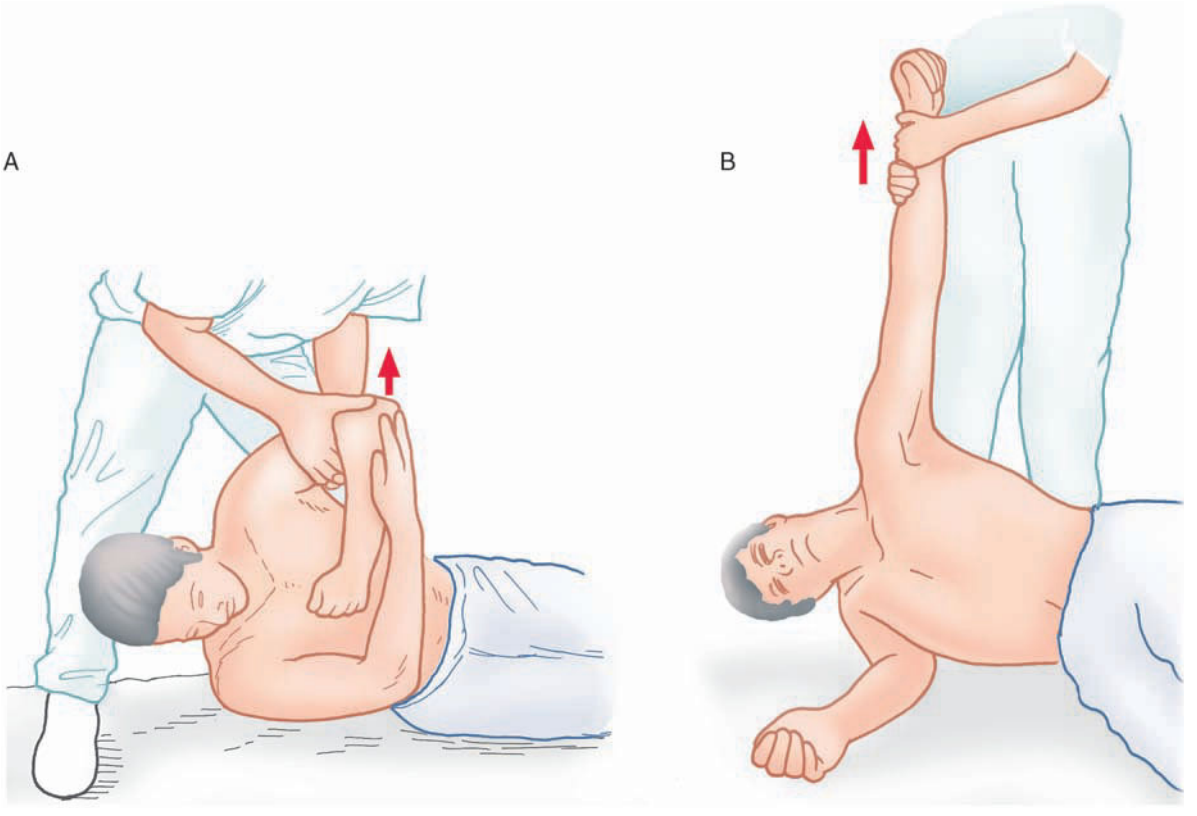


FIGURE 81-10. The Eskimo technique to reduce an anterior shoulder dislocation. The patient is lying on the floor on the unaffected side. **A.** The patient is lifted off the ground by grasping the adducted arm. **B.** The patient is lifted off the ground by grasping the distal forearm of the affected arm.

This technique should never be used to reduce a shoulder dislocation. It will cause stretching and possible rupture of the brachial plexus, ligaments of the shoulder region, muscles and tendons crossing the shoulder, nerves of the upper extremity, vascular structures of the upper extremity, and injury to other joints. Tremendous forces are applied to the extremity with this technique.

Place the patient prone with the affected arm hanging off the gurney (**Figure 81-13**). Wrap a sheet around the patient's waist and hips and the gurney to hold the patient in position. Tie the ends of the sheet into a knot or have them held by an assistant. Wrap the patient's wrist with gauze and tie it to the base or wheel of the gurney. Begin elevating the bed until the dislocation is reduced.

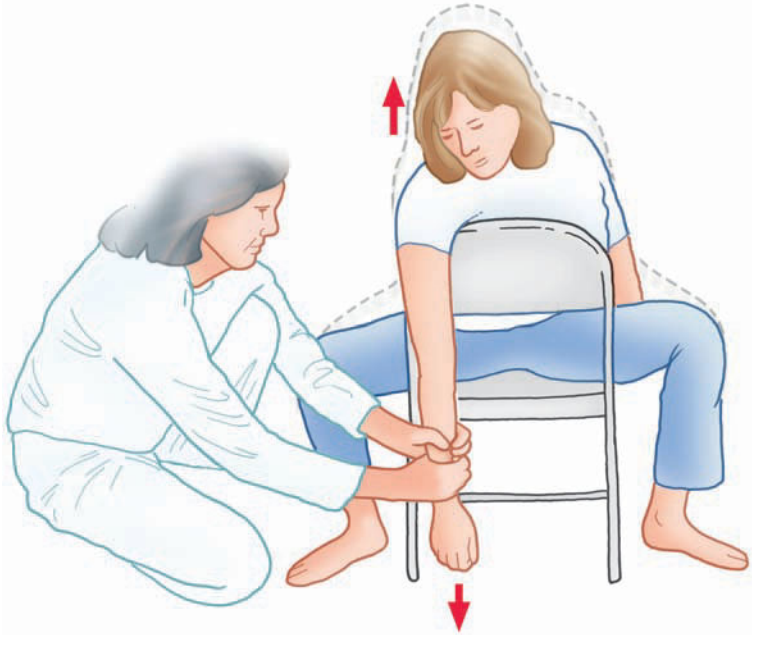


FIGURE 81-11. The chair technique to reduce an anterior shoulder dislocation. Traction is applied to the arm as the patient attempts to stand and provide countertraction.

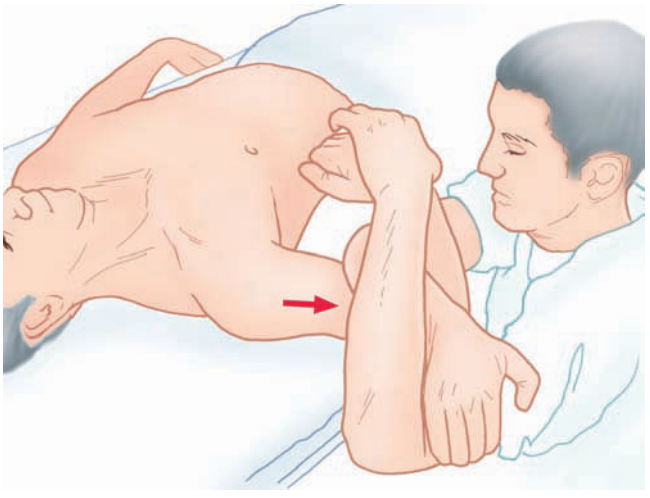


FIGURE 81-12. The wrestling technique to reduce an anterior shoulder dislocation. After the hold is established, traction and external rotation are applied to the arm.

SPASO TECHNIQUE

The Spaso technique is a one person technique that is simple to perform.[81–85] It uses minimal force and can be performed without procedural sedation. This technique is similar to the Stimson technique with the main difference being the patient's position.[82] Successful rates of reduction can be seen in up to 87% of patients.[83–85]

Place the patient supine. Grasp the wrist of the affected arm with the dominant hand and the patient's proximal forearm with the nondominant hand (**Figure 81-14**). Slowly flex the patient's shoulder until the arm is upright and the shoulder flexed 90° (**Figure 81-14**). Apply upward traction to the arm while gently externally rotating the arm. Slowly increase the upward traction until the shoulder reduces. If reduction does not occur, use the nondominant hand to apply externally directed pressure to the humeral head to push it into the glenoid fossa while maintaining the arm in traction and external rotation with the dominant hand. An assistant may be required to push on the humeral head while the EP uses both hands to apply upward traction.



FIGURE 81-14. The Spaso technique to reduce an anterior shoulder dislocation. Upward traction is applied (*arrow*) as the arm is externally rotated (*curved arrow*).

OZA MANAUVER

Direct manipulation of the humeral head with simultaneous arm traction may allow for a simple reduction of the humeral head.[86] This technique is a modification of the traction-countertraction technique. Very little information exists in the literature regarding the effectiveness of this maneuver.

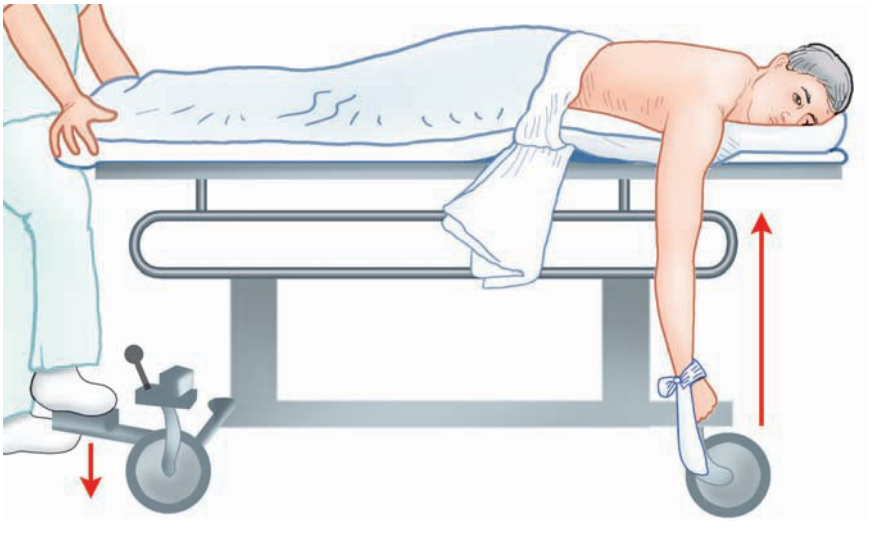


FIGURE 81-13. The pneumatic stretcher technique to reduce an anterior shoulder dislocation. The gurney is raised to provide countertraction to the traction applied to the wrist that is tied to the base of the gurney.



FIGURE 81-15. The Oza maneuver to reduce an anterior shoulder dislocation. Traction is applied to the arm as the humeral head is pushed outward.

Place the patient supine with the affected arm and their body against the edge of the gurney (**Figure 81-15**). Instruct an assistant to grasp the patient's wrist and slowly abduct the arm until it is at 45° to 90°. Stand between the patients abducted wrist and their body, with your back against the patient's body. Place both thumbs against the dislocated humeral head. Wrap the fingers of both hands around the proximal humerus and interlace your fingers. Instruct the assistant to apply traction to the arm while simultaneously using your thumbs to lift and push the humeral head up and over the anterior glenoid lip and back into the glenoid fossa. Alternatively, the EP can stand outside the patient's abducted arm, wrap their fingers around the proximal humerus, and pull the humeral head back into the glenoid fossa.

BEST OF BOTH (BOB) MANEUVER

The BOB maneuver is a combination of distally applied traction and scapular manipulation.[87] This maneuver is quick to perform and does not use procedural sedation. It requires the patient to sit upright with their legs dangling off the gurney. Thus, this maneuver is not appropriate to use with procedural sedation, intubated patients, multiply injured patients, those who cannot sit upright, or anyone with altered mentation. The BOB maneuver can be performed with no analgesia or the instillation of local anesthetic solution intra-articularly.

Lower the gurney as much as possible. Elevate the head of the gurney 90°. Place the patient sitting upright on the side of the gurney with their unaffected arm against the upright head of the gurney. The patient's feet may touch the floor or dangle. Instruct the patient to "scoot over" until their unaffected shoulder and hip are tight against the head of the gurney. Kneel on the gurney facing the patient (**Figure 81-16**). Flex the elbow of the affected arm 90°. Place one hand on the patient's proximal forearm adjacent to the antecubital fossa. Grasp the patient's wrist with your other hand. Lean down with your body weight, pulling the patient's humerus downward (**Figure 81-16**). Instruct an assistant to simultaneously stand behind the patient and perform the scapular manipulation technique. The combination of traction of the humerus and scapular manipulation will allow the humeral head to relocate in the glenoid fossa.

LEGG REDUCTION MANEUVER

This maneuver is a simple technique to reduce an anteriorly dislocated shoulder.[88] It was developed and used to treat athletes in the field. Many patients may not tolerate the pain associated with this maneuver. It is not appropriate to use with procedural sedation, intubated patients, multiply injured patients, those who cannot sit upright in a chair, or anyone with altered mentation. The maneuver can be performed with no analgesia or the instillation of local anesthetic solution intra-articularly.

Place the patient sitting upright in a chair. Instruct an assistant to provide slight downward pressure on the unaffected shoulder (**Figure 81-17A**). Instruct the assistant to maintain downward pressure on the shoulder throughout the maneuver. Place one hand on the affected shoulder and apply downward pressure while abducting the patient's arm with your other hand (**Figure 81-17A**). Externally rotate the arm and flex the elbow 90° until the patient's palm faces

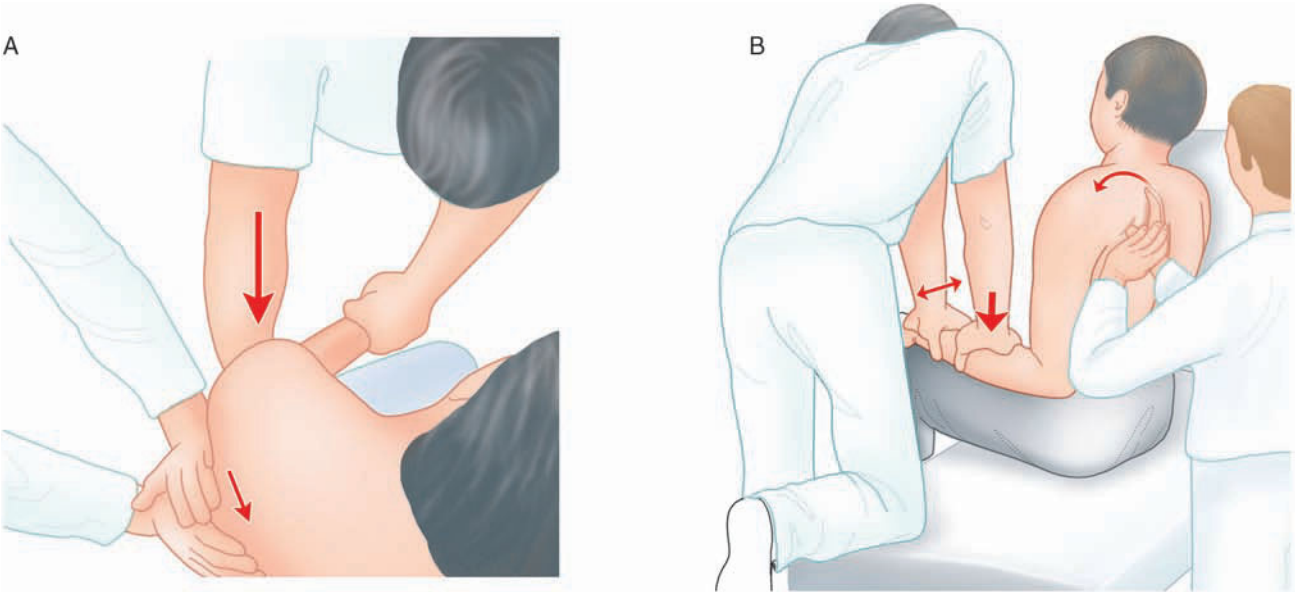


FIGURE 81-16. The best of both (BOB) maneuver to reduce an anterior shoulder dislocation. Traction is applied to the humerus as the tip of the scapula is pushed medially. **A.** Superior view. **B.** Lateral view.

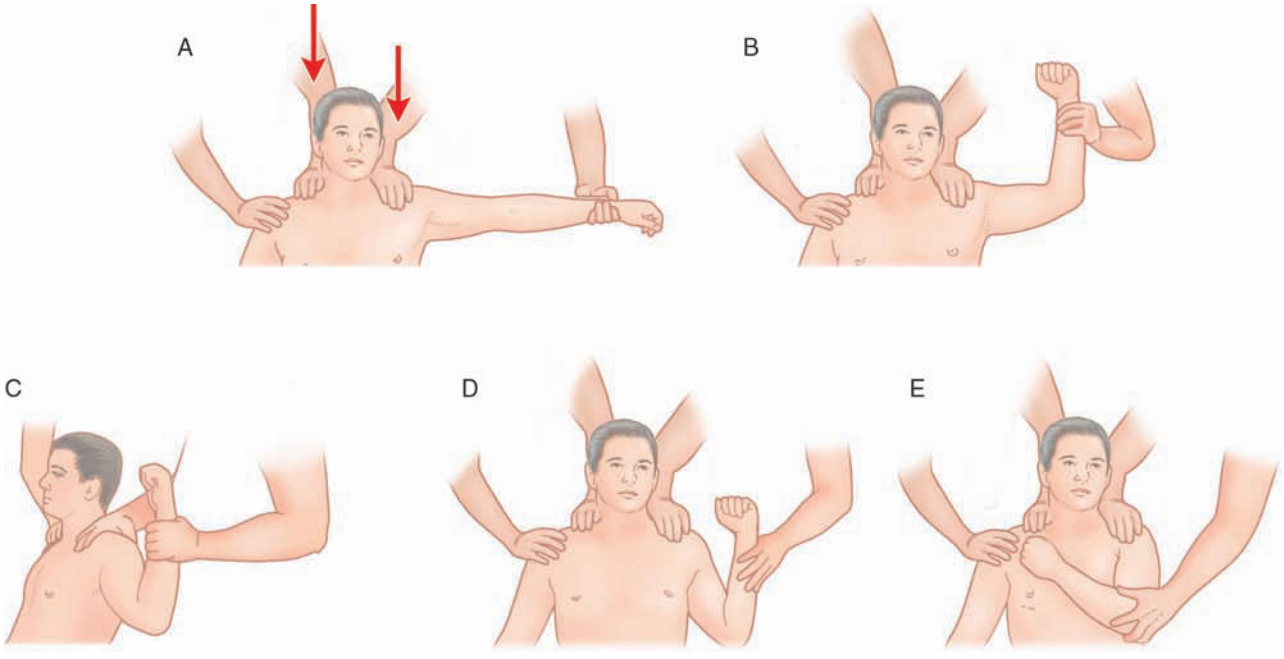


FIGURE 81-17. The Legg reduction maneuver to reduce an anterior shoulder dislocation. **A.** Initial positioning. **B.** The arm is externally rotated and the elbow flexed 90°. **C.** The arm is moved posteriorly. **D.** The arm is adducted while fully flexing the elbow. **E.** Internal rotation of the arm.

outward (**Figure 81-17B**). Pull the elbow and forearm posteriorly until it crosses a plane across the occiput (**Figure 81-17C**). Adduct the arm while simultaneously flexing the elbow from 90° to full flexion (**Figure 81-17D**). Once fully adducted, internally rotate the arm until the hand touches the unaffected shoulder and the humerus relocates (**Figure 81-17E**).

CUNNINGHAM TECHNIQUE

Dr. Cunningham developed a technique to simply, quickly, and painlessly reduce an anterior shoulder dislocation without the use of drugs.[89,90] This small case series is based on the principle of relaxing the biceps brachii muscle with massage while the rhomboids retrovert the scapula to allow the humeral head to relocate.

Place the patient sitting upright in a chair or on a gurney (**Figure 81-18**). Stand next to the affected arm and face the patient. Fully adduct the humerus and flex the elbow 90°. Insert one hand between the patient's forearm and their body. Grasp the patient's proximal forearm so that their hand and wrist is resting on your upper forearm (**Figure 81-18**). Instruct the patient to shrug their shoulders superiorly and posteriorly to square-off the angle of their shoulder. Apply steady and downward pressure to the patient's forearm. With your other hand simultaneously massage the patient's trapezius, deltoid, and biceps muscles sequentially. While maintaining the downward traction, repeat the massage process while concentrating on the biceps until the shoulder reduces.

BOSS-HOLZACH-MATTER TECHNIQUE

This technique allows the patient to self-reduce an anterior shoulder dislocation.[91–93] The patient can control the application of force so that their pain can be minimized during the reduction. It is a hybrid of the traction-countertraction and scapular manipulation techniques. The EP instructs the patient through the technique. This technique is only successful in 60% of anterior shoulder dislocations, significantly lower than many other commonly used reduction techniques.

Place the patient supine on a gurney. Elevate the head of the gurney to 90°. Bind the patient's wrists together with an elastic or gauze bandage. Instruct the patient to flex their knee on the affected side. Instruct the patient to place their bound wrists in front of the flexed knee (**Figure 81-19**). Lower the head of the gurney completely. Instruct the patient to slowly lean back while simultaneously hyperextending their neck and shrugging their shoulders anteriorly to antevert the glenoid fossa. The humeral

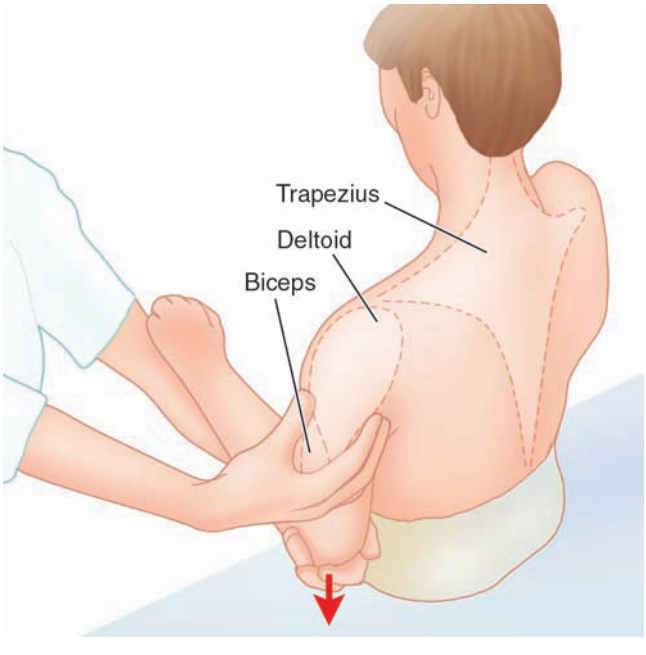


FIGURE 81-18. The Cunningham technique to reduce an anterior shoulder dislocation. Traction is applied to the humerus while the trapezius, deltoid, and biceps muscles are massaged sequentially.

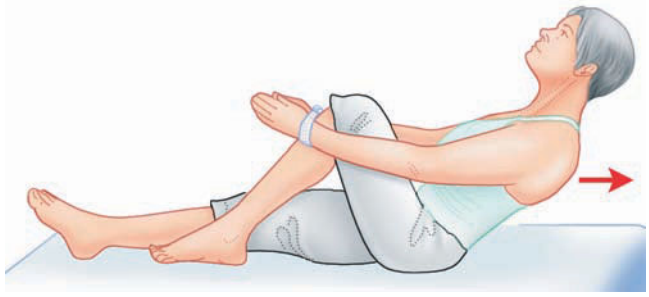


FIGURE 81-19. The Boss-Holzach-Matter technique to reduce an anterior shoulder dislocation. The patient leans back to provide countertraction while the wrists are secured over the knee to provide distal traction.

head will reduce as the glenoid fossa moves toward the humeral head while traction is applied to the humerus.

FARES METHOD

This technique can reduce an anteriorly dislocated shoulder in an average of 2 to 3 minutes with the use of procedural sedation.[94] The FARES method has a 78% success rate and only requires one person to perform the reduction.

Place the patient supine with the affected arm at their side. Fully extend the elbow and place the forearm in the neutral position with the patient's thumb pointing upward. Grasp the distal forearm and hand. Apply longitudinal traction on the arm (**Figure 81-20A**). Oscillate the forearm continuously with brief (two to three cycles per second) and short range (5 cm above and below the horizontal plane) vertical movements of the arm (**Figure 81-20A**). Slowly abduct the arm while maintaining longitudinal traction and vertical oscillatory movements (**Figure 81-20B**). Externally rotate the arm until the palm is facing upward when the arm is approximately 90° abducted. Continue to slowly abduct the arm while maintaining longitudinal traction and vertical oscillatory movements until the shoulder reduces (**Figure 81-20C**). The shoulder usually reduces at approximately 120° of abduction. Once reduced, gently internally rotate the arm and adduct it until the humerus is against the chest and the forearm is resting across the chest.

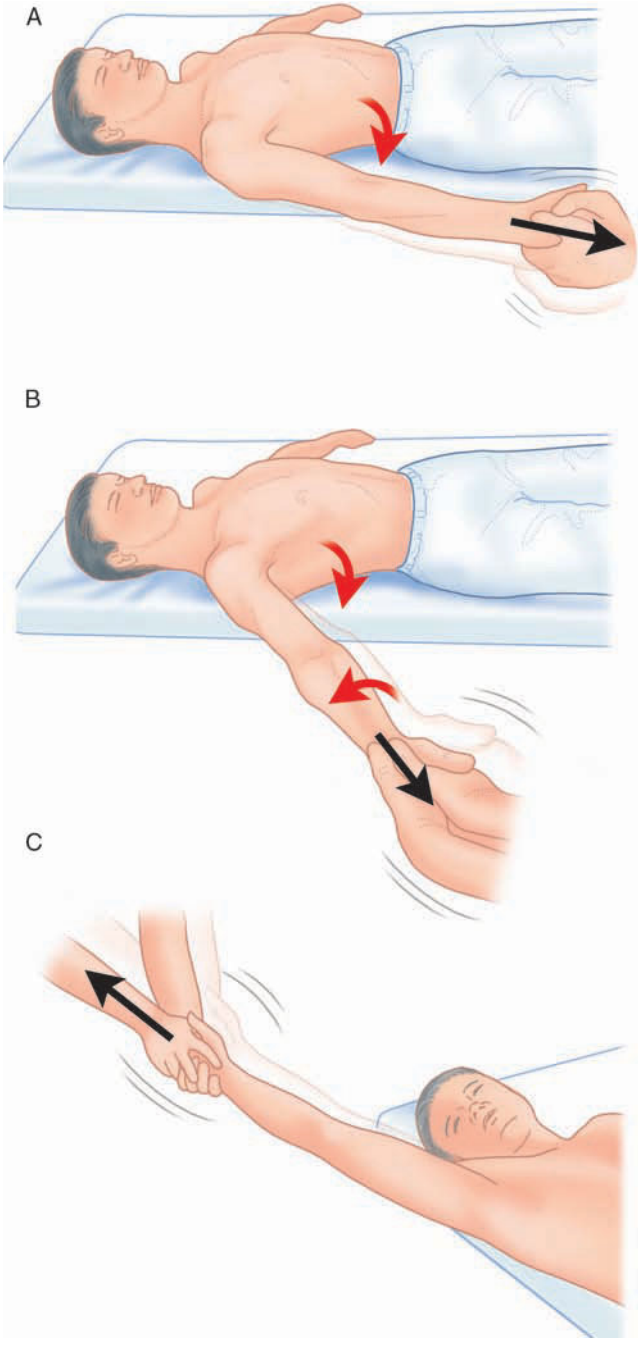


FIGURE 81-20. The FARES method to reduce an anterior shoulder dislocation. **A.** Longitudinal traction is applied to the abducted arm as vertical oscillatory movements are made with the forearm. **B.** The arm is further abducted and externally rotated as longitudinal traction and vertical oscillatory movements are continued. **C.** The arm is further abducted as longitudinal traction and vertical oscillatory movements are continued until the shoulder reduces.

POSTERIOR SHOULDER DISLOCATION REDUCTION TECHNIQUE

An Orthopedic Surgeon should be consulted before attempting to reduce the shoulder due to the rarity of posterior shoulder dislocations, the difficulty of reduction, the high incidence of associated injuries, and the need to operate to repair the associated injuries.[2,4,8,11,99,101] **The only exception is when the affected extremity has signs of neurologic or vascular compromise and the Orthopedic Surgeon is not immediately available to reduce the shoulder.** The patient will require intraarticular instillation of local anesthetic solution and procedural sedation for the performance of this technique.

TRACTION-COUNTERTRACTION

Place the patient supine. Perform procedural sedation. Pass a sheet around the axilla and torso of the affected arm in the same manner as in the traction-countertraction technique (**Figure 81-5A**). Grasp the distal forearm. Apply axial traction in-line with the humerus. Instruct an assistant to apply countertraction on the sheet looped around the patient's torso. The traction and countertraction should be equal in force and in opposite directions. While maintaining traction, gently internally rotate and adduct the arm. The shoulder may reduce. If not, instruct a second assistant to apply simultaneous lateral pressure on the humeral head.[3] While continuing to exert pressure on the humeral head, in trying to work it over the glenoid rim, the arm may need to be gently rotated externally. If this fails to reduce the shoulder, apply lateral traction, with a second assistant using a sheet looped around the proximal humerus, and repeat the

process (**Figure 81-5C**). If the shoulder will still not reduce, this is an indication for general anesthesia and an open or closed reduction in the Operating Room.[4,9] The shoulder joint is usually unstable and may not remain articulated once it is reduced.

An alternative to grasping the forearm is to apply a padded wrist restraint. Tie the loose ends of the restraint straps to create a loop around the EPs hips. A second alternative is to loop a sheet around the patient's flexed forearm and the EPs hips as in the traction-countertraction technique (**Figure 81-5B**). These two alternatives are preferred, as they allow the EPs body to reduce the shoulder rather than depending on biceps strength.

INFERIOR SHOULDER DISLOCATION REDUCTION TECHNIQUE

Like posterior shoulder dislocations, **inferior shoulder dislocations require an Orthopedic Surgeon to be consulted before attempting closed reduction unless neurologic or vascular compromise is present in the affected extremity.** Consultation is required because of the rarity of inferior shoulder dislocations, the difficulty of reduction, the high incidence of associated injuries, and the need to operate to repair the associated injuries.[2–4,10,50–52,100,101] The patient will require intraarticular instillation of local anesthetic solution and procedural sedation for the performance of these techniques.[4] An inferior shoulder dislocation is usually reduced using the traction-countertraction technique.[10,100–102]

TRACTION-COUNTERTRACTION

Place the patient supine. Loop a sheet over the clavicle of the affected shoulder with the loose ends of the sheet at the opposite hip (**Figure 81-21**). Stand above the patient's head and grasp the distal forearm. Apply axial traction to the arm. Instruct an assistant to apply equal countertraction on the sheet. While maintaining axial traction on the humerus, gently adduct the arm in a full arc from the patient's head to their side (**Figure 81-21**). The shoulder should reduce. The shoulder joint is usually unstable and may not remain articulated once reduced. In rare instances, buttonholing of the joint capsule will prevent closed reduction and require an open reduction.[2]

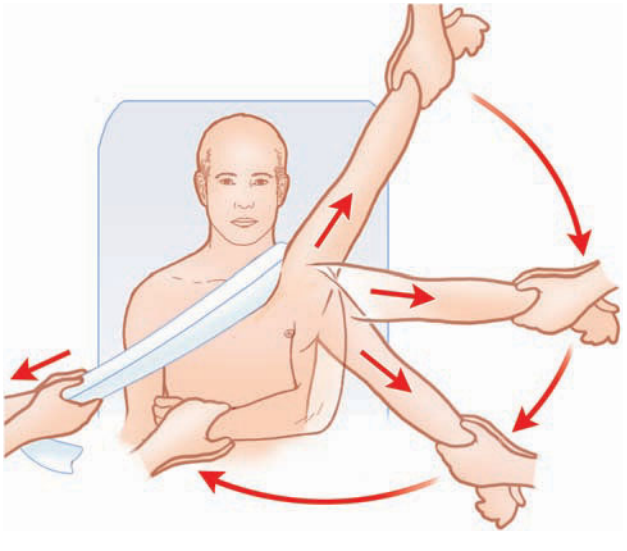


FIGURE 81-21. Reduction of an inferior shoulder dislocation. Axial traction (*straight arrows*) is applied and maintained on the dislocated extremity while it is simultaneously hyperadducted (*curved arrows*).

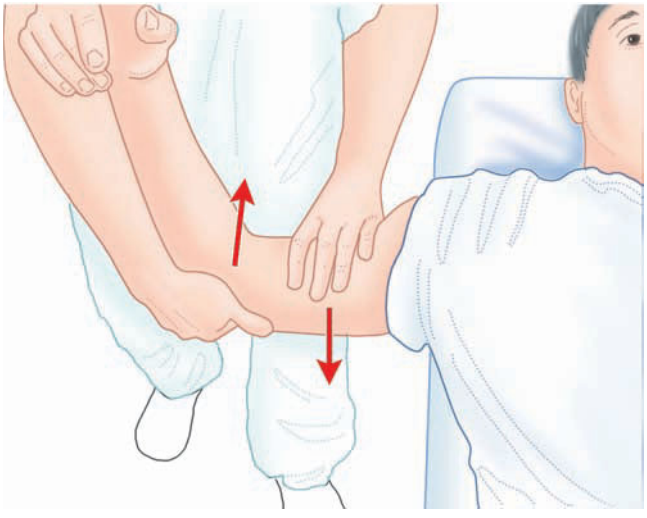


FIGURE 81-22. The two-step maneuver to reduce an inferior shoulder dislocation. Step one involves pushing the lateral aspect of the distal humerus while pulling on the medial condyle to convert the inferior dislocation into an anterior dislocation. Step two is the external rotation technique (**Figure 81-2A**).

TWO-STEP MANEUVER

This maneuver consists of two steps.[103] The first step converts an inferior shoulder dislocation into an anterior shoulder dislocation. Step two is the reduction of the anterior shoulder dislocation using the external rotation technique described previously in this chapter. The two-step maneuver has several advantages over using the traction-countertraction technique. This includes requiring a single person, using one reduction attempt, possibly using less sedation, and not requiring a trip to the Operating Room for the reduction.

Place the patient supine. Stand adjacent to the affected shoulder and facing the patient's feet. Place one hand on the distal aspect of the lateral humerus and the other hand on the medial epicondyle (**Figure 81-22**). Use the hand on the lateral aspect of the distal humerus to push inward while simultaneously pulling the elbow outward (**Figure 81-22**). This will convert the inferior dislocation into an anterior dislocation. Apply the external rotation technique to reduce the anterior dislocation.

ASSESSMENT

The postprocedural care of the dislocated shoulder is as important as the initial reduction. Successful shoulder reduction is usually sensed by the operator as a shift or "clunk" in the shoulder joint. Sometimes this can be a very subtle sign. Generally, the normal contour of the shoulder is restored and patients often report marked improvement in their pain. A simple test to evaluate the success of the reduced joint, especially in anterior and posterior dislocations, is to have the patient touch their nose or contralateral shoulder with the hand of the affected limb.[3] The ability to do so usually signifies a relocated shoulder joint. **The patient should have a thorough examination to evaluate the extremity for vascular and/or neurologic compromise. Any compromise requires immediate consultation with an Orthopedic Surgeon.**

It is important to immobilize the shoulder to prevent further external rotation or abduction of the reduced shoulder by the patient. Place the affected extremity in a shoulder immobilizer (**Figure 81-23A**) or a conventional sling with a swath (**Figure 81-23B**).[1,2,11,20,53,54] The shoulder should be immobilized in

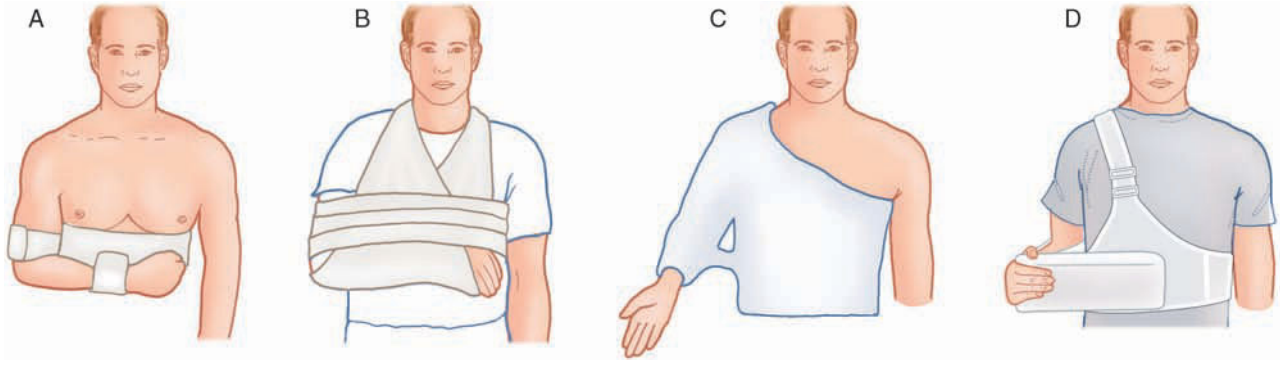


FIGURE 81-23. Methods of shoulder immobilization after reduction of a dislocation. **A.** Shoulder immobilizer. **B.** Velpeau dressing. **C.** Spica cast. **D.** Immobilization in external rotation.

external rotation in a spica cast if a successful reduction is unstable[3] (**Figure 81-23C**). Recent studies have shown that splinting the shoulder with the arm adducted and in 10° to 20° of external rotation may prevent recurrent dislocations.[106–109] Patients should remain in this position for 3 weeks.[106] A splint to hold the shoulder in external rotation can be made with splinting material or a commercially available product may be purchased (**Figure 81-23D**).[106–109]

Postreduction films are indicated after immobilization to confirm the reduction of the joint, to rule out missed fractures on the original radiographs, to rule out a fracture from the reduction procedure, and to evaluate for displacement of fracture fragments. There is some evidence that postreduction radiographs may be unnecessary, but further study is warranted before this can be routinely recommended.[13,14]

Bedside ultrasound (US) can be used to verify the shoulder is reduced.[104,105] A high frequency (7-13 MHz) US probe is preferred, but a lower frequency probe can also be used if available. Place the US probe transversely on the patient's back just inferior to the lateral aspect of the scapular spine to obtain a posterior US.[104] It may be more practical to obtain anterior or lateral US image in the supine patient.[105] The advantages of bedside US over plain radiographs include time saving, lack of radiation, not waiting for procedural sedation to wear off before transporting the patient to the radiology suite, US can be performed with the patient in any position, and it does not require patient cooperation.

AFTERCARE

Following procedural sedation, the patient will need to be observed before being discharged home in the care of friends or family. It is necessary to have the patient awake, alert, oriented, and to have the pain adequately controlled before discharge. The patient should be discharged with adequate pain control and follow-up care by an Orthopedic Surgeon. Generally, oral nonsteroidal anti-inflammatory drugs are sufficient to control pain. Oral narcotics may be given as needed for 2 to 3 days to aid with pain during the acute inflammatory response period. Orthopedic follow-up should be arranged within 24 hours for anterior shoulder dislocations complicated by fractures or soft tissue injuries beyond ligamentous strain. Orthopedic follow-up within 5 to 7 days is generally sufficient for uncomplicated anterior shoulder reductions.

The duration of immobilization depends on the patient's age.[2,11,20] The only large-scale prospective study of first-time anterior shoulder dislocations followed patients over a 10 year period. It found that the duration of immobilization had no effect on the incidence of recurrence. Age was the only prognostic factor for recurrence. Patients under 20 years of age should be immobilized for 3 weeks and then begin active range-of-motion exercises. Patients aged 20 to 40 years should be immobilized for 1 to 2 weeks and begin active range-of-motion exercises 5 days postreduction. Patients older than 60 years of age should have minimal immobilization—less than 1 week—and begin active range-of-motion exercises within 72 hours postreduction to limit subsequent shoulder stiffness.[2,11] Patients should be instructed to avoid external rotation and abduction activities, such as combing their hair, to avoid a recurrent dislocation.[1]

Range-of-motion exercises should include dangling-arm rotation.[2,11] While supporting the torso with the other arm, the patient makes a small circular motion with the injured arm against the force of gravity. For anterior dislocations, strengthening the subscapularis muscle by doing internal rotation against a resistance band with the elbow flexed 90° is advocated.[2]

COMPLICATIONS

Complications of shoulder dislocations can occur as a result of the initial injury, the reduction technique, or a combination of both. Complications are discussed with respect to both the initial injury and the reduction. They include fractures, displacement of fracture fragments, rotator cuff tears, vascular injury, neurologic injury, recurrence of dislocation, hemarthroses, and the inability to reduce the shoulder.

FRACTURES

Most fractures are caused during the dislocation and rarely during the reduction procedure if the proper techniques are used.[2,4,8,11,50] Prereduction radiographs will identify most fractures. Postreduction radiographs are required to identify fractures initially missed or new ones associated with the reduction. Fractures of the humerus and coracoid process are rare and almost always associated with traumatic anterior shoulder dislocations.[1,2,8] These fractures make closed reduction very difficult and should generally be treated under general anesthesia by an Orthopedic Surgeon or by open reduction.

More common bony injuries include the Hill–Sachs deformity and the Bankart lesion, both caused during and from the dislocation. The Hill–Sachs lesion occurs in up to 50% of shoulder dislocations.[1,2] More significant fractures can occur during reduction in rare situations in which the humeral head is dislocated anteriorly with impaction on the glenoid rim.[1,2,8,11] The Bankart lesion is more commonly seen in recurrent dislocations and is associated with rupture of the joint capsule, but it spares the rotator cuff.[1,2,8,11]

DISPLACEMENT OF FRACTURE FRAGMENTS

Prereduction radiographs should be obtained on all traumatic shoulder dislocations. They will identify most fractures and any associated displacement. Many of the reduction techniques use significant force and may displace a fracture fragment. Postreduction radiographs are required to evaluate for displacement of fracture fragments. The displacement of fracture fragments may make reduction difficult or impossible, in some cases necessitating operative reduction under general anesthesia.

ROTATOR CUFF TEARS

Rotator cuff injury is most commonly seen in inferior dislocations and in patients greater than 60 years of age.[11,51,52] Overall, 38% of shoulder dislocations will have associated rotator cuff tears at the time of injury. This injury is not typically seen as a complication of the reduction technique.[3,11] Rotator cuff tears generally do not impede reduction, as they are often missed during the initial evaluation. One study showed that 86% of shoulder dislocations had rotator cuff tears diagnosed by arthroscopy an average of 7 months after the dislocation.[1,4] Rotator cuff injuries complicate restoration of normal shoulder function and may require surgical correction.

VASCULAR INJURY

Vascular injuries are seen in the arteries and veins of the shoulder region in association with shoulder dislocations.[1,8,11,50,55,56] **An evaluation for the signs of an axillary artery injury should be sought before and after any reduction attempt.** The most common vessel injured, during both dislocation and forceful reduction, is the axillary artery.[110–112] Such an injury is usually seen in older patients who have brittle vessels that have lost some elasticity. Inferior dislocations have the highest association with vascular injuries.[11] The second and third parts of the axillary artery are deep to the pectoralis major muscle and sustain the most damage.[8] These injuries include a decreased radial pulse, an axillary mass, an axillary bruit, or lateral chest wall bruising.[1] An angiogram is indicated if a vascular injury is suspected.

The subclavian vein is rarely injured. Direct injuries to venous vessels are atypical. The most common injury is a venous thrombosis.[113,114] Physical signs include extremity edema and occasionally paresthesias. However, these signs are typically seen days after the reduction. The diagnostic test of choice for venous evaluation is an ultrasound with Doppler study.[8]

NEUROLOGIC INJURY

Neurologic injury is seen in 5% to 12% of all shoulder dislocations.[8,11,50,56–59] **An evaluation for the signs of any neurologic injury should be sought before and after any reduction attempt.** Anterior shoulder dislocations with humeral fractures have a 45% incidence of nerve injury, with the axillary nerve being injured in up to 36% of cases.[8] Older patients tend to be more prone to nerve injury from the dislocation and the reduction techniques.[8] Of the techniques described, those that cause significant downward traction typically cause more reduction-induced neurologic injuries. Fortunately, most neurologic injuries are neuropraxias and will completely resolve within 2 to 5 months.[11,115–118] A small percentage of axillary nerve injuries that do not resolve may require nerve grafting. Brachial plexus injuries are much more common in posterior and inferior shoulder dislocations. Because the brachial plexus surrounds the axillary artery, injuries to the artery should raise the suspicion for a brachial plexus injury.

DISLOCATION RECURRENCE

The incidence of recurrence is variable, age-dependent, and gender-dependent.[54,60,119,120] Among patients under the age of 20 years, 90% will dislocate again, while only 14% of those over the age of 40 will redislocate.[1] Recurrences are much more common in men, with a ratio of 4:1 to 6:1 as compared to women.[11] Recurrent shoulder dislocations have other associated morbidities. A triad of lesions—including a detached labrum and anterior capsule, a Hill–Sachs deformity, and erosion of the anterior glenoid—develops in 85% of recurrent shoulder dislocations.[4] The methods for reduction are not different from those of a first-time shoulder dislocation. Patients who have had multiple shoulder dislocations are generally easier to reduce using nonanalgesic manipulation techniques. The orthopedic literature suggests that three shoulder dislocations in a single extremity indicate the need for surgical repair.[11]

HEMARTHROSIS

Blood collections in the shoulder joint are rare complications and are seen almost exclusively in traumatic shoulder dislocations associated with fractures. Typically, older patients (greater than 60 years of age) will return to the Emergency Department within 24 to 48 hours with a tense, swollen, painful shoulder. The shoulder joint should be aspirated. Refer to Chapter 77 for the complete details regarding shoulder arthrocentesis. Aspiration is usually sufficient to relieve pain and restore function.

INABILITY TO REDUCE

There are a few reasons for the inability to reduce a dislocated shoulder completely.[121,122] The most common is inadequate medication and sedation to overcome muscle spasm and pain. Occasionally, the humeral head may be "buttonholed" through the joint capsule.[11] A fracture fragment may be impinged or interposed between the humeral head and the glenoid cavity. Significant or complete disruption of ligamentous structures, as in an inferior or posterior dislocation, or soft tissue interposition will not allow the humeral head to remain in the glenoid cavity.[121] The inability to reduce a shoulder dislocation is an indication for reduction, open or closed, under general anesthesia in the Operating Room.

SUMMARY

Shoulder dislocations are common due to the inherent instability of the glenohumeral joint. There are three different types of dislocation, each of which has different mechanisms of injury and incidences of associated injuries. The vast majority are anterior shoulder dislocations. The diagnosis of a shoulder dislocation is generally uncomplicated given the history and patient presentation. The EP must be expeditious in reducing the dislocated joint once the patient is stabilized, other injuries have been ruled out, pain control has been addressed, and radiographs have been obtained to confirm the type of dislocation along with associated injuries.

Orthopedic Surgeons may need to be involved with the acute care of a dislocated shoulder. They should be involved in the initial reduction care of all posterior and inferior dislocations because of the rarity of these shoulder dislocations, the difficulty of reduction, the high incidence of associated injuries, and the need to operate to repair the associated injuries.

Multiple closed reduction techniques are available. They have similar success rates. The method chosen, as well as the decision to use analgesia, is individualized to the EP and the patient. Certain traditional techniques (e.g., Hippocratic and Kocher) have been demonstrated to have a higher incidence of complications and

should be avoided. Patients should be thoroughly evaluated before and after any closed reduction attempt for neurologic, vascular, soft tissue, or bony injury. The shoulder should be immobilized after it is reduced.

Patients should be instructed on proper aftercare and should be provided with adequate oral analgesia. This can be accomplished with nonsteroidal anti-inflammatory drugs supplemented with narcotics. All patients discharged from the Emergency Department should follow-up with an Orthopedic Surgeon within 24 hours to 5 days based on associated injuries and age.

82 Elbow Joint Dislocation Reduction

Angelique S. Kelly Campen

INTRODUCTION

The elbow is inherently subjected to dislocations because of its mechanical structure.[1] Elbow dislocations are one of the more common joint dislocations in the body, second only to dislocations of the shoulders and fingers.[2] Injuries to the elbow have a high potential for complications and residual disability.[3] **Timely reduction is imperative to relieve pain and reduce the possibility of neurovascular sequelae.**[3] Closed reduction of the elbow is unlikely to be successful if not performed promptly.[4]

The most common mechanism for a dislocation is a fall onto an extended and abducted arm. The patient usually presents with a swollen and painful arm that is held in flexion. Elbow dislocations require a significant amount of force. Up to 20% of elbow dislocations are associated with fractures.[2] Simple elbow dislocations have a better prognosis and are less likely to require surgical intervention than complex ones (fracture-dislocations). This chapter deals with the closed reduction of simple elbow dislocations.

One particular type of dislocation pertains primarily to the pediatric population. Subluxation of the radial head, often referred to as a "nursemaid's elbow," occurs commonly in preschool children. It is rarely seen after age 7 and represents 20% of upper extremity injuries in children.[5] It occurs after sudden traction on the radius with an extended elbow, as when an adult pulls a child up into a standing position by one arm. The annular ligament slips between the capitellum and the head of the radius, impeding supination of the arm. The patient will present with the arm held in slight flexion and pronation, usually in not much distress, and not using the affected arm. The simple reduction of this dislocation is also addressed.

ANATOMY AND PATHOPHYSIOLOGY

The elbow is a hinge joint comprising articulations between the humerus, the ulna, and the radius (**Figure 82-1**). The distal humerus consists of the extraarticular medial and lateral epicondyles, which are diverging columns separated by the intraarticular trochlea and capitellum. The trochlea articulates with the proximal ulna. The articular surfaces of the trochlea extend from the coronoid fossa anteriorly to the olecranon fossa posteriorly. The anterior and posterior fossae provide space for the coronoid and olecranon, respectively, at the extremes of motion. The capitellum is a spherical structure that articulates with the concave radial head.

Numerous neurovascular structures cross the elbow (**Figure 82-2**). The prominent medial epicondyle protects the ulnar nerve, which travels in its posterior sulcus. The radial nerve travels just anterior to the lateral epicondyle. The median nerve travels with the brachial artery through the antecubital fossa.

There are four ligamentous structures of importance in considering injuries to the elbow: the radial collateral ligament, the ulnar collateral ligament, the annular ligament, and the anterior capsule (**Figure 82-3**). The annular ligament and radial collateral ligament hold the radial head in position. The annular ligament allows the radial head to rotate under it during pronation and supination.

The relationship of the radius and ulna to the humerus is used to classify elbow dislocations into posterior, anterior, medial, lateral, and divergent (**Figure 82-4**). The majority of elbow dislocations are posterior in direction.[6] The other types of elbow dislocations are uncommon.[6] The radius and ulna are held tightly together by the annular ligament and the interosseous membrane (**Figure 82-3**). Posterior elbow dislocations result in the radius and ulna projecting posterior to the humerus (**Figures 82-4A & 82-5**). The radius and ulna may be slightly lateral or medial in posterior elbow dislocations in addition to being posteriorly displaced. This does not affect the management or prognosis. The presence of a fracture of the radial head or coronoid process may frequently render any attempt at reduction unstable and will usually require an open reduction.[7] Anterior elbow dislocations occur from traction

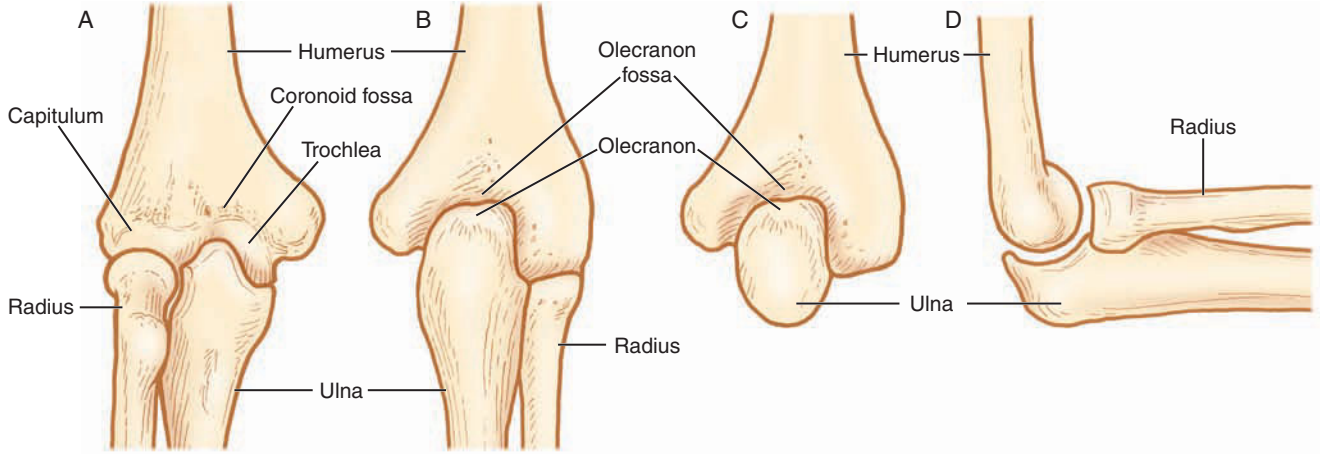


FIGURE 82-1. Bony anatomy of the elbow region. The right arm is demonstrated in these illustrations. **A.** Anterior view. **B.** Posterior view. **C.** Posterior view of the elbow in 90° of flexion. **D.** Lateral view of the elbow in 90° of flexion.

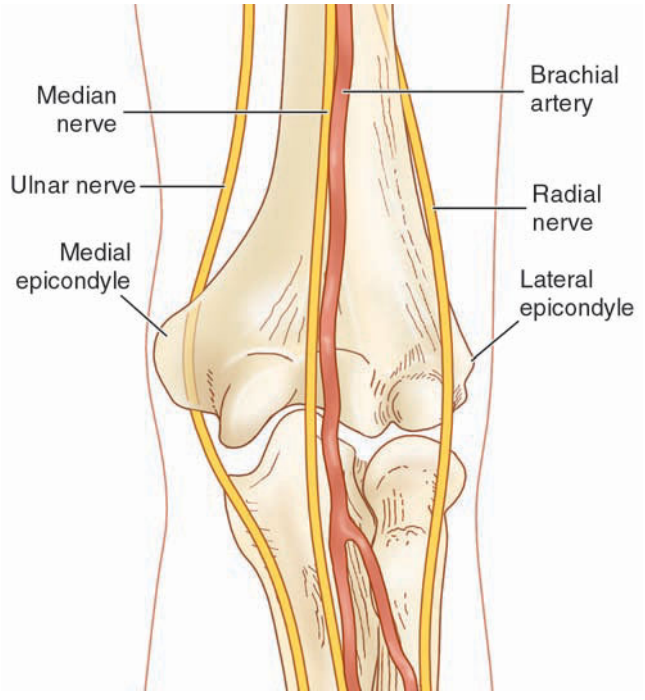


FIGURE 82-2. Major neurovascular structures that cross the elbow.

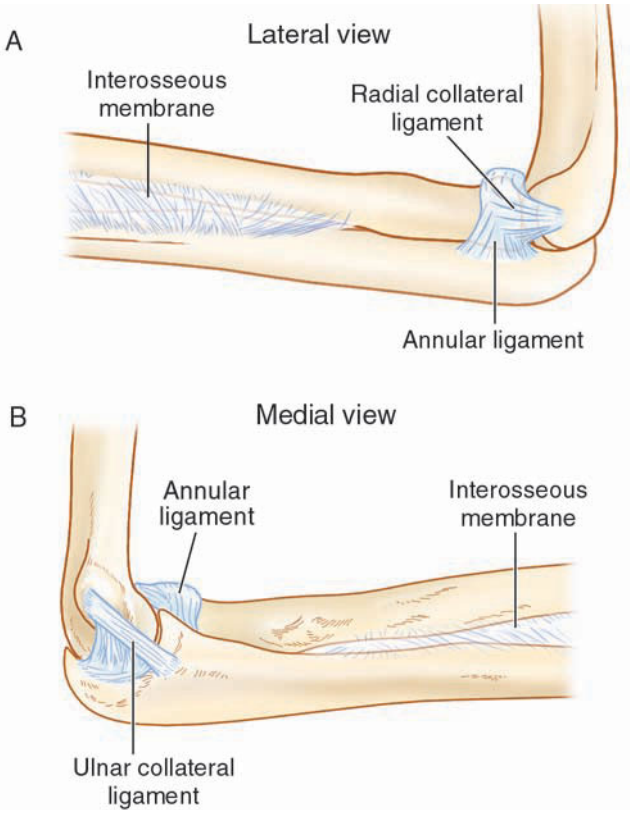


FIGURE 82-3. Major ligamentous structures of the elbow. **A.** Lateral view. **B.** Medial view.

of the forearm with the elbow extended or a blow to the posterior aspect of the flexed elbow. Anterior elbow dislocations result in the radius and ulna projecting anterior to the humerus (**Figure 82-4B**). Medial (**Figure 82-4C**) and lateral (**Figure 82-4D**) dislocations are rare injuries with poorer prognoses. Divergent dislocations (**Figure 82-4E**) are rare injuries that are distinct from the other types of elbow dislocations because there is dissociation of the radius and ulna. The annular ligament and interosseous membrane must be torn for a divergent dislocation to occur.

The patient usually presents with pain and swelling of the elbow. All elbow dislocations are characterized by loss of the normal relationship of the humeral epicondyles to the tip of the olecranon. The bony landmarks may be identified if the patient is seen immediately after the injury. However, the swelling and hemarthrosis that develop over time make it difficult to palpate these landmarks. Posterior dislocations are further apparent by a shortening of the forearm and the elbow being fixed in flexion.

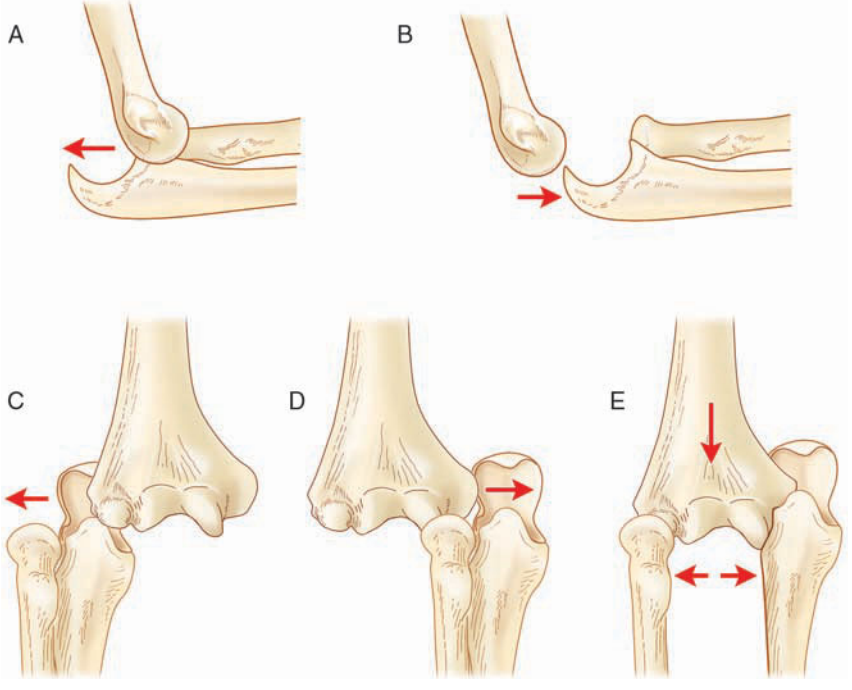


FIGURE 82-4. Classification of elbow dislocations. **A.** Posterior. **B.** Anterior. **C.** Lateral. **D.** Medial. **E.** Divergent.



FIGURE 82-5. Radiograph of a posterior elbow dislocation.

INDICATIONS

All elbow dislocations require reduction. **Early reduction of a dislocation, by open or closed means, is of paramount importance if good functional results are to be obtained.** Closed reduction is unlikely to be successful if attempted later than 14 days after the injury.[4] The more promptly the reduction is attempted, the more likely it is to be successful.

The vascular status of the extremity also dictates the need for emergent relocation. **Emergent and immediate relocation is necessary when there is neurologic or vascular compromise of the distal extremity.** Relocation can await titration of sedation and analgesia when the extremity is neurovascularly intact.

CONTRAINDICATIONS

There are no absolute contraindications to the closed reduction of an elbow dislocation. A relative contraindication to the procedure is when there is uncertainty, before radiographic evaluation, if the injury is a dislocation or a fracture. Closed reduction is not indicated if there is an interposed osteochondral fragment preventing concentric reduction or when there is a concomitant displaced fracture of the radial head or neck. Elbows that have been dislocated for a prolonged period of time may have closed reduction attempted but will most likely require an open procedure.

EQUIPMENT

- Towel or sheet to aid in applying traction
- Splinting materials
- Weight (sandbag, bucket with water, or any other weight)
- Procedural sedation supplies (see Chapter 129)

PATIENT PREPARATION

Explain the risks, benefits, and potential complications to the patient and/or their representative. The postprocedural care should also be discussed. Obtain an informed consent for the reduction procedure.

Carefully assess and document the preprocedural neurologic (median, radial, and ulnar nerves) and vascular (brachial, radial, and ulnar arteries) status of the extremity. Splint and/or sling the affected extremity until radiographs are obtained and a closed reduction can be performed. Obtain anteroposterior and lateral radiographs to confirm the diagnosis of an elbow dislocation. Oblique views may be helpful to further define the relationship between the distal humerus, radius, and ulna. **The only case for which a preprocedure radiograph is not indicated is when neurologic or vascular compromise exists in the distal extremity and an expeditious reduction is required.**

Closed reduction of elbow dislocations requires adequate analgesia and muscle relaxation. In most cases, procedural sedation is useful. Regional anesthesia (axillary nerve or Bier blocks) is useful if procedural sedation is contraindicated. Refer to Chapters 126 and 127 for details regarding regional anesthesia of the upper extremity. General anesthesia with fluoroscopy is rarely necessary unless the dislocation is associated with an undisplaced fracture of the radial head or neck.

TECHNIQUES

POSTERIOR ELBOW DISLOCATION REDUCTION TECHNIQUES

The goal of closed reduction is to distract the radius and ulna, allowing them to relocate. **The preferred technique that provides the least complications is a modification of the Stimson technique used for shoulder dislocations.**[8] Place the patient prone with the affected arm hanging off the gurney (**Figure 82-6**). Place padding anteriorly in front of the arm and shoulder so that the arm does not drag along the side of the gurney. **Care must be taken that the patient does not fall from the gurney.** Tie a sheet circumferentially around the patient's hips and the gurney. **Ensure that the patient does not have any respiratory difficulty while in the prone position.** Suspend a weight from the patient's wrist to apply traction to the arm (**Figure 82-6**). The weight should be approximately 5 pounds and may go up to 15 pounds, depending on the patient's musculature and weight. Allow the arm to dangle over the edge of



FIGURE 82-6. The modified Stimson technique for reducing posterior elbow dislocations.

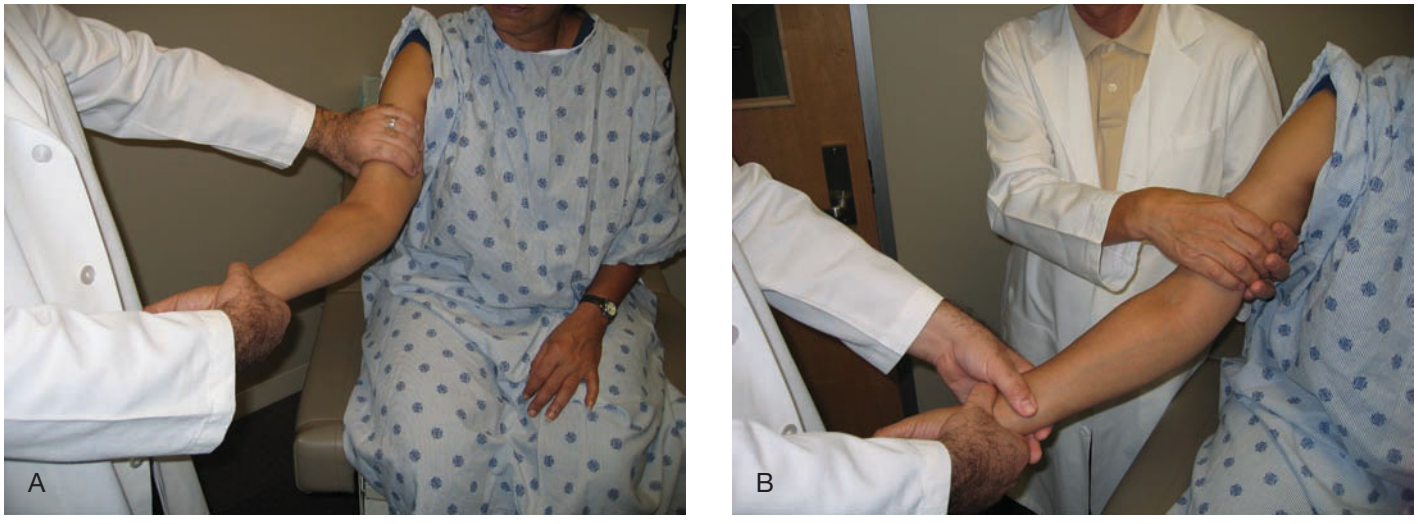


FIGURE 82-7. The traction-countertraction technique to reduce a posterior elbow dislocation. **A.** The one-person technique. The physician stabilizes the humerus with one hand and distracts the forearm with the other hand. **B.** The two-person technique. The assistant stabilizes the humerus and provides countertraction while the physician applies traction to the forearm.

the gurney for 10 minutes. If the elbow dislocation will not reduce, attempt the traction-countertraction technique.

The traction-countertraction technique can be performed but is not the optimal approach. Place the patient's arm in slight flexion. Grasp the patient's midhumerus with the nondominant hand and the patient's wrist with the dominant hand (**Figure 82-7A**). Alternatively, an assistant can grasp the humerus while the physician uses both hands to grasp the patient's wrist (**Figure 82-7B**). Stabilize the patient's humerus. Apply steady and constant traction to the patient's wrist to distract the coronoid process and allow it to slip past the humerus and back into anatomic position. The application of downward pressure on the proximal forearm can help to disengage the coronoid process from the olecranon fossa and ease the reduction.

MEDIAL AND LATERAL ELBOW DISLOCATION REDUCTION TECHNIQUE

Medial and lateral dislocations of the elbow are extraordinarily uncommon. They are usually associated with a posterior elbow dislocation. These dislocations can be reduced in a similar manner using the traction-countertraction technique for that of the posterior elbow dislocation. For lateral dislocations, apply traction to the patients wrist with one hand while using your other hand to guide the proximal ulna downward, then medially, and finally backward. For medial dislocations, apply traction to the patients wrist with one hand while using your other hand to guide the proximal ulna downward, then laterally.

Emergency Physicians should not reduce a medial or lateral elbow dislocation. They are uncommon, may be associated with neurovascular complications, have severe ligamentous tears, and should be reduced by an Orthopedic Surgeon. The only exception to this is if there is neurologic and/or vascular compromise of the distal extremity and no Orthopedic Surgeon is immediately available.

ANTERIOR ELBOW DISLOCATION REDUCTION TECHNIQUE

Anterior elbow dislocations are uncommon. They are often associated with intimal injuries to the brachial artery, from being stretched during the injury.

Anterior elbow dislocations should be reduced by an Orthopedic Surgeon for the same reasons as a medial or lateral elbow dislocation. The only exception to this is if there is neurologic and/or vascular compromise of the distal extremity and no Orthopedic Surgeon is immediately available.

DIVERGENT ELBOW DISLOCATION REDUCTION TECHNIQUE

Fortunately, divergent dislocations are exceedingly rare. They are commonly associated with severe articular damage, interosseous ligamentous tears, neurologic injuries, and vascular injuries. The reduction technique is complex; the elbow is reduced as a two-part dislocation and often requires surgical fixation to be stabilized. Simple traction can be applied to relieve stress on the neurovascular structures but will not reduce the dislocation due to the instability of the joint.

Divergent elbow dislocations should be reduced by an Orthopedic Surgeon in the Operating Room. The only exception to this is if there is neurologic and/or vascular compromise of the distal extremity and no Orthopedic Surgeon is immediately available.

RADIAL HEAD SUBLUXATION REDUCTION

This condition is also referred to as a "nursemaid's elbow." Reduction of a radial head subluxation is a maneuver involving supination and flexion of the affected forearm. The forearm is quickly supinated and the elbow flexed completely in one smooth motion. A pop or click is sometimes heard or felt by the Emergency Physician as the subluxation is reduced. Most patients are asymptomatic within 5 to 10 minutes and 90% within 30 minutes.[9] The Emergency Physician should leave the room for 5 to 10 minutes after the procedure. Ask the parents to distract the child to see if they begins to move the arm. A fearful child will often not use a successfully reduced arm in fear of pain. Place an object (e.g., car keys, popsicle, toy, or other object the child may want) within grasp of the reduced extremity to encourage the child to use the extremity. Refer to Chapter 83 for the complete details regarding the reduction of a radial head subluxation.

ASSESSMENT

After a reduction, gently move the joint through the entire range of motion to ensure smooth movement and proper joint reduction. This also tests for joint stability and whether or not the joint will easily re-dislocate. The joint may need to be repaired operatively if it dislocates during this examination. **The neurovascular status of the extremity must again be evaluated and documented.** The integrity of the median, ulnar, and radial nerves as well as the brachial artery and its distal branches must be evaluated and documented. All reductions except radial head subluxations should have postprocedural radiographs to ensure proper bony alignment and the lack of a fracture. If full and smooth passive range of motion is not possible, which is especially common in children, postreduction radiographs should be examined for entrapment of the medial epicondyle.

AFTERCARE

Place the reduced extremity in a posterior long arm splint, from the midhumerus to the base of the fingers, with the elbow in 90° of flexion. Do not apply a circumferential cast due to the subsequent swelling and edema. Suspend the arm with a sling to aid in elevating the extremity. The patient should be carefully observed for 12 to 36 hours for vascular impairment. Instruct the patient to return to the Emergency Department if they develop weakness, numbness, paresthesias, cold fingers, or cyanotic fingers. The patient should be admitted for observation if there is any question of neurovascular compromise. Gentle range-of-motion exercises can be started as early as 3 to 5 days postreduction if the elbow is stable.[10] Schedule follow-up with an Orthopedic Surgeon 3 to 4 days postreduction to test for joint stability. Prescribe nonsteroidal anti-inflammatory drugs supplemented with narcotic analgesics to control pain.

No immobilization is necessary for a radial head subluxation that is reduced. Immobilization in a sling with follow-up by an Orthopedic Surgeon is recommended only for recurrent radial head subluxations.

COMPLICATIONS

Several serious complications exist with elbow dislocations. The most serious and first to happen are ischemic complications. Damage to and obstruction of the brachial artery can occur with any of the elbow dislocations. Brachial artery injury occurs in 5% to 13% of patients with an elbow dislocation.[11] It is a serious complication that can occur even without an associated fracture.[11] **The presence of a distal pulse is not proof that there is no vascular injury.** Collateral circulation around the elbow can result in a distal pulse despite a complete brachial artery laceration or occlusion.[12] Signs of an arterial injury include: cyanosis, an expanding hematoma, pallor, pulselessness, and severe pain. Any suspicion of a brachial artery injury necessitates prompt angiography.[12,13]

The second serious complication resulting from an elbow dislocation is nerve injury from traction or entrapment. Loss of median nerve function postreduction should prompt an immediate consultation with an Orthopedic Surgeon. The ulnar nerve is most commonly injured.[14] It is seen in 8% to 20% of patients with posterior elbow dislocations.[14]

Fractures commonly occur with elbow dislocations. **Radiographs should always be obtained before and after any attempt at reduction. The only exception to obtaining prereduction radiographs is if the extremity has signs of distal neurovascular compromise and obtaining radiographs will delay the reduction.** A fractured coronoid process can sometimes become entrapped in the joint, requiring an open reduction. Fractures of the coronoid process are commonly associated injuries and will usually come into near-normal opposition once reduction occurs (**Figure 82-8**). Large fragments that are displaced may require operative fixation.



FIGURE 82-8. Postreduction radiograph demonstrating a fracture of the coronoid process.

Late complications of elbow dislocations include posttraumatic stiffness, posterolateral joint instability, ectopic ossification, and occult distal radioulnar joint disruption.[15]

SUMMARY

Elbow dislocations are the second most common large joint dislocations that occur in adults. The majority of dislocations are posterior elbow dislocations, although the radius and ulna can dislocate into just about any other position. Relocation involves distracting the forearm while stabilizing the humerus and putting pressure counter to the direction of the dislocation. It is not uncommon to have associated fractures, so radiographic studies are imperative. The neurovascular status of the extremity must be carefully monitored and documented both before and after any attempts at reduction. Splint the elbow in flexion postreduction. Follow-up with an Orthopedic Surgeon and early range-of-motion exercises are recommended to ensure proper joint function.

83 Radial Head Subluxation ("Nursemaid's Elbow") Reduction

Mark P. Kling and Eric F. Reichman

INTRODUCTION

Subluxation of the radial head is one of the most common pediatric orthopedic injuries. This can occur in children whose age ranges from less than 6 months to the preteens. The majority of radial head subluxations occur between 1 and 3 years of age.[1] It is a rare injury before 1 year of age and after 8 years of age.

ANATOMY AND PATHOPHYSIOLOGY

Historically, the classic mechanism involves axial or longitudinal traction on an extended elbow with the forearm pronated. This often occurs while someone is holding onto the child by the hand

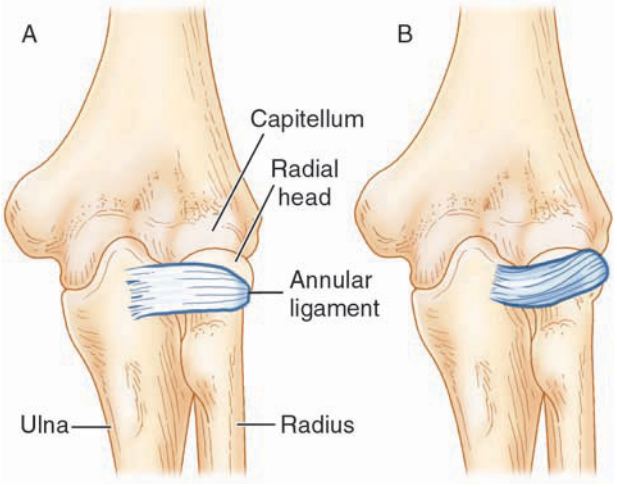


FIGURE 83-1. Anatomy of the elbow region. **A.** Normal anatomy. **B.** A radial head subluxation. Note the entrapped annular ligament.

or wrist. While being held, the child is then pulled or the child falls and is suspended by the arm. The subluxation is seen more often in the left arm than the right. This is due to more people being right-handed and holding the child's left hand or wrist while walking. It is not uncommon, however, for the child to present with a history of a fall or rolling over in bed.[1]

This orthopedic injury involves the region of the elbow (**Figure 83-1**). The annular ligament is a thick band that wraps around the upper radial neck and radial head (**Figure 83-1A**). It guides the radial head as the forearm moves through pronation and supination. The injury causes the radial head to become partially dislocated from its articulation with the ulna and the capitellum of the humerus while the forearm is in a pronated state. The annular ligament then slips proximally and its lateral end becomes entrapped between the radial head and the capitellum (**Figure 83-1B**). The forearm becomes locked in pronation due to the entrapped annular ligament. This condition is painless as long as the forearm is held in pronation. Supination of the forearm causes pain, so the child holds the extremity in pronation. The act of supination would also spontaneously return the annular ligament to its anatomic position and reduce the subluxation.

Children will present in no apparent distress.[2] They are usually resting comfortably and have some reservation in using the affected extremity. The arm will be held with slight flexion of the elbow and pronation of the forearm (**Figure 83-2A**). The child may point to an area of pain, but this is not often the case. A child may be much more comfortable with the parent examining and questioning areas of tenderness as opposed to the unknown and sometimes intimidating Emergency Physician.

Radiographs are not required unless other trauma or diagnoses are suspected. If radiographs are obtained, the child often returns from the radiology suite using the affected extremity. Radial head subluxations often reduce spontaneously during positioning for radiographs (**Figure 83-2B**).

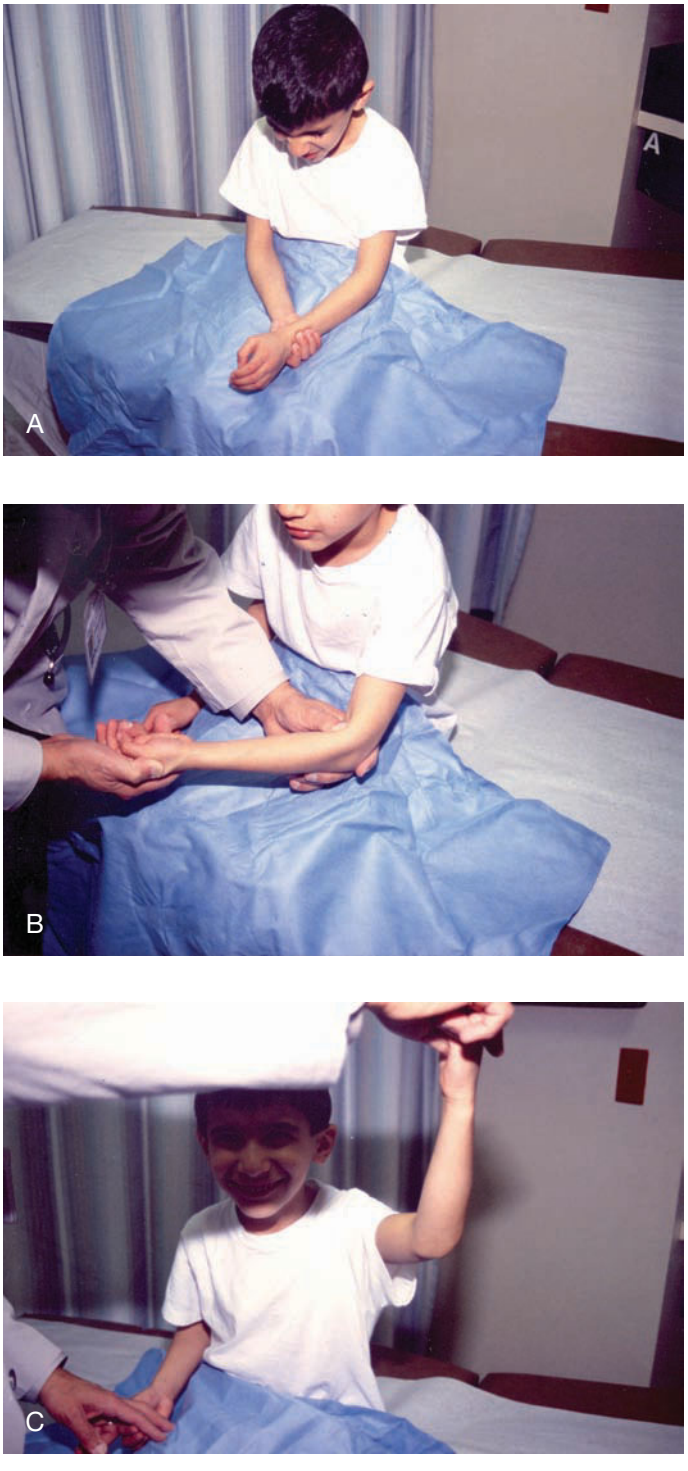


FIGURE 83-2. A child with a radial head subluxation. **A.** The subluxed left forearm is held flexed, pronated, and adducted. **B.** Reduction technique. **C.** Postreduction. The forearm is freely mobile with normal extension and abduction.

INDICATIONS

Any child presenting with the inability to utilize the partially flexed elbow, the forearm pronated and adducted, and a mechanism for a radial head subluxation should be reduced. Many Emergency Physicians may be hesitant to repeat the procedure multiple times if a child was not utilizing the arm normally within 15 to 30 minutes after a clinically successful reduction. However, if the radiographs appear normal and a repeat history and physical examination are consistent with the original diagnosis, a decision to repeat the reduction should be considered.

CONTRAINDICATIONS

The presence of edema, ecchymoses, tenderness other than over the radial head, suspicion of a fracture, or a mechanism of injury not consistent with a radial head subluxation should first be

evaluated radiographically.[2,8] The presence of any distal neurologic or vascular compromise excludes the diagnosis of a radial head subluxation.

EQUIPMENT

No equipment is required for the reduction of a radial head subluxation.

PATIENT PREPARATION

Explain the risks, benefits, potential complications, and aftercare of the procedure to the child and their representative. Obtain a signed consent to perform the reduction. Place the patient sitting in the parent's lap or supine on an examination table or gurney. No premedication is required.

TECHNIQUES

SUPINATION AND FLEXION

Place one hand on the child's elbow with the thumb over the radial head (**Figure 83-3A**). This will aid in palpation of the traditional "click" of reduction. Gently grasp the child's wrist with the other hand (**Figure 83-3A**). Perform the following maneuvers in one smooth motion to reduce the subluxation. Apply distal traction while supinating the forearm (**Figure 83-3B**), followed by flexion of the elbow (**Figure 83-3C**). A click may be felt as the radial head is reduced.[1,4] If not, flex the forearm until the hand is upright. Other methods of reduction are often compared to this method.[3,5]

If you feel the traditional click or feel satisfied with the attempted reduction, allow 5 to 15 minutes to pass and return for a repeat examination. Children may cry at the end of the procedure but will generally only do so for a moment. As the child feels more comfortable, they will proceed to use the arm (**Figure 83-2C**). This freedom of use can be accelerated by the caregiver or physician stimulating the patient to use the arm with an incentive (e.g., by offering candy, a pen, or a popsicle for the child to grab).

HYPERPRONATION

Position the patient as described above. There are two variations on this technique. The first holds the child's elbow at 90° of flexion and hyperpronates the forearm without any additional flexion at the elbow (**Figure 83-4**).[5] The second holds the child's elbow at 90° of flexion and hyperpronates the forearm while simultaneously fully flexing the elbow (**Figure 83-5**).[9] Both of these techniques can successfully reduce a radial head subluxation. Some feel that hyperpronation causes less pain to the child than the supination technique.[5,9–11] This is because the arm is already being held in pronation and the additional pronation (hyperpronation) requires less force and motion than the supination technique.

ASSESSMENT

The child should have uninhibited use of the forearm within 30 minutes. If not, reconsider the diagnosis. Alternative diagnoses include clavicular fractures, distal humeral fractures, osteomyelitis, radial head fractures, septic arthritis, and stress fractures. Reevaluate the elbow joint for signs of trauma. Obtain plain radiographs if not done previously. Full recovery may take 24 to 48 hours if the reduction is delayed for more than 8 hours from the time of injury.

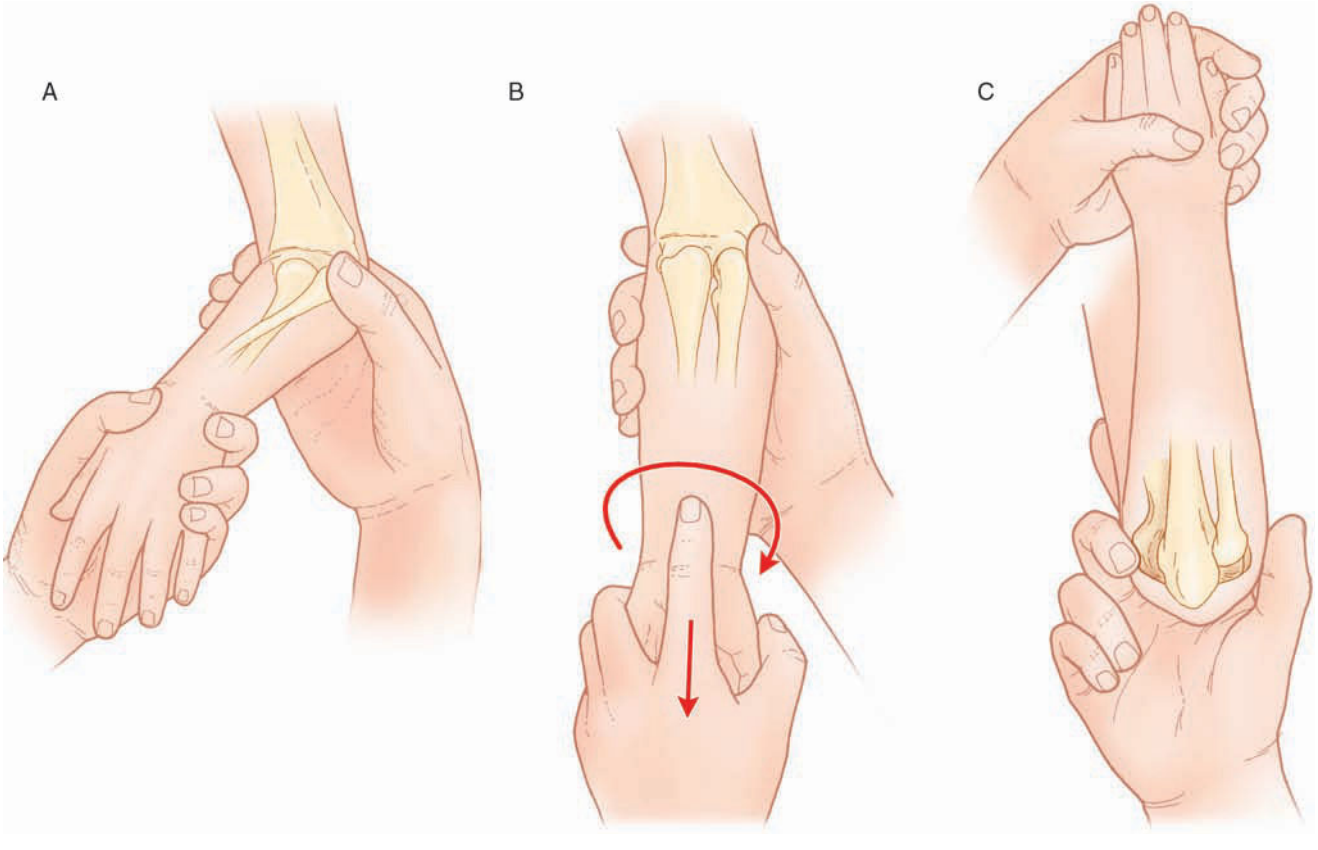


FIGURE 83-3. Reduction of a radial head subluxation using supination and flexion. **A.** Positioning of the physician's hands. **B.** Distal traction is applied (*straight arrow*) while supinating the forearm (*curved arrow*). **C.** The forearm is maximally flexed.

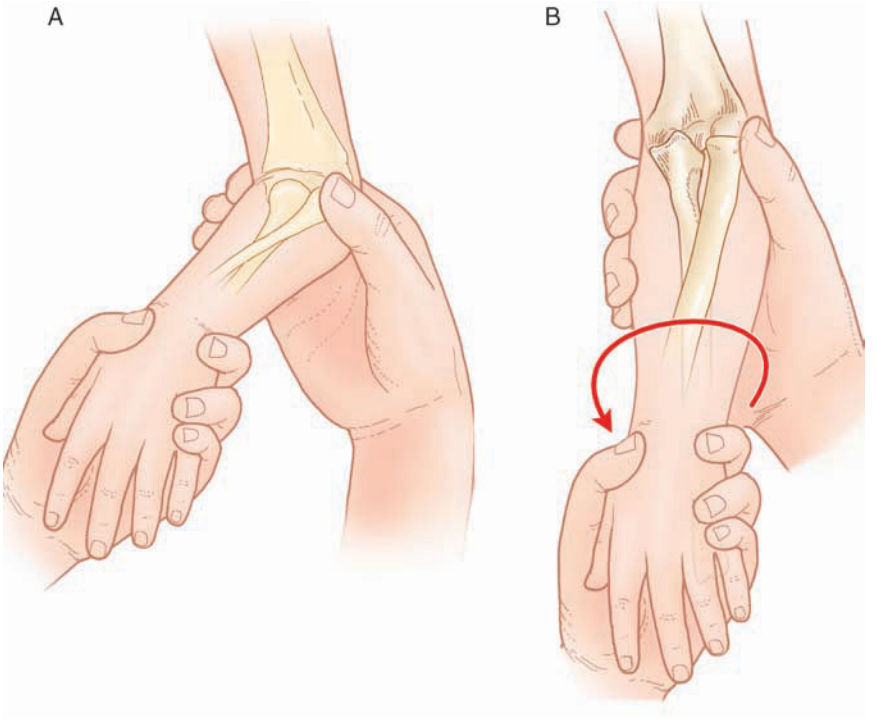


FIGURE 83-4. Reduction of a radial head subluxation using hyperpronation. **A.** Positioning of the physician's hands. **B.** Hyperpronation of the forearm.

AFTERCARE

Radiographs, immobilization, splinting, analgesics, and orthopedic follow-up are not necessary if the subluxation is reduced and the child is using their arm. Educate the caregiver regarding the mechanism of injury and prevention of future subluxations.[6,7]

Phone consultation with an Orthopedic Surgeon is recommended if the reduction is unsuccessful. It is not unusual to have a spontaneous reduction on repeat examination and follow-up. Immobilize the arm until the child is evaluated by an Orthopedic Surgeon. Immobilization will aid in pain relief. Consider the use of nonsteroidal anti-inflammatory drugs.

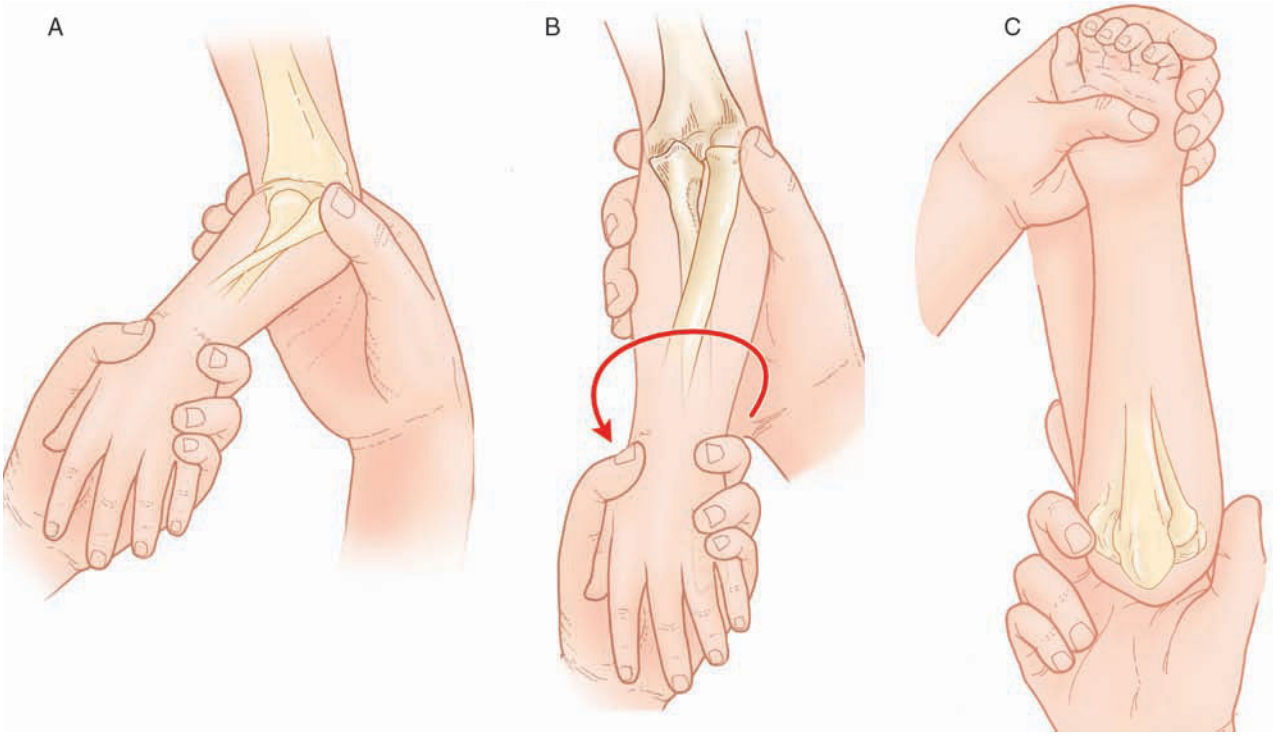


FIGURE 83-5. Reduction of a radial head subluxation using hyperpronation and flexion. **A.** Positioning of the physician's hands. **B.** Hyperpronation of the forearm. **C.** Flexion of the hyperpronated forearm.

COMPLICATIONS

There are no complications associated with the reduction of a radial head subluxation.

SUMMARY

A radial head subluxation is one of the more common orthopedic injuries of childhood. Children present with the inability to utilize the affected upper extremity. They hold the forearm flexed, pronated, and adducted. The reduction technique is quick and simple. It is important to educate the caregivers regarding the mechanism of injury and prevention of future subluxations.

84 Metacarpophalangeal Joint Dislocation Reduction

Michael Bublewicz and Antonio E. Muñiz

INTRODUCTION

Hand injuries are among the most common injuries encountered in the Emergency Department (ED). They are responsible for 5% to 10% of ED visits, with approximately 6% of these patients having significant injuries.[1,2] Many hand injuries occur from sports-related events or in the workplace. Data suggest that hand injuries account for 19% of lost-time injuries and 9% of workers' compensation cases.[3] Approximately 3 to 4 million working days are lost each year as a result of hand injuries.[4] It is estimated that 10% of patients with hand injuries require referral to a hand specialist.[5] Proper motion and function of the hand are intimately related to normal anatomic alignment. The Emergency Physician (EP) must be skilled in the diagnosis and management of injuries about the hand. An improperly managed hand injury can result in significant disability that the patient is reminded of on a daily basis and may include chronic pain, decrease range of motion, stiffness, joint swelling, deformity, or early degenerative arthritis.

Dislocations of the metacarpophalangeal (MCP) joint are relatively uncommon due to the protected location of this joint in the hand.[6] Injuries to the MCP joint of the thumb are more common than the other digits. Most of these injuries are to the collateral ligaments rather than a true dorsal or volar dislocation.[7] The spectrum of injury to the ligaments extends from a minor stretch or sprain to a complete disruption.

The deformity caused by a joint dislocation is classified by the position of the distal skeletal unit in relation to its proximal counterpart. A dorsal MCP joint dislocation describes a dislocation in which the proximal phalanx is displaced in a dorsal direction relative to the metacarpal bone (**Figure 84-1A**). A volar MCP joint dislocation describes a dislocation in which the proximal phalanx is displaced in a volar direction relative to the metacarpal bone (**Figure 84-1B**).

ANATOMY AND PATHOPHYSIOLOGY

FUNCTIONAL ANATOMY

The metacarpals are tubular bones structurally divided into a head, neck, shaft, and base. When viewed in the sagittal plane, the metacarpal head has an increasing diameter beginning dorsally and extending along the articular surface to the volar side. When viewed in the coronal plane, the metacarpal head is pear-shaped or dumbbell-shaped, with the volar surface extending out of each side. The metacarpal head is broader in volar orientation, which results in increasing bony stability as the joint is flexed. The volar plate, collateral ligaments, dorsal capsule, deep transverse intermetacarpal ligament, extensor tendon, and intrinsic tendons provide additional support and stability to the MCP joint.

The MCP joints are resistant to ligamentous injury and dislocation because of their inherent ligamentous structure, their surrounding supporting structures, and their protected position at the base of the fingers. The volar plate is a fibrocartilaginous structure that is attached firmly to the base of the proximal phalanx. It originates just proximal to the metacarpal head where it is thin and transparent. This allows for hyperextension of the MCP joint yet makes it vulnerable to injury during dorsal dislocations.

Side-to-side stability of the MCP joint is provided mainly by the collateral and accessory collateral ligaments, and to some extent by the lumbrical and the interossei muscles and tendons.[8] The collateral ligaments originate from the mediolateral recesses in the metacarpal head and travel to insert onto the base of the proximal phalanx. The eccentric configuration of the metacarpal head and the relatively fixed length of the collateral ligaments cause it to tighten when the joint is in flexion (**Figure 84-2**). This accounts for the limited abduction and adduction of the MCP joint in flexion as compared to the laxity in extension. The collateral ligaments of the MCP joint are most vulnerable to injury from forces directed ulnarly and dorsally. The accessory collateral ligament spans from the true collateral ligament to the volar plate, providing additional joint stability in extension. The central extensor tendon and sagittal band augment the thin dorsal capsule. The tendons of the palmar and dorsal interossei add a small degree of dynamic stability.

The interphalangeal (IP) joints are hinges and motion only occurs as flexion and extension while the MCP joints are condyloid joints. The range of motion about the MCP joint includes 120° of flexion and 30° of hyperextension. It has up to 30° of additional mediolateral laxity and a small degree of rotational laxity to facilitate an efficient grasp.[9] **The clinical importance of these**

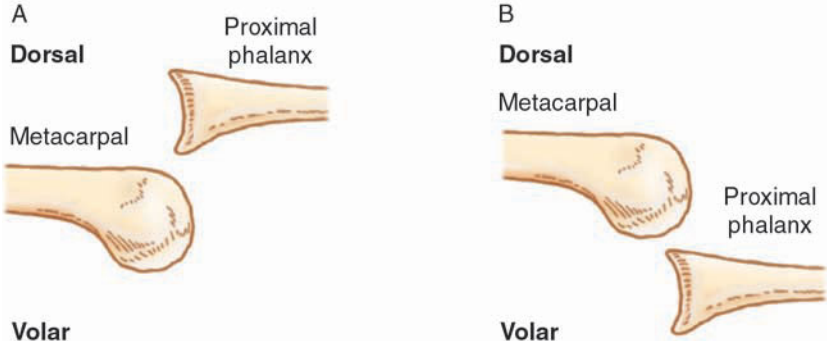


FIGURE 84-1. Dislocations are classified by the position of the distal skeletal unit in relation to its proximal counterpart. **A.** Dorsal MCP joint dislocation. **B.** Volar MCP joint dislocation.

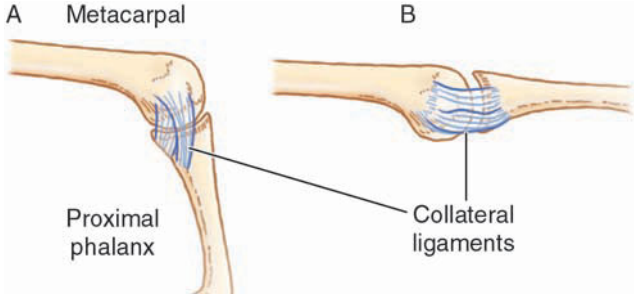


FIGURE 84-2. The shape of the metacarpal head is eccentric, making the collateral ligaments tighter in flexion (**A**) than in extension (**B**).

differences is that to minimize the development of contractures after joint injuries. The preferred position of immobilization of the IP joints is in extension, whereas the MCP joints are immobilized in flexion.

The opposable thumb is an essential structure for countless activities. Despite its strong ligamentous and capsular support, the exposed positioning of the thumb makes it a frequent site of dislocations and subluxations. The MCP joint of the thumb is similar to those of the fingers but has a stronger volar plate and collateral ligaments with less side-to-side mobility.[2] The MCP joint of the thumb is also a condyloid joint with a quadrilateral rather than a spherical metacarpal head that allows mainly flexion and extension. However, it also permits some degree of abduction, adduction, and rotation. There is a large variability among individuals in its range of flexion and extension.

The metacarpal head is bicondylar, with the radial condyle being slightly larger. This structural difference provides the thumb proximal phalanx with a modest degree of pronation during flexion. Its range of motion consists of 15° to 20° of extension and 80° of flexion. However, the range of motion of the MCP joint of the thumb is restricted, especially in lateral motion with only 10° of adduction and abduction.

PATTERNS OF INJURY

MCP joint dislocations are considerably less common than dislocations of the IP joints. Most MCP joint dislocations are dorsal. These were first described by Kaplan in 1957.[10] A volar MCP joint dislocation is a rare finding.[11] Dislocation of any of the MCP joints is possible from hyperextension injuries. The dorsal dislocation of the thumb MCP joint is the most common type of MCP joint dislocation.

Hyperextension of the MCP joint results in the rupture of the volar plate. Injuries are classified as simple (reducible with closed technique) or complex (irreducible with closed technique). Unless there is associated twisting of the finger, the collateral ligaments remain intact. Clinical and radiographic features can be used to differentiate simple from complex dislocations. In cases of simple dislocations, the joint usually hyperextends to approximately 90° and the volar plate is not interposed between the dislocated bones.[12] The deformity is obvious with the finger in a claw position of extreme dorsiflexion at the MCP joint. In complex dislocations, the metacarpal and proximal phalanx usually lie more parallel to each other, with the metacarpal head causing a dimple on the volar skin and palpable underneath the skin. Clinical features that suggest a complex MCP dislocation include a proximal phalanx that is less acutely angulated than with a simple dislocation.[2] The volar plate, sesamoids, flexor tendon, adductor tendons, extensor expansion, collateral ligaments, or capsule may become entrapped and prevent reduction.[2] A widened joint space is seen on radiographs when the volar plate is interposed in the joint. Complex MCP dislocations occur more frequently in the index finger. They can be difficult to manage because reduction is often blocked by the interposed soft tissue.[13]

The MCP joint of the thumb is very mobile. Dislocations of the thumb MCP joint are more common than the MCP joints of the fingers. The MCP joint can be dorsally dislocated by a hyperextension injury or shearing forces that ruptures the volar plate, joint capsule, and at least part of the collateral ligament. The proximal phalanx will come to rest in a position dorsal to the first metacarpal. Displacement of the proximal phalanx varies from a subluxation to the complete dislocation. For the latter to occur, the volar plate and the collateral ligaments must completely tear. Volar dislocations are rare and result from extensive tearing of the dorsal capsule and the extensor pollicis brevis tendon, leaving the joint very unstable.[14]

A simple MCP joint dislocation can be converted into a complex one during prolonged or repeated reduction attempts, especially those in which axial traction is the primary component.[2] This should not deter the EP from attempting a closed reduction for any MCP dislocation.

RADIOGRAPHIC EVALUATION

Radiographic evaluation of all hand injuries is relatively straightforward. It should include at least three views (i.e., anteroposterior, oblique, and lateral) of the injured area. The most important radiographic error in evaluating joint injuries of the hand is failing to get a true lateral view of the injured joint. This may result in missing a fracture or a loose body in the joint.[2] Radiographic examination will show an obvious dislocation in the lateral view. Anteroposterior views may reveal widening of the joint space in complex dislocations. In addition, the sesamoid bones may be seen in the joint space, a pathognomonic sign for a complex MCP joint dislocation.

INDICATIONS

All MCP joint dislocations should have an initial attempt at reduction in the ED unless they are unstable, chronic, open, or associated with a fracture. This is true even if it is suspected to be a complex MCP joint dislocation.[15] Reduction of the dislocation will provide significant pain relief. If a Hand Surgeon is not immediately available, an open MCP joint dislocation should be reduced after copious irrigation with sterile saline to remove any dirt and debris.

CONTRAINDICATIONS

Certain MCP joint dislocations require an immediate evaluation by a Hand Surgeon for open reduction and repair of any ligamentous or associated injuries. Closed reduction of an MCP joint dislocation should not be performed in the ED for unstable, chronic, and open injuries or if it is associated with a fracture. Instability in a joint through active range of motion indicates complete and multiple ligament disruption requiring an open surgical repair.[2,17] Chronic injuries greater than 3 weeks old generally require surgical repair.[16]

If the closed reduction attempt is unsuccessful, repeated attempts at reduction are contraindicated as a simple dislocation can be converted to a complex dislocation requiring an open surgical reduction. The ligaments, tendons, or sesamoid bones may become entrapped by bony and soft tissue structures in and around the MCP joint and prevent the reduction. Complex dislocations usually require open surgical reduction.[15,18] Open MCP joint dislocations, whether reduced in the ED or not, will require operative management after initiation of antibiotics in the ED.

There are few contraindications to the use of local anesthesia solutions.[19] Relative contraindications include injection through infected skin, history of coagulopathy from heparin or warfarin therapy, factor deficiencies, liver dysfunction or bleeding disorder, or an allergy to the anesthetic medication. Another relative contraindication includes preexisting neurovascular damage prior to the procedure. Uncooperative patients can make the injection procedure technically more difficult and dangerous to perform. Procedural sedation should be considered for these patients and children.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- 18 gauge needle to draw up the local anesthetic solution
- 27 or 30 gauge needle, 2 in. long
- 10 mL syringe
- Alcohol swab
- Sterile gloves
- Sterile drapes
- Local anesthetic solution without epinephrine
- Equipment and supplies for procedural sedation (Chapter 129)
- Adhesive tape, ½ in.
- Webril padding
- Casting material
- Ace bandage
- Scissors

PATIENT PREPARATION

Explain the risks, benefits, potential complications, and aftercare of the reduction to the patient and/or their representative. The patient must be aware that irreducible dislocations will require an open surgical reduction and possible repair of damaged structures within and surrounding the joint. Inform the patient that the injury can result in joint swelling for weeks to months and possibly permanent joint enlargement. Loss of motion with stiffness and residual soreness may last for months. Obtain an informed consent for the reduction procedure. An informed consent should also be obtained for procedural sedation (Chapter 129) and/or the intraarticular injection (Chapter 77) if they are performed in addition to the reduction procedure.

Clean the involved joint of any dirt or debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Perform a wrist block (Chapter 126), the instillation of the local anesthetic solution into the joint (Chapter 77), and/or procedural sedation and analgesia (Chapter 129).

TECHNIQUES

Early closed reduction may be easy provided that the thumb is maintained in adduction, the fingers are flexed, and the wrist is flexed to relax the intrinsic hand muscles. The major obstruction preventing reduction of the dislocated MCP joint is the displaced volar fibrocartilaginous plate lying dorsal to the metacarpal head. Approximately 50% of MCP joint dislocations can be reduced in the ED using the closed method.

DORSAL MCP JOINT DISLOCATIONS

Dorsal MCP joint dislocations (Figure 84-3A) require minimal, if any, distally applied traction for reduction. It is important to remember that applying simple traction alone as an initial maneuver risks trapping the volar plate and transforming a simple dislocation into a complex dislocation.

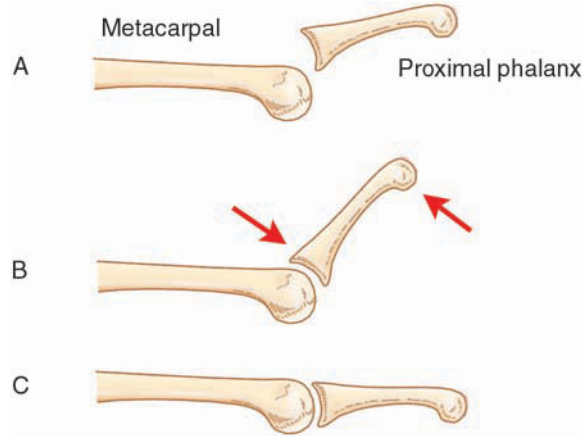


FIGURE 84-3. Reduction of a dorsal MCP joint dislocation. **A.** Dorsal dislocation of the MCP joint. **B.** The deformity is exaggerated by hyperextension of the MCP joint as the proximal end of the proximal phalanx is pushed volarly and over the metacarpal head while simultaneously flexing the IP joint to relax the flexor tendons. **C.** The reduced MCP joint.

Hyperextend the MCP joint while simultaneously pushing the proximal end of the proximal phalanx volarly and over the metacarpal head (**Figure 83-3B**). This maneuver diminishes the buttonhole effect on the metacarpal neck that is accentuated by traction. Flex the MCP joint as the proximal phalanx returns to position (**Figure 84-3C**). Simultaneously flexing the IP joint and wrist can help to relax the flexor tendons and make the reduction easier. This maneuver can sometimes trap the displaced fibrocartilaginous plate and carry it to its normal position anterior to the metacarpal head.

If the reduction is unsuccessful, repeated attempts to reduce the dislocation are contraindicated. Consider open reduction to disengage the metacarpal head from a probable buttonhole slit in the anterior capsule and from the surrounding muscles and tendons. Consult a Hand Surgeon for these MCP joint dislocations that cannot be reduced after one attempt in the ED.

VOLAR MCP JOINT DISLOCATIONS

Volar MCP joint dislocations (**Figure 84-4A**) are generally associated with collateral ligament ruptures. They are commonly irreducible due to interposition of the extensor tendons and the dorsal joint capsule. Consultation with a Hand Surgeon is often required for operative reduction.

Volar MCP joint dislocations require minimal, if any, distally applied traction for reduction. It is important to remember that applying simple traction alone as an initial maneuver risks trapping the volar plate and transforming a simple dislocation into a complex dislocation. Flex the MCP joint while simultaneously pushing the proximal end of the proximal phalanx dorsally and over the metacarpal head (**Figure 84-4B**). Extend the MCP joint as the proximal phalanx returns to position (**Figure 84-4C**).

If the reduction is unsuccessful, repeated attempts to reduce the dislocation are contraindicated. Consider open reduction to disengage the metacarpal head from a probable buttonhole slit in the anterior capsule and from the surrounding muscles and tendons. Consult a Hand Surgeon for these MCP joint dislocations that cannot be reduced after one attempt in the ED.

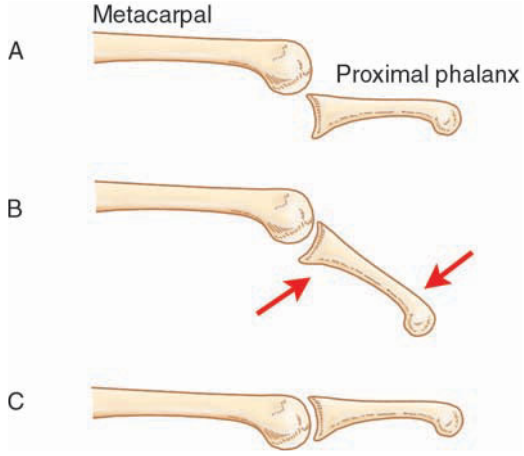


FIGURE 84-4. Reduction of a volar MCP joint dislocation. **A.** Volar dislocation of the MCP joint. **B.** The deformity is flexed at the MCP joint as the proximal end of the proximal phalanx is pushed dorsally and over the metacarpal head. **C.** The reduced MCP joint.

ASSESSMENT

CLINICAL ASSESSMENT

Assess the collateral ligaments for stability. **Because the goal of treatment is to restore functional stability, it is essential to perform a systematic evaluation of joint stability.** An accurate assessment generally requires adequate pain control, even in the most cooperative patients. Active stability is tested by allowing the patient to move the joint through the normal range of motion. Completion of a full range without displacement indicates adequate joint stability. Passive stability is assessed by applying gentle radial and ulnar stress to each collateral ligament and posteroanterior stress to assess volar plate integrity. Stress testing should be performed in extension and flexion to avoid the stabilizing effect of the volar plate. Comparisons with the same joint of the uninvolved hand may assist in the diagnosis.[2] Stability of the joint provides strong evidence that optimal functional recovery would result from short-term immobilization rather than surgical intervention.

Joint stability of the thumb MCP joint is tested in full extension as well as in 30° of flexion. Complete ligament disruption is suspected if the joint can be stressed in a radial direction 25° to 35° beyond a similar stress to the patient's opposite thumb MCP joint. This instability should be demonstrated in both full extension and 30° of flexion. Flexion at 30° lessens the stabilizing effects of the volar plate.[2] The presence of ecchymosis suggests a complete ligament tear as well as a volar subluxation of the proximal phalanx.[19]

RADIOGRAPHIC ASSESSMENT

Postreduction radiographs are essential to demonstrate adequate reduction. Occasionally, a fracture is only visible on these views and not on the prereduction films.[1,20] Joint subluxation after reduction is associated with interposed soft-tissue or severe capsular injury.

AFTERCARE

Splinting of any MCP joint dislocation should provide adequate immobilization and protection. Splinting is maintained for at least 1 week to no more than 3 weeks to prevent joint stiffness. Simple dorsal finger MCP joint dislocation injuries generally require splinting for 1 to 3 weeks with the joints in 45° to 50° of flexion.[2] Volar finger MCP joint dislocations require splinting in extension for 1 to 3 weeks. The thumb should be immobilized in a thumb spica splint in 20° of flexion for dorsal dislocations and in extension for volar dislocations for 3 weeks. A proper program of gradual active range-of-motion exercises should follow splinting.[18] With adequate protection and splinting of uncomplicated dislocations, athletes may return to activities within 1 to 2 weeks, sooner for low-risk sports with minor injuries, and longer for more serious injuries requiring surgery.[20]

COMPLICATIONS

Allergic reactions can occur from hypersensitivity to the local anesthetic solution. Symptoms can range from mild pruritus and urticarial rash to circulatory collapse and even death. Severe allergic reactions are extremely rare. Taking a thorough history might prevent such a reaction. The preservative in the anesthetic is often the culprit. The possibility of injury to structures in the joint may occur from improper insertion of the needle or needle movement within the joint cavity. Infection of the joint can occur when the needle penetrates unclean skin, infected skin, or infected subcutaneous tissue. If proper aseptic technique is followed, the risk of infection is negligible. Please refer to Chapters 77 and 123 regarding the complete details of local anesthetic complications and joint injection complications.

Complications of the reduction procedure are primarily related to failure of reduction, especially complex dislocations. Entrapment of ligaments, tendons, or sesamoid bones leads to an unsuccessful reduction. A simple MCP joint dislocation can be converted into a complex one during prolonged or repeated reduction attempts, especially those in which axial traction is the primary component.[2] Irreducible MCP joint dislocations require an immediate evaluation by a Hand Surgeon.

Collateral ligament injuries occur infrequently and are often missed in the acute setting. The presence of an avulsion fracture from the metacarpal head or corner fracture of the base of the proximal phalanx suggests a collateral ligament injury. Consultation with a Hand Surgeon is recommended for patients with a collateral ligament injury. Some surgeons prefer immediate operative repair of these injuries. ED care involves immobilization in a gutter splint, with the MCP joint in 45° to 50° of flexion, and appropriate referral.

Ulnar collateral ligament of the thumb rupture, also known as gamekeeper's or skier's thumb, results from a laterally directed force at the thumb MCP joint. The ligament is important to the grasping function of the thumb. **Early recognition of this injury is key.** The diagnosis is generally made through stress testing of the reduced MCP joint. Radiographs occasionally demonstrate an avulsion-type fracture. Treatment of partial ligament tears requires splinting in a thumb spica for 6 weeks, while complete rupture requires operative repair.

Radial collateral ligament injuries of the MCP joint of the thumb are less common but equally debilitating. The usual mechanism is forced adduction with or without hyperextension. The diagnosis is generally made through stress testing of the reduced MCP joint. Radiographs occasionally demonstrate an avulsion-type fracture. Treatment of partial ligament tears requires splinting in a thumb spica for 6 weeks, while complete rupture requires operative repair.

Degenerative arthritis may occur after multiple closed reductions or an unrecognized chronic dislocation.[21] Inadequate immobilization or early return to high-stress activities may result in ligamentous laxity or recurrent instability. Excessive joint contractures unresponsive to physical therapy may require surgical release.

SUMMARY

Injuries to the MCP joints of the hand are occasionally encountered in the ED. They may be associated with significant morbidity if not properly managed. The most common dorsal MCP joint dislocation seen is that of the thumb. Volar dislocations of the MCP joints are rarely seen. A thorough understanding of the anatomy and function of the MCP joint is essential to diagnose and manage these injuries. A detailed physical assessment of the soft tissues, bones, and neurovascular structures is essential to prevent occult injuries. Radiographic evaluation is required for all potential injuries. This should include anteroposterior, lateral, and obliques views in order to not miss associated avulsion fractures or evidence of complex dislocations. All MCP joint dislocations should have an attempt at reduction, except those that are unstable, chronic, open, or associated with a fracture. A Hand Surgeon should evaluate any unstable, chronic, open, or irreducible dislocation. MCP joint dislocations reduced in the ED must be appropriately splinted and follow-up arranged with a Hand Surgeon.

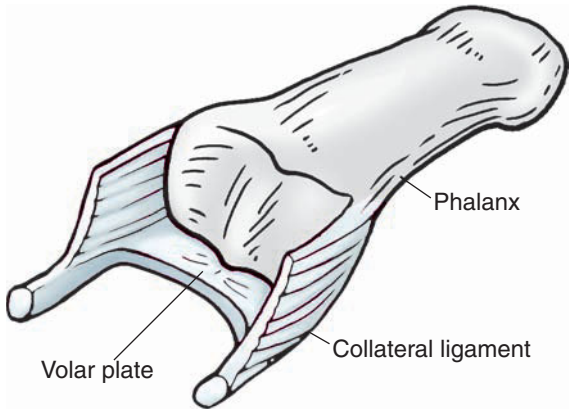


FIGURE 85-1. A schematic drawing of the box complex surrounding the PIP joint.

85 Interphalangeal Joint Dislocation Reduction

Matt Kleinmaier and Sanjeev Malik

INTRODUCTION

Dislocation of the interphalangeal (IP) joints is one of the most common orthopedic injuries seen in the Emergency Department (ED).[1–3] Most of these injuries occur during athletic activities. The proximal interphalangeal (PIP) joint is especially susceptible to injury during ball-handling sports.[2–4] An epidemiologic study of injuries in the National Football League over a 10-year period from 1996 to 2005 showed that PIP dislocations accounted for 17% of all hand injuries, making it the second most common hand injury in professional football.[14] Among dislocations, IP joint injuries are second only to shoulder dislocations in incidence.[4] While IP joint dislocations are generally easy to reduce, improperly treated injuries can result in chronic pain, swelling, restricted range of motion, deformity, and early degenerative arthritis.[1,5,6] The Emergency Physician (EP) must be proficient in diagnosing and treating IP joint dislocations.

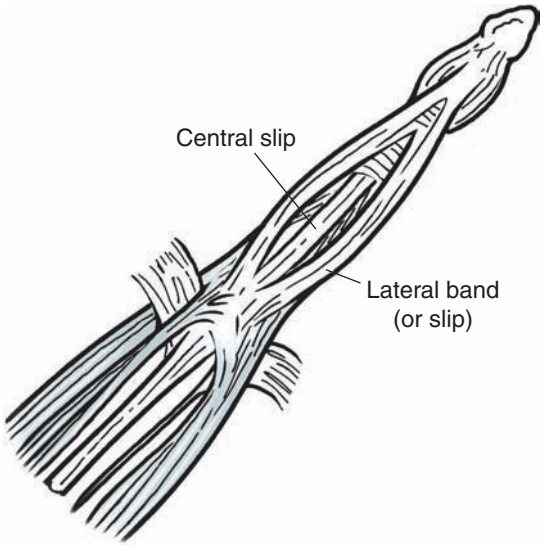


FIGURE 85-2. Dorsal view of the extensor mechanism.

ANATOMY AND PATHOPHYSIOLOGY

The bicondylar conformation of the PIP joint creates an inherently stable hinge joint with movement restricted to flexion and extension from 0° to 120°.[1,7,8] Additional stability comes from the complex of ligaments and tendons, which form a box around the joint (**Figure 85-1**). The elements of this complex include the volar plate, lateral and collateral accessory ligaments, and the extensor tendon dorsally. The volar plate's dense, fibrous distal aspect attaches firmly to the middle phalanx, while its more membranous proximal portion is continuous with the synovial reflection. This conformation resists dorsal dislocation at the joint.[4] The three bands of the extensor tendon mechanism (the central slip with a lateral band on each side) provide dorsal support which resists joint dislocation (**Figures 85-2 & 85-3**). Lateral collateral ligaments bridge the PIP on the radial and ulnar sides, stabilizing it against lateral dislocation.[3]

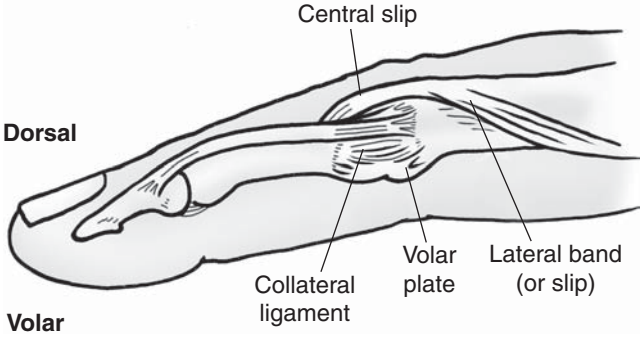


FIGURE 85-3. Lateral view demonstrating the anatomy of supporting structures. The volar plate and collateral ligaments form a box around three sides of the joint, while the extensor mechanism (consisting of central and lateral slips) lies along the dorsal aspect of the joint.

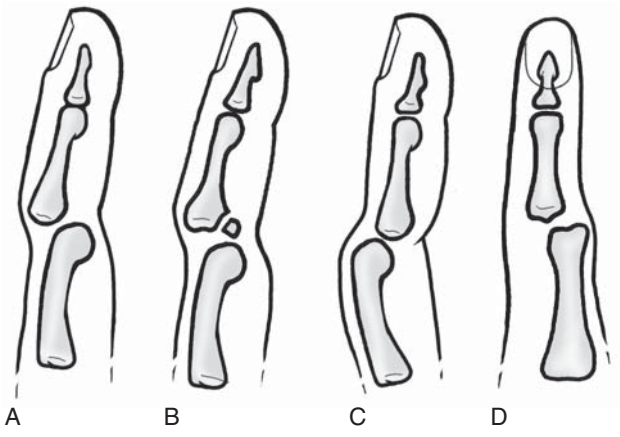


FIGURE 85-4. Dislocations of the PIP joint. They are classified based on the relationship of the distal bone to the proximal bone. **A.** Dorsal or posterior dislocation. **B.** Dorsal dislocation with an associated fracture. **C.** Volar, ventral, or anterior dislocation. **D.** Lateral dislocation.

The less-commonly dislocated IP joints (finger DIP and thumb IP joint) are similar in anatomy to one another. They are more broad-based than the PIP and range from 0° in extension to 90° in flexion, with no significant lateral or rotary movement.[3] The distal phalanx in both joints is firmly attached to the skin, accounting for the high percentage of open dislocations involving these joints.

Dislocations of the PIP joint are the most common and may be classified as dorsal, volar, and lateral (**Figure 85-4**).[1,4] Each type of dislocation results from a different mechanism of injury and has specific associated complications.

Dorsal (or posterior) dislocations are the most common type of PIP joint dislocation (**Figures 85-4A**). They usually result from hyperextension injuries.[4,7,8] A dorsal dislocation occurs when the middle phalanx is displaced dorsally from the proximal phalanx. These dislocations involve injury to the volar plate and may be associated with an avulsion fracture of the base of the middle phalanx (**Figures 85-4B & 85-5**). Avulsion fractures involving greater than 30% of the articular surface are considered unstable and require immediate referral to an Orthopedic or Hand Surgeon.[4]

Volar (or anterior) PIP joint dislocations are far less common and are more severe than dorsal PIP joint dislocations (**Figures 85-4C & 85-6**). They occur from a simultaneous axial load and a rotational force on the IP joint. Volar PIP joint dislocations are associated with rupture of the collateral ligament and disruption of the central slip of the extensor tendon mechanism. These injuries may preclude closed reduction.[4] These injuries can be more difficult to diagnose



FIGURE 85-5. Lateral view of dorsal dislocation with a minor avulsion fracture involving less than 30% of the articular surface. This is a stable fracture-dislocation.



FIGURE 85-6. Volar dislocation with an associated fracture of the middle phalanx.

than other types of dislocation, often presenting as subtle subluxation at the PIP joint with rotational deformity of the middle and distal phalanx seen on plain films.[9]

If left untreated, volar PIP joint dislocations may result in a boutonniere deformity (**Figure 85-7**).[1] This injury should be suspected in patients with pain over the PIP joint and the inability to fully extend the digit against active resistance. Plain films are usually unremarkable. Splinting in full extension with early follow-up with an Orthopedic or Hand Surgeon is mandatory in all suspected cases.

Lateral PIP joint dislocations are uncommon (**Figure 85-4D**).[3] They result from a pure radial or ulnar force on the joint with either partial or complete rupture of the collateral ligament. Ulnar dislocation with radial collateral ligament injury is six times more common than radial dislocation with ulnar collateral ligament disruption.[3] Lateral PIP joint dislocations are often reducible by closed methods.

Distal IP joint dislocations and IP joint dislocations of the thumb (**Figure 85-8**) are rare. They are often due to a direct blow to the distal portion of the digit.[7] They are most often dorsally dislocated and frequently open due to the firm attachment of the distal phalanx to the subcutaneous tissue and skin. All open dislocations require immediate orthopedic consultation.

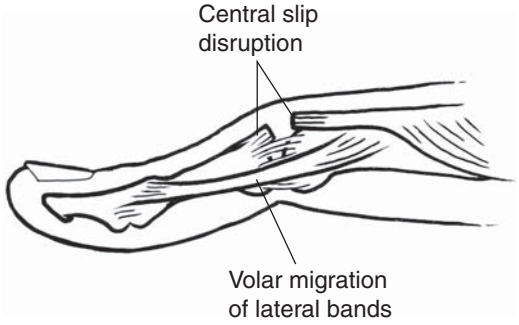


FIGURE 85-7. The boutonniere deformity.

IP joint dislocations of the toes are primarily dorsal. They occur secondary to an axial compression load to the digit, such as kicking a toe against a wall. IP joint dislocations of the toe are reduced similarly to dorsal IP dislocations of the finger.

INDICATIONS

Most IP joint dislocations that present to the ED are amenable to closed reduction by the EP. Factors to be considered include time from injury, closed versus open dislocation, associated fracture patterns, and direction of dislocation. The majority of IP joint dislocations present within hours of the injury, and closed reduction may be safely performed up to 3 weeks from the time of injury.[6] If there is no disruption of the skin overlying an IP joint dislocation, it is considered a closed injury and suitable for closed reduction. Small fractures involving less than 30% of the joint surface are considered stable for closed reduction.[3]

The direction of the dislocation should also be considered prior to any attempted reduction. Most dorsal dislocations are reducible by closed methods. Open reduction is occasionally necessary due to interposition of the ruptured volar plate or trapping of the proximal phalanx between the volar plate and flexor tendon.[10] Lateral dislocations are almost always successfully managed by closed reduction.[10]

The management of volar dislocations is more controversial. These injuries are often irreducible with closed methods due to trapping of soft tissue in the joint space (usually the ruptured extensor mechanism) or are unstable after reduction due to extensive damage to the supporting ligaments.[10] A single attempt at closed reduction may be performed. If successful, splint the finger in extension and consult an Orthopedic or Hand Surgeon as open repair of the extensor mechanism is usually required to prevent boutonniere deformity.[9,10] All irreducible injuries require emergent consultation with an Orthopedic or Hand Surgeon.

CONTRAINDICATIONS

Contraindications to closed reduction of IP joint dislocations include chronic dislocations, open dislocations, unstable dislocations, or complex dislocations. A chronic dislocation is defined as an IP joint dislocation of longer than 3 weeks duration. These injuries generally require open reduction and should not be reduced in the ED.[7] Careful inspection of the digit should be made looking for any breaks in skin integrity. Any skin wound, especially in the direction of the dislocation, mandates treatment as an open dislocation by an Orthopedic or Hand Surgeon. Unstable injuries are generally fracture-dislocations involving greater than 30% of the articular surface.[3] Complex injuries involve complete disruption of multiple ligaments or tendons surrounding the joint and often require open reduction and repair due to interposition of disrupted soft tissues between the articular surfaces of the IP joint.[1,7,11,12]



FIGURE 85-8. Dorsal dislocation of the thumb IP joint.

EQUIPMENT

Digital Block

- Povidone iodine or chlorhexidine solution
- 27 gauge needle, 2 in. long
- 5 mL syringe
- Alcohol swab
- Local anesthetic solution without epinephrine (1% lidocaine, 0.25% or 0.5% bupivacaine)

Postreduction Splint

- Aluminum finger splint with foam padding
- Gauze padding
- Adhesive tape, ½ in.
- Scissors

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Obtain a written consent for the reduction procedure. Inform the patient that up to 30% of PIP and DIP joint injuries may remain swollen for many months and will likely result in permanent joint enlargement. Loss of motion and residual soreness may last several months.[1,6]

The use of local anesthesia is based on EP and patient preference. Many EPs and patients believe that the pain of reduction is less than that of a digital block and more tolerable. For this reason, many EPs will reduce an IP joint dislocation without the use of local anesthesia.

Clean the finger of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Insert a 27 gauge needle into the lateral aspect of the base of the proximal phalanx. Inject 0.5 mL of local anesthetic solution. Redirect the needle dorsally while depositing 1 mL of local anesthetic solution. Withdraw the needle and redirect it volarly while depositing 1 mL of local anesthetic solution. Repeat the procedure on the medial aspect of the base of the proximal phalanx. Refer to Chapter 126 for a more detailed description of the methods to anesthetize a finger.

TECHNIQUES

DORSAL DISLOCATION OF THE PIP JOINT

A dorsal dislocation of the PIP joint involves a partial or complete disruption of the volar plate. Most dorsal dislocations of the PIP joint are easily reduced (**Figure 85-9**). Firmly grasp the middle phalanx of the affected finger with the dominant hand. Grasp the base of the proximal phalanx with the nondominant hand. Hyperextend the PIP joint and apply longitudinal traction to separate the articular surfaces (**Figure 85-9B**). The nondominant hand is used to stabilize the proximal phalanx and apply countertraction. Flex the PIP joint while maintaining traction and apply dorsal pressure on the base of the middle phalanx (**Figure 85-9C**). This should restore the proper alignment of the proximal and middle phalanx.

Immobilize the reduced PIP joint in 30° of flexion for approximately 3 weeks (**Figure 85-9D**). Alternatively, tape the injured finger to an adjacent unaffected finger ("buddy taping"). Gauze padding must be placed between the fingers before buddy taping to prevent skin breakdown. During immobilization, it is important to avoid hyperextension if the finger is buddy taped, as this may lead to further injury of the volar plate. The presence of an avulsion fracture involving less than 30% of the articular surface does not alter this management plan.

Rarely, a dorsal dislocation can be irreducible due to interposed soft tissue or impingement of the proximal phalangeal head between the central slip and the lateral bands.[9] This type of dislocation is referred to as "complex." Failure of two or three attempts at closed reduction should raise the suspicion of an irreducible joint and an Orthopedic or Hand Surgeon should be consulted.

VOLAR DISLOCATION OF THE PIP JOINT

Volar dislocations of the PIP joint are almost always accompanied by an injury to the central slip of the extensor tendon, causing an inability to extend the PIP joint (**Figure 85-7**). These dislocations are generally irreducible and need early consultation with an Orthopedic or Hand Surgeon for operative repair due to the extensive soft tissue damage. Although controversial, some authors recommend a single attempt at closed reduction by applying a longitudinal (distal) force, hyperextending the joint, and applying dorsal pressure to the base of the middle phalanx. During this procedure, the metacarpophalangeal and DIP joints should be flexed and the wrist extended to relax the anteriorly displaced lateral bands and extensor mechanism. Splint the joint in extension and arrange for early follow-up with an Orthopedic or Hand Surgeon if closed reduction is achieved. **It is important to note that splinting in even mild flexion or "buddy taping" may lead to a boutonniere deformity (Figure 85-7).**

LATERAL DISLOCATION OF THE PIP JOINT

Lateral dislocations of the PIP joint involve a partial or complete rupture of the radial and ulnar collateral ligaments. There is a 6:1 ratio of radial to ulnar collateral ligament tears with the digit being displaced in the opposite direction of the ligament rupture.[3] Generally, reduction is easy and the joint is stable after the procedure. Recreate

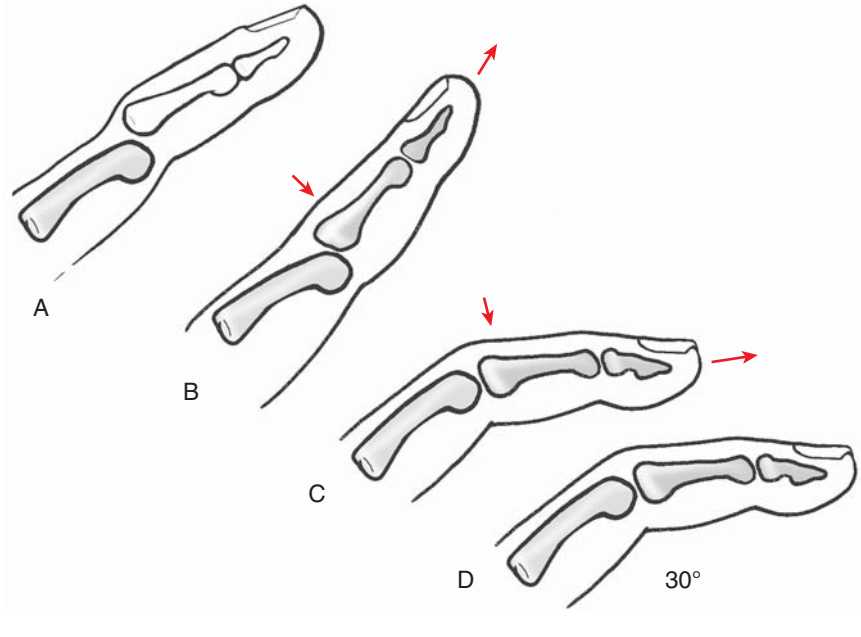


FIGURE 85-9. Reduction technique for an IP joint dislocation. **A.** Dorsal PIP joint dislocation. **B.** Exaggerate the deformity by hyperextending the middle phalanx and applying longitudinal traction distal to the injury. **C.** Flex the PIP joint while applying pressure to the dorsum of the middle phalanx with continued traction. **D.** The PIP joint is placed in 30° of flexion for splinting.

the injury and apply longitudinal (distal) traction to the finger. Bring (move) the distal phalanx in line with the proximal phalanx.

After reduction, determine by physical examination if the collateral ligaments are partially or completely torn. Buddy tape the finger to the adjacent finger for 3 weeks for incomplete collateral ligament tears. Early active motion of the finger is encouraged after this time. Complete collateral ligament tears are repaired operatively and require early consultation by an Orthopedic or Hand Surgeon.

INTERPHALANGEAL JOINT OF THE THUMB DISLOCATION

Dislocations of the IP joint of the thumb are rare. The injury is usually dorsal and open. If the dislocation is closed, the joint can be reduced in the same manner as PIP dislocations of the fingers.[11] Splint the reduced joint in slight flexion and arrange for early follow-up by an Orthopedic or Hand Surgeon.

DISTAL INTERPHALANGEAL JOINT DISLOCATION

DIP joint dislocations are rare, usually dorsal, and open. They are easily reduced in a similar manner to other IP joint dislocations and are generally stable after reduction.[12] Reduction is accomplished by application of longitudinal (distal) traction, hyperextension of the distal phalanx, and the application of dorsal pressure on the base of the distal phalanx. Immobilize only the DIP joint with a dorsal splint in 5° to 10° of flexion. Arrange for follow-up with an Orthopedic or Hand Surgeon.

The DIP joint may be irreducible if there is an avulsion and entrapment of the volar plate in the joint, entrapment of the long flexor tendon in the joint, or entrapment of a bony fragment. Immediate consultation with an Orthopedic or Hand Surgeon should be sought if the DIP joint is irreducible.

ASSESSMENT

Fully evaluate the finger after the reduction or any reduction attempt. **Perform and document a complete neurologic and vascular exam of the finger. An Orthopedic or Hand Surgeon should be consulted immediately if any neurologic or vascular deficits are identified.** Obtain postreduction radiographs of the digit to identify an avulsion injury or an incomplete reduction. Test the joint for functional stability by having the patient actively move the injured finger through a full range of motion. Stability of the joint is maintained if the collateral ligaments and volar plate are intact and no subluxation or dislocation occurs. Test the collateral ligaments by applying radially and ulnarly directed stresses with the joint in 20° of flexion. Test the integrity of the volar plate by having the patient hyperextend the joint and comparing the range of motion to that of the other fingers. The joint is considered stable if there is no displacement during active range of motion and passive stressing of the joint. If stable, place the joint in an appropriate splint and refer the patient to an Orthopedic or Hand Surgeon for follow-up. Immediately consult an Orthopedic or Hand Surgeon if the joint is not easily reduced or if it is not stable after the reduction. All open dislocations require immediate evaluation by an Orthopedic or Hand Surgeon for irrigation, reduction, and closure.

AFTERCARE

Splinting of any finger injury should provide adequate immobilization and protection while allowing maximal range of motion of the unaffected joints. The method of splinting for each specific dislocation is described in the "Techniques" section for each type of dislocation.

COMPLICATIONS

Most complications of IP joint dislocations are secondary to the injury itself rather than the reduction procedure. Even seemingly minor injuries can have complications such as prolonged swelling, pain, and stiffness. A thorough evaluation of the digit, prompt diagnosis, and proper treatment will help minimize these complications.

Complications of the reduction procedure are primarily related to failure of reduction.[13] Entrapment of soft tissues should be suspected in cases with multiple failed attempts at reduction. Numerous attempts at reduction may lead to trauma at the articular surface, predisposing to the development of premature degenerative arthritis. Irreducible or complex IP joint dislocations require an immediate evaluation by an Orthopedic or Hand Surgeon.

Prolonged or improper splinting of a joint can lead to chronic complications. Extended splinting and immobilization can lead to permanent joint stiffness. In general, IP joints should not be immobilized for greater than 3 weeks. Inappropriate splinting of a volar dislocation in even mild flexion may lead to long-term complications such as the boutonniere deformity.

SUMMARY

Injuries to the IP joints of the hand are commonly encountered in the ED and may be associated with significant morbidity. The most common injury encountered is a dorsal IP joint dislocation. Other dislocations include volar and lateral IP joint dislocations. A thorough understanding of the anatomy and function of the IP joint is essential to diagnose and treat these common injuries appropriately. A detailed physical examination of the soft tissues, bones, and neurovascular structures is necessary. Radiographic evaluation is required for all potential injuries, including an anteroposterior and a lateral view of the affected digit. Acute stable dislocations can be reduced immediately in the ED. An Orthopedic or Hand Surgeon should evaluate any unstable, chronic, open, or complex dislocation. Joints reduced in the ED must be splinted and appropriate follow-up arranged.

86 Hip Joint Dislocation Reduction

George Chiampas and Steve Zahn

INTRODUCTION

Hip dislocations are true orthopedic emergencies. The Emergency Physician (EP) must be capable of reducing a dislocated hip. Neurovascular damage to the hip and leg is a consequence of a hip dislocation. Avascular necrosis (AVN) may occur in up to 20% of patients with a hip dislocation. Other studies show that AVN following a hip dislocation is a time-dependent phenomenon. **The longer a hip is dislocated, the higher the incidence of avascular necrosis.** Dislocation of a hip for more than 6 hours almost universally results in this devastating complication.

The main etiologies of a hip dislocation are traumatic dislocations of a normal hip, mechanical dislocations of a prosthetic hip, spontaneous dislocations, and pathologic dislocations. Less impressive mechanisms may result in hip dislocations in the young and the elderly. A simple fall from standing may dislocate a geriatric hip. Dislocations may occur with minor force in children, as during athletic activities.

Many techniques have been described to reduce dislocated hips.[1–7] The EP must be familiar with some of these methods and how to apply them appropriately to optimize patient management and outcome. Dislocations of both normal and prosthetic hips are seen in the Emergency Department. Dislocations of prosthetic hips are now more common than those of normal hips.[8] While these are not associated with avascular necrosis, the pressure from the dislocated prosthetic head may result in other neurovascular complications.

ANATOMY AND PATHOPHYSIOLOGY

Ball-and-socket joints are inherently stable. The strong muscles, ligaments, and fibrous joint capsule of the hip reinforce this innate stability. Consequently, in the average adult, a great deal of force must be transmitted to dislocate the hip. This is significant, as the patient with a hip dislocation may have other life-threatening injuries that take precedence over the management of the hip dislocation. The mortality associated with a hip dislocation results from associated injuries of the head, thorax, or pelvis.

Hip dislocations are classified into anterior, posterior, and central based upon the relationship of the dislocated femoral head to the acetabulum. Anterior hip dislocations occur with the leg in a neutral or abducted position. The femoral head is pushed anterior to the coronal plane of the acetabulum. These patients present in extreme pain with the hip and knee flexed 90°. The leg will be held in external rotation. A slight shortening of the leg may be noted, but this is difficult to detect with the knee in flexion. There are three subtypes of an anterior hip dislocation: anterior obturator, anterior iliac, and anterior pubic. The femoral head displaces medially and lies in the obturator canal in anterior obturator dislocations. The femoral head moves superiorly and lies over the iliac wing in anterior iliac dislocations. The femoral head moves inferiorly over the pubic ramus in anterior pubic dislocations.

Posterior hip dislocations are the most common type. They account for nearly 90% of all hip dislocations. This is because the posterolateral half of the femoral neck lies outside the joint capsule and the weaker posterior support of the hip. Posterior dislocations result from force transmitted along the femoral shaft with the leg adducted. The most common mechanism of injury is a motor vehicle collision where the knees strike the dashboard and the femoral head is pushed posterior to the coronal plane of the acetabulum. The presentation of a posterior dislocation is of a patient in extreme pain. The leg will be internally rotated with marked knee flexion and adduction of the thigh. The femoral head is rarely visible but may be palpable in the buttock region. Posterior hip dislocations are further categorized into posterior ischial and posterior iliac sub-types. The femoral head is displaced inferiorly and lies over the ischium in posterior ischial dislocations. The femoral head is displaced superiorly and lies over the iliac wing in posterior iliac dislocations.

Central hip dislocations are the rarest form. The femoral head remains on the same coronal plane as the acetabulum in central dislocations. However, it is displaced superiorly. Most central hip dislocations are associated with acetabular fractures.

INDICATIONS

All hip dislocations must be reduced. **Emergent hip reduction by the EP is indicated when distal neurologic or vascular deficits are present or if the Orthopedic Surgeon is not immediately available.** The incidence of avascular necrosis is time-dependent and necessitates reduction as soon as possible to limit this complication.

CONTRAINDICATIONS

Any life-threatening conditions must be treated before the hip is reduced. Closed reduction is contraindicated if a surgical indication for repair exists. Surgical exploration is required for hip dislocations associated with femoral head fractures, femoral shaft fractures, or the finding of sciatic nerve dysfunction. Surgery is also indicated for an irreducible dislocation, persistent instability of the joint after closed reduction, and for any postreduction neurovascular deficits.

EQUIPMENT

- Procedural sedation equipment and supplies (Chapter 129)
- Assistants
- Sheets

PATIENT PREPARATION

The patient must be appropriately stabilized with prioritization of the ABCs (airway, breathing, and circulation). Life-threatening associated injuries and comorbid conditions must be adequately addressed. Obtain plain radiographs to define the anatomic dislocation pattern, to rule out any associated fractures, and to guide relocation attempts.

Explain the risks, benefits, complications, and aftercare of the reduction procedure and obtain an informed consent from the patient and/or their representative. **The patient must be sedated to achieve optimal muscle relaxation and pain control.** Perform procedural sedation after obtaining a separate informed consent for this procedure.

TECHNIQUES

Hip reduction techniques have been described with the patient in every imaginable position.[1–9] The relative success rates for each technique have not been reliably reported.[8] Therefore EPs typically use the technique(s) that was demonstrated to them during their residency training. **The editor recommends using the Allis maneuver as the treatment of choice for the reduction of posterior hip dislocations.** The other techniques are described in the text primarily for historical information, to give the reader full information regarding procedures that have been used and described for the reduction of this common problem, and as alternative techniques if the Allis maneuver is not successful in reducing the hip.

ALLIS MANEUVER

This is the most common hip reduction method (**Figure 86-1A**). It was described by Allis in 1893.[1] The technique has been improved by the addition of procedural sedation. Place the patient supine and perform procedural sedation. Instruct an assistant to stabilize the patients pelvis to the gurney by pressing down on the anterior superior iliac spines. It may be necessary for the assistant to use both hands on the side of the pelvis associated with the hip dislocation to stabilize the pelvis. Flex the affected knee and hip 90°. Grasp the affected knee with both hands. Apply axial traction to the thigh with incrementally increasing force. Simultaneously rotate the femur laterally and medially until the hip relocates.

If relocation is not easily accomplished, instruct a second assistant to apply lateral traction to the inner thigh of the affected proximal femur (**Figure 86-1B**). Repeat the entire procedure with the addition of lateral traction to reduce the dislocation.

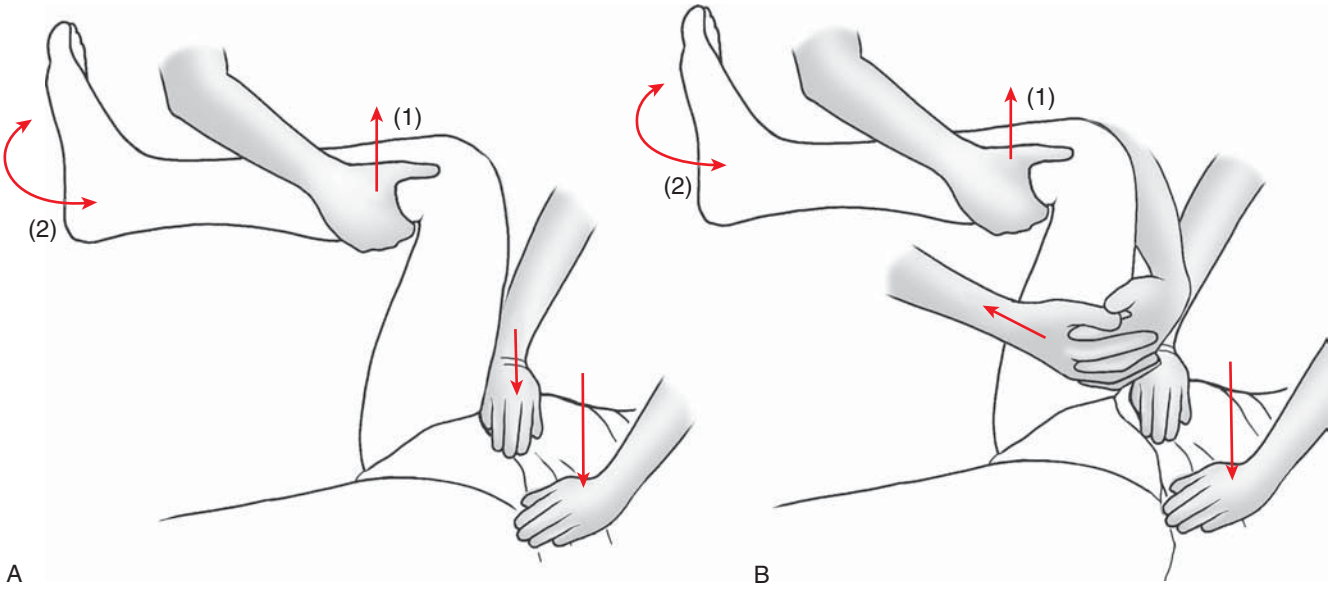


FIGURE 86-1. The Allis maneuver. **A.** An assistant stabilizes the pelvis. The EP simultaneously distracts the femur (1) and rocks it medial to lateral (2, *curved arrow*). **B.** The same maneuver with the addition of a second assistant to apply lateral traction to the thigh.

MODIFIED ALLIS MANEUVER

This technique incorporates all of the maneuvers described above. Additionally, place the hip in maximum adduction. Apply longitudinal traction to the femur while an assistant presses down on the pelvis with one hand and pushes the head of the affected femur toward the acetabulum with the other hand.

GRAVITY METHOD OF STIMSON

Place the patient prone on the gurney. Perform procedural sedation. Monitoring may be more difficult due to the prone positioning. **Extra attention must be paid to the patient's airway and breathing when placed prone.** Associated injuries may preclude prone positioning of the patient.

Place the affected leg hanging over the side of the gurney with the knee and hip each flexed 90°. Alternatively, hang both legs off the distal edge of the gurney with the knees and hips flexed 90° (**Figure 86-2A**). Instruct an assistant to hold the patient down on the gurney by applying downward pressure on the posterior pelvis at the posterior superior iliac spines.

Grasp the ankle in one hand to support the limb and to be able to apply internal and external rotation to the extremity (**Figure 86-2A**). Place the other hand on the proximal posterior calf. Exert gradual longitudinal traction on the femur by placing pressure on the affected calf until the hip is felt to pop into place.

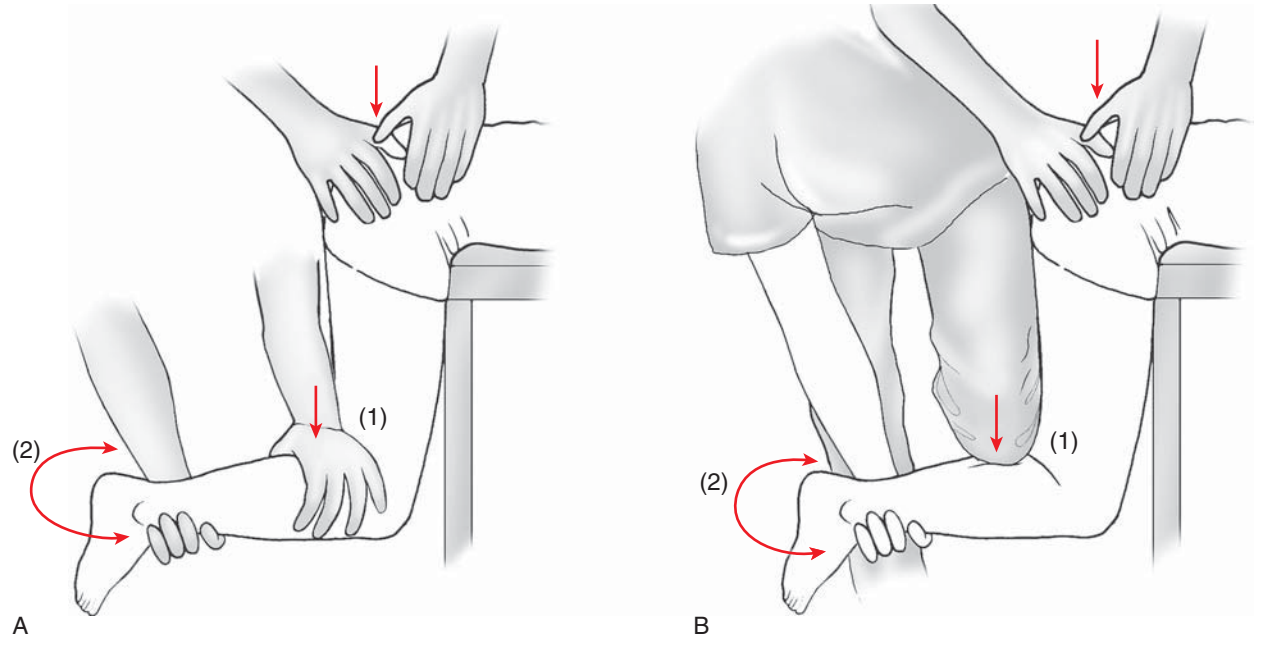


FIGURE 86-2. The gravity method of Stimson. **A.** An assistant stabilizes the pelvis. The EP applies downward pressure on the calf (1, *straight arrow*) while applying subtle and external rotation to the femur (2, *curved arrow*). **B.** An alternative method.

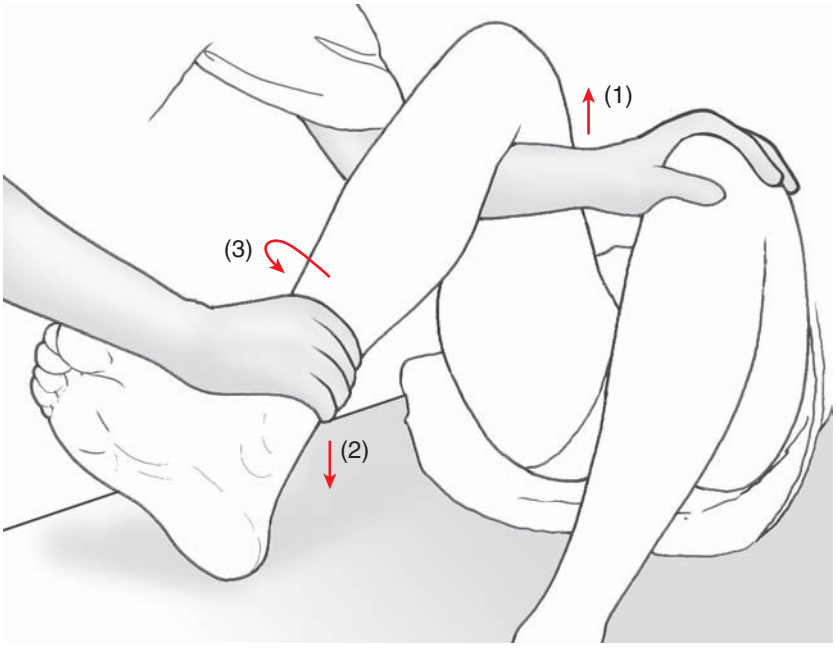


FIGURE 86-3. The Whistler (or Rochester, or Tulsa) technique. Elevation of the EPs shoulder (1) while simultaneously flexing the patient's knee (2) moves the femoral head anteriorly and around the acetabular rim. Externally rotating the patient's leg (3, *curved arrow*) by swinging the ankle laterally allows the femoral head to reduce.

A subtle internal and external rotary motion may help to move the femoral head over the acetabular rim. **Care must be taken not to compress the structures in the popliteal fossa with excessive pressure behind the knee.**

A much greater degree of force can be applied to the hip if the EP, instead of generating traction with their arm, places a knee in the affected popliteal fossa (**Figure 86-2B**). Pull the affected ankle upward while simultaneously exerting downward force on the calf to reduce the dislocation.

WHISTLER/ROCHESTER/TULSA TECHNIQUE

This technique was described at three separate sites (**Figure 86-3**). Whistler Healthcare Center in Vancouver, Canada, described it in 1997.[10] The Orthopedic Associates of Rochester described it in 1999. Vosburgh described it in 1995 as the "Tulsa method."[11] It is reported as being easier to implement than the other techniques and appropriate for use in the Emergency Department.[10,11] Another advantage is that it can be performed without the aid of an assistant. Pelvic stabilization is provided by a counterforce on the uninjured knee. The force and counterforce occur through the same fulcrum and are therefore exactly equivalent.[9]

Place the patient supine. Perform procedural sedation. Stand to the side of the affected hip. Flex the unaffected knee 130°. Place your elbow under the affected knee, allowing the leg to dangle over your forearm. Reach to grasp the flexed unaffected knee with the palm. Grasp the affected ankle with your other hand in order to flex the knee and rotate the hip. The hold is now established (**Figure 86-3**).

Elevate the affected knee by raising your shoulder and using your arm as a lever (**Figure 86-3(1)**). Simultaneously apply a longitudinal force by progressively flexing the patient's knee over your arm (**Figure 86-3(2)**). This applies traction to the femoral head, moving it anteriorly and around the acetabular rim. Once the acetabular rim is cleared, externally rotate the leg to allow the femoral head to reduce (**Figure 86-3(3)**). External rotation is achieved by swinging the ankle laterally. A pop should be felt as the femoral head falls into the acetabulum. Reduction can be verified by internal and external rotation of the hip. An assistant may occasionally be required to stabilize the pelvis.

FULCRUM TECHNIQUE

Lefkowitz described this technique in 1993 and Bergman described it in 1994.[6] The advantage of this technique is that leverage allows greater reduction forces to be applied to the hip with less strength and effort on the part of the EP (**Figure 86-4**). A steady and constant force can easily be applied that reduces the risk of fractures and nerve injuries. This constant traction is superior to the sudden jerks that are inevitable in some of the other reduction techniques.[6]

Place the patient supine and perform procedural sedation. Secure the patient to the gurney with a sheet or use an assistant to stabilize

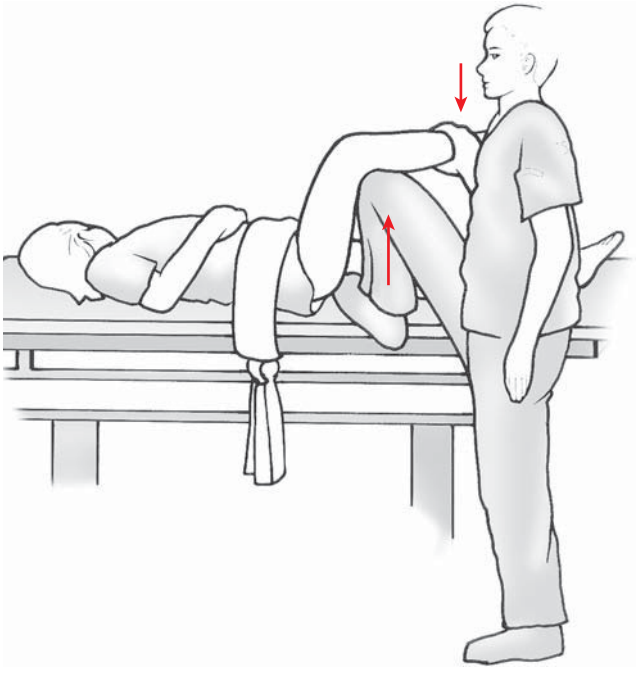


FIGURE 86-4. The fulcrum technique. The EP applies downward pressure on the patient's ankle while simultaneously plantarflexing their foot to move the femoral head around the acetabular rim and reduce the hip.

the patient's pelvis. Lower the bed, preferably to within 2 to 3 feet of the floor. Stand on the side of the affected hip. Place one foot on the edge of the bed at the level of the patient's hip. A platform or footstool may be used to gain a mechanical advantage if the level of the bed is too high or you are too short.

Flex the affected knee 90° over your knee (**Figure 86-4**). Grasp and hold the affected ankle. Apply steady, gentle downward traction on the ankle to flex the knee while simultaneously plantarflexing your foot on the gurney. This will cause the knee to exert an upward force on the patient's knee, raising the femoral head around the edge of the acetabulum and reducing the hip. It may be necessary to gently rotate the affected foot internally and externally if the hip does not reduce easily.

SIMPLE LONGITUDINAL TRACTION

This technique is similar to the reduction of a shoulder dislocation (**Figure 86-5**). Place the patient supine and perform procedural sedation. Extend the affected lower extremity at the hip and knee. Wrap a sheet around the affected proximal thigh. Grasp the patient's ankle with both hands. **Do not grasp the foot, as this can result in secondary injury.** Instruct an assistant to apply lateral traction to the sheet and proximal thigh to move the femoral head over the acetabular rim while simultaneously exerting longitudinal traction to the leg by pulling on the patient's ankle to reduce the hip (**Figure 86-5**).

The editor prefers to use a padded leather restraint around the affected ankle. Wrap the two ties of the restraint around your hips and secure them with a knot. You can then slowly lean backward to allow your body weight to reduce the hip. This method is especially useful if you are small in stature or do not have significant upper body strength. Do not wrap the ties around your waist, as this can cause low back strain.

BIGELOW MANEUVER

Bigelow described this technique in the literature in 1870 (**Figure 86-6**). It was the first documented hip reduction technique. Perform procedural sedation. Place the patient supine with the affected hip and knee flexed 90°. Hold the affected knee in the crook of your flexed elbow with the patient's foot in the opposite hand (**Figure 86-6A**). Instruct an assistant to stabilize the pelvis by applying downward pressure to the anterior superior iliac spines. Lift your shoulder and arm supporting the patient's knee to apply distal traction to the femur (**Figure 86-6A**). Externally rotate and extend the hip while distracting the femur to reduce the hip (**Figure 86-6B**).

This is considered the "classic" reduction technique. Its disadvantages are that it requires great strength on the part of the EP to reduce the hip. The force applied is often jerking and inconsistent. The aid of a strong assistant is required to stabilize the pelvis.

LATERAL REDUCTION TECHNIQUE

This technique was described in 1986 by Skoff.[8,12] It gives a mechanical advantage to the EP, as most of the force exerted is by the EPs own body weight (**Figure 86-7**). It also capitalizes on the principle of recreating the position of injury in order to exactly reverse the forces of the injury to produce the reduction.

Place the patient in the lateral decubitus position lying on the unaffected extremity. Perform procedural sedation. Flex the affected hip 100° and allow it to gravitate to adduction. This position recreates the typical position of the hip during the dislocation. Internally rotate the patients hip 45° while maintaining 45° of adduction to exaggerate the hip dislocation. Place a looped sheet around the patient's hips and an assistant's hips. Place a second looped sheet around the patient's knee and your own hips. The

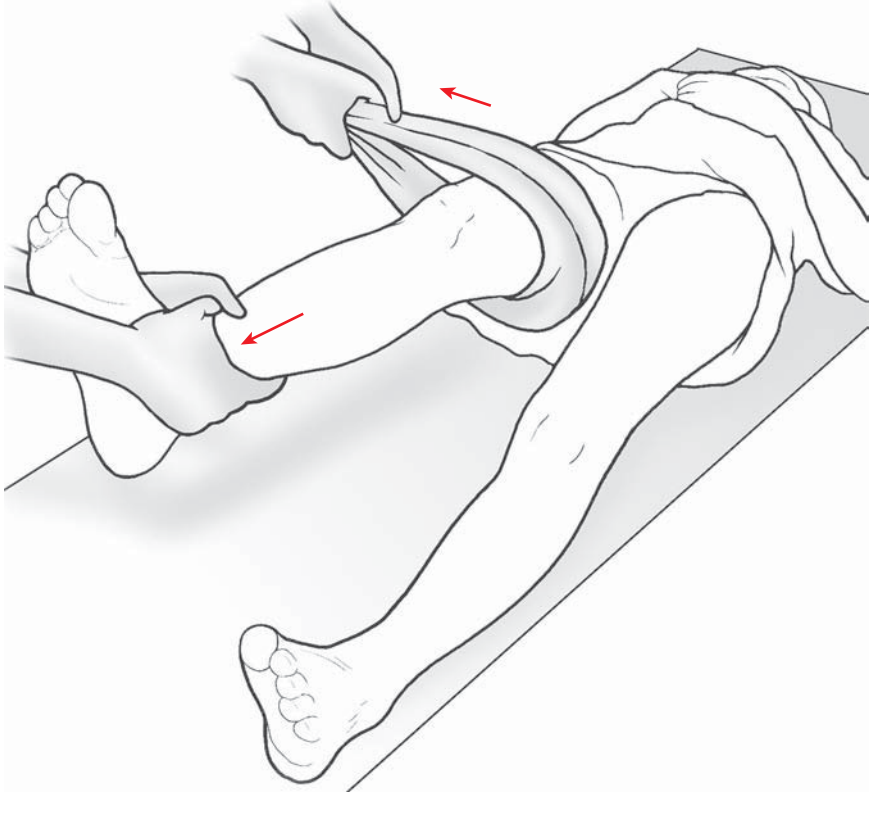


FIGURE 86-5. The simple longitudinal traction technique. An assistant applies lateral traction to the thigh while the EP simultaneously applies in-line traction to the leg.

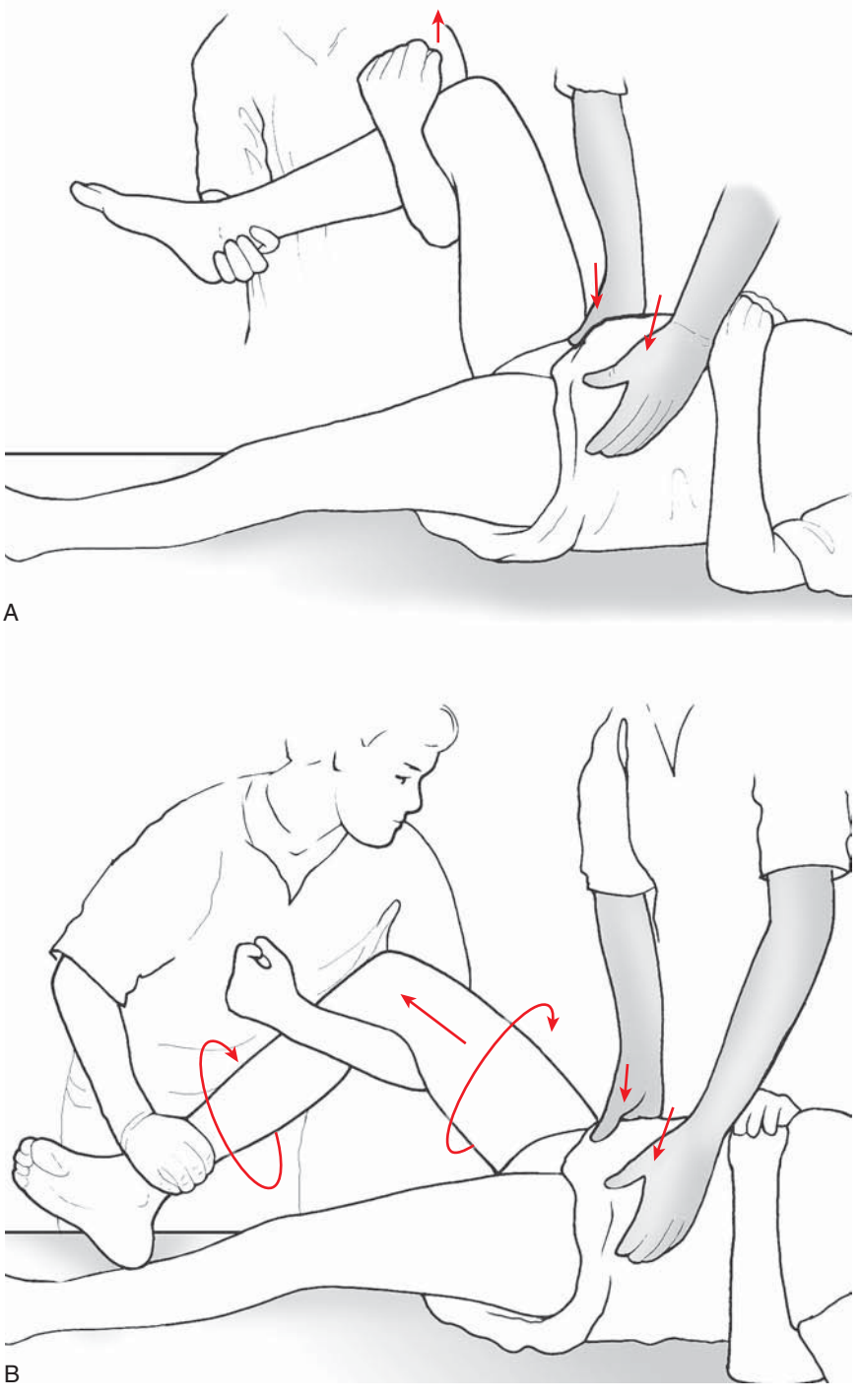


FIGURE 86-6. The Bigelow maneuver. **A.** The EP applies upward traction on the femur while an assistant stabilizes the pelvis. **B.** The hip is externally rotated and extended while the femur is distracted.

use of sheets allows optimal leverage by using body weight as the reduction force. Grasp the affected ankle to maintain the patient's knee flexed 90°. Apply distal traction to the femur by slowly leaning backward while the assistant simultaneously applies posteriorly directed countertraction to the femoral head. The assistant can use their hands to apply a distally directed force to the femoral head to assist in the reduction.

ASSESSMENT

The appropriate evaluation of any dislocation requires a thorough pre- and postreduction neurologic and vascular examination of the distal extremity. Any neurologic or vascular deficits require immediate evaluation by an Orthopedic Surgeon. Obtain a postreduction radiograph to confirm the reduction and rule out any fractures missed on the initial radiographs or as a result of the reduction procedure. Monitor the patient until they recover from the procedural sedation. A computed tomography scan may help identify any acetabular or osteochondral fractures.

AFTERCARE

All patients with a hip dislocation require an evaluation by an Orthopedic Surgeon. All native hip dislocations and most prosthetic hip dislocations require hospitalization and traction after reduction.[13]

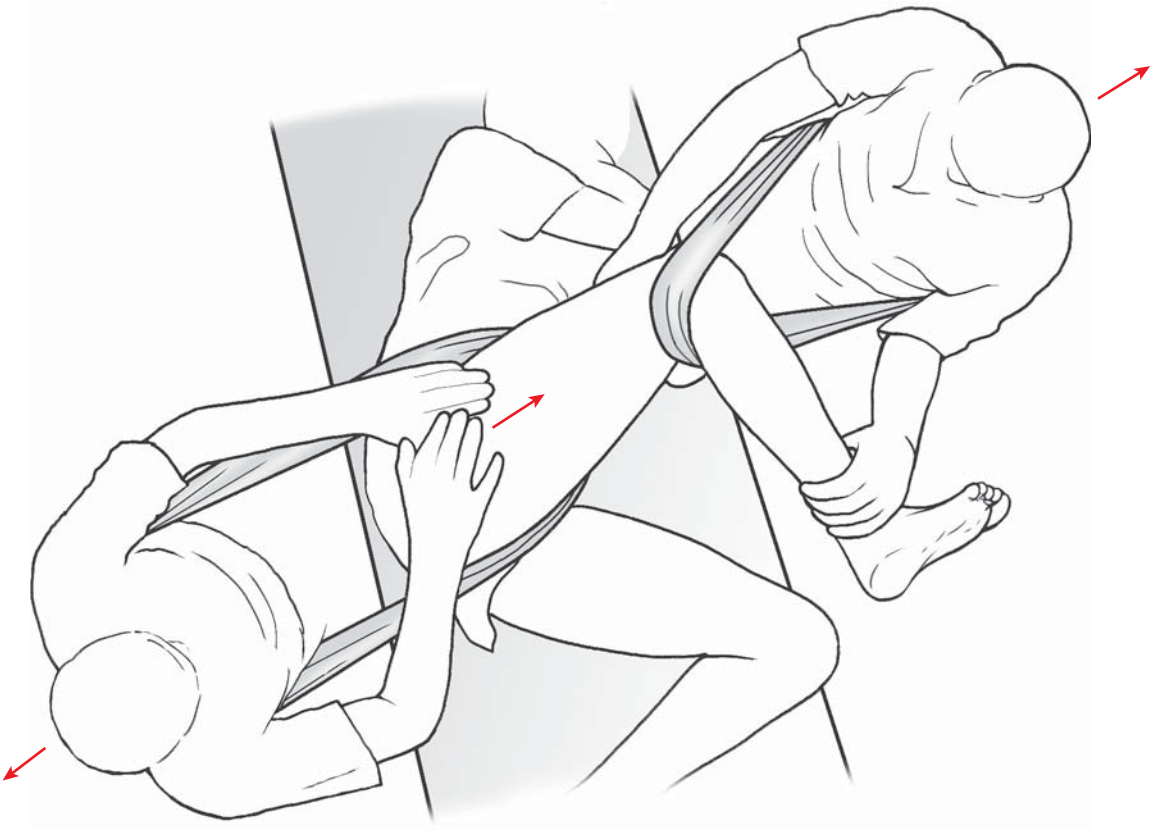


FIGURE 86-7. The lateral reduction technique. The hip is flexed 100°, adducted 45°, and rotated internally 45°. The EP applies traction to the femur. The assistant applies countertraction while simultaneously applying distally directed pressure on the femoral head with their hands.

COMPLICATIONS

The complications of a hip dislocation itself are fractures, avascular necrosis of the femoral head, injury to the sciatic and femoral nerve, and injury to the femoral artery. Posttraumatic arthritis, recurrent dislocation, and myositis ossificans can also occur.[13] Complications may occur despite the most expedient treatment, and prosthetic hip replacement may become necessary.

The complication of avascular necrosis is time-dependent. Reductions delayed over 6 hours are at an extreme risk for avascular necrosis. The risk of avascular necrosis increases as the time of the dislocation increases. Reductions that apply steady, non-jerking force to the limb have a lower incidence of associated fractures as well as fewer neurovascular complications. Multiple attempts at reduction are also associated with an increase risk of avascular necrosis. More than three attempts at closed reduction are associated with an increase risk of avascular necrosis and should prompt the EP to seek orthopedic consultation.[14]

Neurologic injury is one of the most common complications of hip dislocations, even when successful closed reduction is achieved. Sciatic neurapraxia, from peroneal branch damage, occurs in up to 15% of adult traumatic dislocations though symptoms resolve in 60% to 70% of cases.[15] Sciatic dysfunction may lead to an equinus deformity and will need immediate consultation with an Orthopedic Surgeon.[15]

SUMMARY

Multiple techniques exist to reduce hip dislocations. The EP should master one or two methods in order to provide essential care to these patients, limit complications, and enhance outcomes. The sooner a dislocated hip is reduced, the fewer the potential complications.

87 Patellar Dislocation Reduction

Mark P. Kling

INTRODUCTION

Dislocation of the patella generally results from a traumatic event.[1–9] It is most commonly due to a direct blow to the flexed knee. It may also occur from a forceful quadriceps contraction while the femur is internally rotated on the tibia. Many patients may not notice the dislocation as it may spontaneously reduce immediately after the injury. There are numerous theories as to the predisposition, if any, to a patella dislocation.[1,2] These include adolescents, females, flat intercondylar groove, joint laxity, "knock-knees" or genu valgus, large Q-angles, obesity, and vastus medialis muscle atrophy. This condition is most commonly seen in adolescents and females.

ANATOMY AND PATHOPHYSIOLOGY

The knee consists of the patellofemoral and the tibiofemoral joints. The patellofemoral joint is a gliding joint. The patella is an oval-shaped sesamoid bone that develops in the tendon of the quadriceps muscle. It is suspended between the quadriceps superiorly and

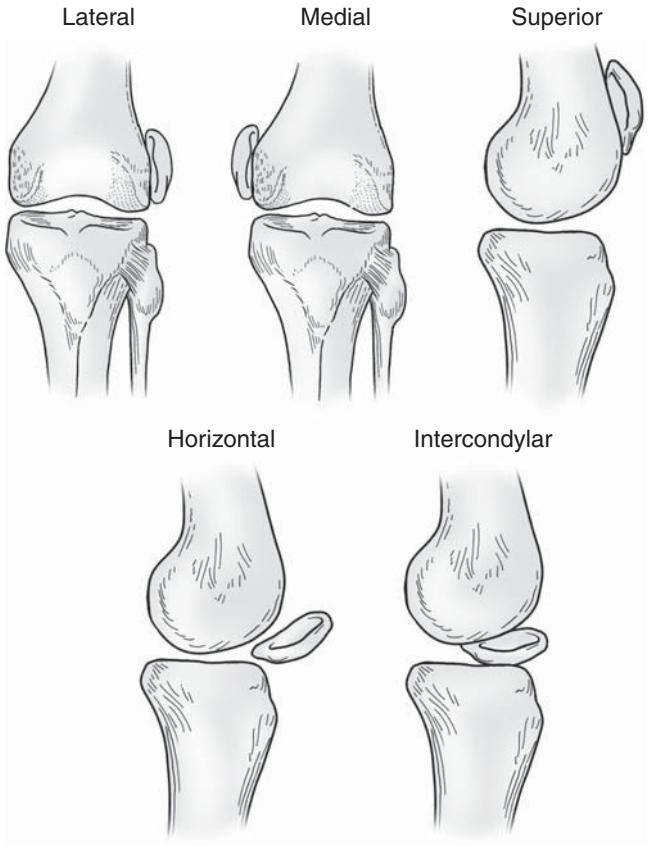


FIGURE 87-1. Types of patellar dislocations.

the tibial tuberosity inferiorly. The patella articulates between the femoral condyles. It is held in place by the vastus medialis muscle, the medial retinaculum, the medial and lateral patellofemoral ligaments, and the patellotibial ligament.

The patella may dislocate in numerous directions (**Figure 87-1**). Lateral dislocations are the most common type (**Figure 87-2**). The patella usually dislocates laterally due to its asymmetrical shape and the normal upward and lateral pull of the quadriceps muscle. The patella may also dislocate superiorly, medially, and intraarticularly in rare instances.[3,4]

The clinical determination of a lateral patellar dislocation is usually simple and quite obvious (**Figure 87-3**). The knee is held in partial flexion. The patella can be seen and palpated on the lateral surface of the knee. This may be accompanied by edema and/or ecchymoses over the anterolateral knee.

Pain over the parapatellar ligaments may be the only clinical sign in patients whose patellar dislocation has spontaneously reduced. The physical examination usually reveals mild edema in the parapatellar recesses. There is often laxity in the tendons and ligaments surrounding the patella. A patellar apprehension test is generally positive. The knee joint is usually stable.

The pathophysiology of this dislocation may include abnormalities secondary to malalignment, laxity, and hyper-elasticity of the joint. Osteochondral fractures are common but seen only on arthroscopy.[1,2,5] Magnetic resonance imaging, bone scans, and arthroscopy are considerations for further evaluation and diagnosis of the patellofemoral joint by the Orthopedic Surgeon.

Prereduction radiographs should be obtained to document patellar fractures or other bony abnormalities prior to the reduction. These may be difficult to obtain if the patient has significant discomfort and may be delayed until after the reduction. Radiographs may also be used to identify a foreign body if abrasions or lacerations are present over the knee. The patella often reduces spontaneously in the radiology suite as the leg is extended to obtain the radiographs.

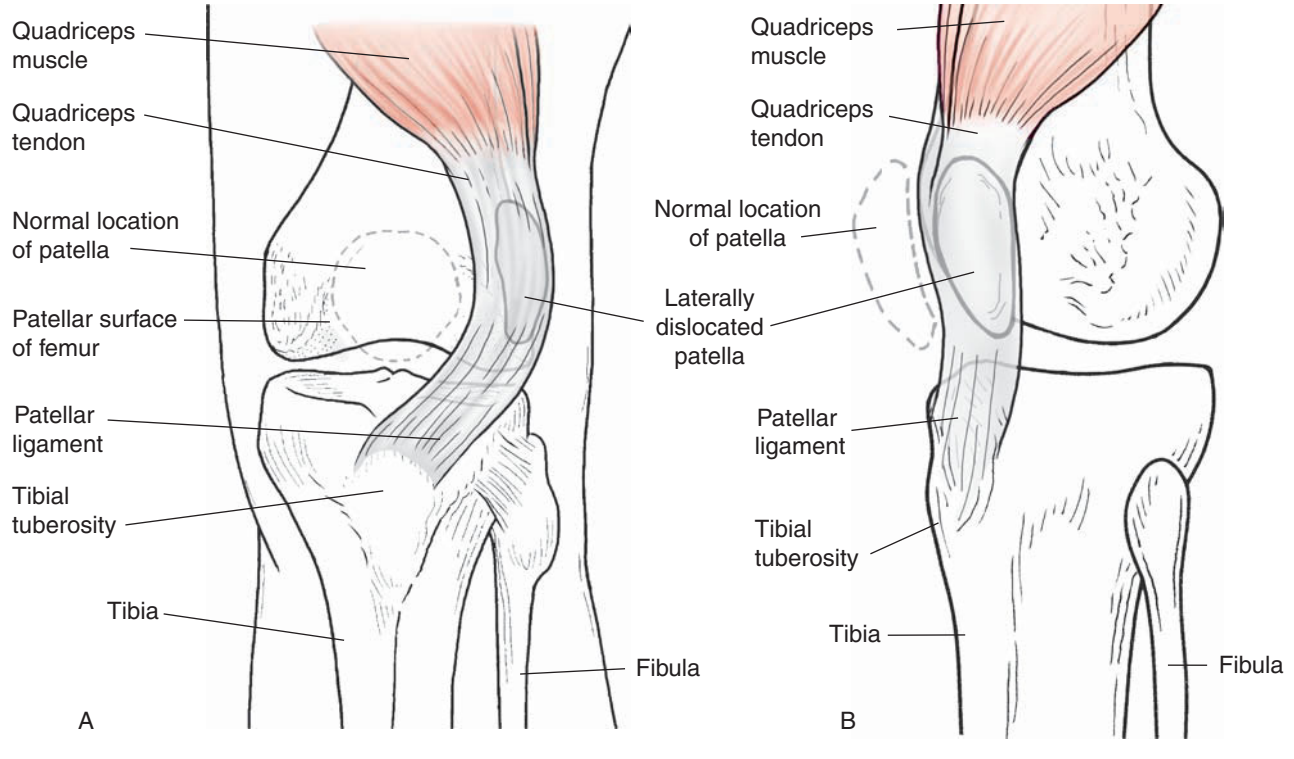


FIGURE 87-2. Anatomy of a lateral patellar dislocation. **A.** Anteroposterior view. **B.** Lateral view.



FIGURE 87-3. The lateral patellar dislocation. The presentation is often clinically dramatic. (Photograph courtesy of Dr. Robert R. Simon.)

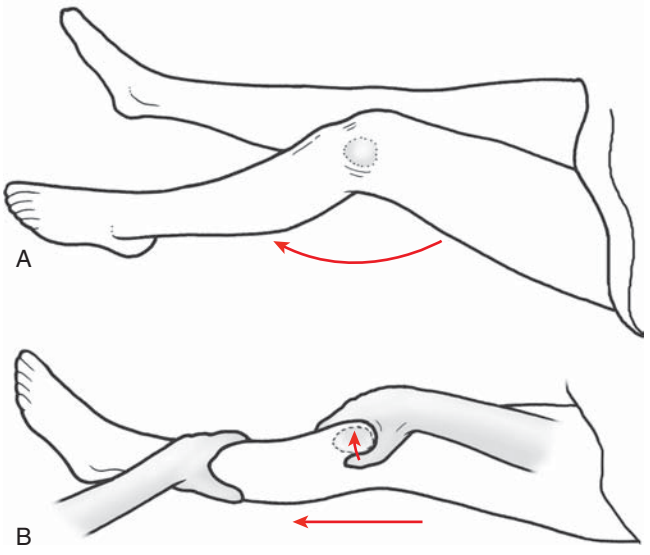


FIGURE 87-4. Reduction of a lateral patellar dislocation. **A.** Manipulation of the knee begins with gradual extension. **B.** Medially directed pressure applied to the patella when the knee is fully extended reduces the dislocation.

INDICATIONS

Any medial or lateral patellar dislocation that does not reduce spontaneously should be reduced manually.

CONTRAINDICATIONS

As with any traumatic injury, the evaluation and management of the patient's airway, breathing, circulation, and other significant injuries take priority over the reduction of a patellar dislocation. There are a few relative contraindications to the reduction of a patellar dislocation. An Orthopedic Surgeon should be consulted for the evaluation and reduction if the dislocation is superior, horizontal, intercondylar, or associated with fractures of the distal femur or proximal tibia. **The only exception to this is if there is neurologic and/or vascular compromise of the distal extremity.** This requires immediate reduction by the Emergency Physician if, after phone consultation, the Orthopedic Surgeon is not immediately available to perform the reduction.

EQUIPMENT

No special equipment is required for the reduction of the dislocation. A knee immobilizer or splinting material (plaster, fiberglass, and prepackaged splints) should be available to temporarily splint the patella and knee after the reduction.

PATIENT PREPARATION

Patient preparation is minimal in the case of a lateral or medial patellar dislocation. Explain the risks, benefits, complications, and aftercare to the patient and/of their representative. Obtain an informed consent prior to performing the procedure. Verbal consent is usually sufficient, since the reduction of a patellar dislocation is relatively simple, with infrequent complications. Place the patient supine on a gurney. No premedication or sedation is required for this procedure.

TECHNIQUES

The technique for the reduction of a lateral patellar dislocation is rather simple (**Figure 87-4**). Slightly flex the patient's hip to release the tension on the quadriceps muscles. Slowly and gently extend the knee (**Figure 87-4A**). The patella may relocate spontaneously by simply extending the knee. If it is still dislocated, apply gentle and medially directed pressure to the lateral surface of the patella (**Figure 87-4B**). This will allow the patella to move into its normal anatomic position in the intercondylar fossa of the femur. The technique to reduce a medially dislocated patella is similar with the exception of the application of a laterally directed force on the patella.

Intraarticular and horizontal patellar dislocations are sometimes reduced by closed manipulation, although most require open reduction. Superior patellar dislocations require operative reduction. These dislocations should not be reduced in the Emergency Department. Patients with these types of patellar dislocations require urgent consultation with an Orthopedic Surgeon and hospital admission for reduction.

AFTERCARE

Obtain a postreduction radiograph to rule out any osteochondral fractures that were not diagnosed initially and to ensure positioning of the patella. Maintain the knee in extension by immobilization with a long leg splint or knee immobilizer until follow-up for reevaluation. The Orthopedic Surgeon may elect to take a conservative approach with the leg in a long leg cast and the knee in full extension for 6 weeks.[6] Some Orthopedic Surgeons believe that all first-time dislocations should be repaired surgically. Thus, phone consultation with an Orthopedic Surgeon is recommended before the patient is discharged home.

The general principles of orthopedic care can be applied. These include rest, ice, elevation, and nonsteroidal anti-inflammatory drugs. Narcotic analgesics are not necessary or required in most cases. The patient should follow up with an Orthopedic Surgeon in 5 to 7 days. The patient will most likely need physical therapy. The instability and resultant tracking abnormalities will require strength, proprioceptive, and isometric rehabilitation.[7] Patients who are placed in splints or casts should use crutches and not bear weight on the affected extremity. Crutches may be of use to those placed in a knee immobilizer.

COMPLICATIONS

Patellar dislocations are subject to degenerative arthritis, osteochondral fractures (which may be difficult to diagnosis initially), and recurrent dislocations or subluxations. No complications are associated with the reduction procedure.

SUMMARY

Patellar dislocations are common. The reduction of a lateral or medial patellar dislocation is a safe, simple, and gratifying procedure. Education of the patient and follow-up with an Orthopedic Surgeon is a requirement for successful rehabilitation.

88 Knee Joint Dislocation Reduction

Sharad Pandit and Zach Kassutto

INTRODUCTION

Dislocations of the knee are rare. They are true orthopedic emergencies and have a significant association with soft tissue injuries and neurovascular compromise. A dislocated knee occurs most commonly after a major force is applied to the knee joint from motor vehicle trauma, pedestrian–vehicle collisions, bicycle collisions, or motorcycle collisions. The forces necessary to cause a dislocation of the knee joint often fracture the bones of the leg.

Complete dislocation of the knee joint results in a gross deformity that is confirmed by plain radiographs. Reduction by the Emergency Physician (EP) may be reasonable if the Orthopedic Surgeon is not immediately available and/or if the injured extremity shows signs of distal neurologic or vascular compromise.

A careful examination of the distal extremity must be performed and documented. **It must include an assessment of the capillary refill, the dorsalis pedis pulse, the posterior tibial pulse, peroneal nerve function, and tibial nerve function.**

ANATOMY AND PATHOPHYSIOLOGY

A knee dislocation is the displacement of the tibiofemoral articulation (**Figure 88-1**). It involves the rupture of the anterior cruciate ligament, the posterior cruciate ligament, the joint capsule, and/or the collateral ligaments of the knee. Anterior knee dislocations are the most common type of knee dislocation. This injury is defined as anterior displacement of the tibia relative to the femur (**Figure 88-1A**). It results from an acute hyperextension injury to the knee joint that ruptures the anterior cruciate ligament completely, the posterior cruciate ligament partially, and the posterior joint capsule. The distal femur is driven posterior to the proximal tibia. The collateral ligaments usually remain intact. Tibial spine fractures, osteochondral fractures of the tibia or femur, and meniscal injuries are avulsion-type fractures resulting from the rupture of the anterior cruciate ligament. Distal femoral epiphyseal separation, rather than complete dislocation, as a result of a hyperextension injury is more common in children.

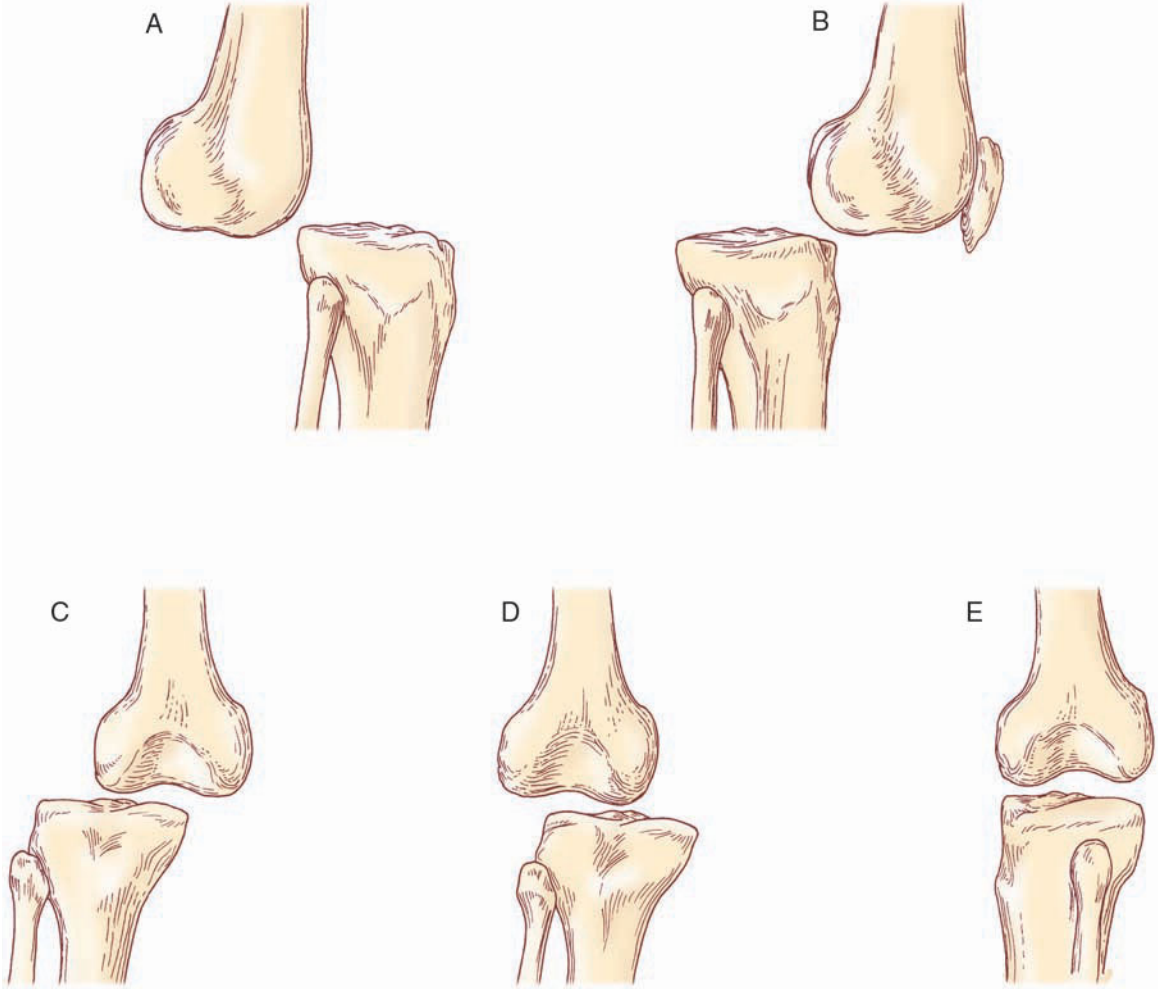


FIGURE 88-1. The classification of knee dislocations. **A.** Anterior. **B.** Posterior. **C.** Lateral. **D.** Medial. **E.** Rotary.

An anterior knee dislocation is associated with a popliteal artery injury in 30% to 40% of patients.[1] The popliteal artery is at particular risk for injury because it is anchored proximally at the adductor hiatus and distally at the soleus arch. The collateral circulation around the knee joint is relatively poor. Therefore disruption of the popliteal artery may result in distal ischemia and limb loss if the reduction is delayed. **It is important to note that the presence of distal peripheral pulses and capillary refill does not preclude an arterial injury.**

The peroneal nerve is tethered as it winds around the fibular neck. With knee dislocations, the peroneal nerve is at risk. Peroneal nerve injury may occur in up to 23% of patients with knee dislocations. Nearly one-half of the patients with peroneal nerve injuries have a permanent deficit.[10]

A posterior knee dislocation is defined as the posterior displacement of the tibia relative to the femur (**Figure 88-1B**). It occurs less commonly than an anterior knee dislocation. It results from a direct force applied to the anterior tibia with the knee slightly flexed, which ruptures the posterior joint capsule and both cruciate ligaments. The collateral ligaments usually remain intact. It is associated with popliteal artery damage and disruption of the extensor mechanism of the knee joint.

A posterolateral knee dislocation is a rare type of knee dislocation that is associated with peroneal nerve injury in up to 35% of patients.[2–4] These patients must be examined for peroneal nerve dysfunction (i.e., anesthesia or paresthesia on the lateral aspect of the leg and impaired dorsiflexion of the foot).

Medial, lateral, and rotary dislocations of the knee joint are less common than anterior or posterior knee dislocations (**Figures 88-1C, D, & E**). Medial knee dislocations result from an adduction force on the tibia that ruptures the lateral collateral ligament, the posterior joint capsule, and both cruciates. Damage to the peroneal nerve is common, while injury to the popliteal artery is not. Lateral knee dislocations result from an abduction force on the tibia that ruptures the medial collateral ligament, the posteromedial joint capsule, and both cruciates. Neurovascular injuries are uncommon with a lateral knee dislocation.

Rotary dislocations are subdivided into posterolateral and posteromedial types. Posterolateral rotary dislocations result from an anteromedial force on the tibia that ruptures the posterior and medial joint capsule, partially avulses the gastrocnemius, damages the menisci, and has an associated chondral fracture. Posteromedial rotary dislocations result from an anterolateral force on the tibia that ruptures both cruciates, the medial collateral ligament, the posteromedial joint capsule, partially avulses the gastrocnemius, damages the menisci, and has an associated chondral fracture. Both of these rotary dislocations are associated with peroneal nerve and popliteal artery injuries.

Medial, lateral, and rotary dislocations of the knee are uncommon injuries that should be managed by an Orthopedic Surgeon. The reduction technique for these dislocations is quite similar to that for the reduction of anterior or posterior knee dislocations.

Although the presentation of a knee dislocation is usually clinically obvious, it can also occur with a spontaneous reduction. **This type of injury is classified as an occult dislocation and can be easily missed if the patient is not thoroughly examined.**

Anteroposterior and lateral radiographs of the knee will confirm the diagnosis of a knee dislocation. Postreduction films in two planes will detect any occult fractures of the tibial spine, the distal femoral physis, or the proximal tibial physis. Obtain postreduction stress views if damage to the collateral ligaments is suspected. Radiographs of the pelvis and hip should also be considered to rule out any associated injuries.

INDICATIONS

Any dislocation of the knee joint requires prompt reduction in order to reestablish the normal anatomy of the knee joint. The reduction should ideally be accomplished within 6 to 8 hours after the injury. The incidence of limb loss is greater than 85% if the knee is dislocated longer than 6 to 8 hours.[5] **Knee dislocations associated with distal neurologic or vascular insufficiency require immediate and emergent reduction.**

CONTRAINDICATIONS

There are no absolute contraindications to the reduction of a dislocated knee joint. Reduction of the knee joint may be performed intraoperatively if the patient requires surgery for other reasons. An Orthopedic Surgeon should reduce the knee if it is dislocated medially, laterally, or rotatorily; if it is associated with fractures of the extremity; or if the joint is open. **Emergent reduction by the EP is indicated if the Orthopedic Surgeon is not immediately available and/or if there is evidence of distal neurologic or vascular compromise.**

EQUIPMENT

- Procedural sedation equipment and supplies (Chapter 129)
- Assistants
- Compressive cotton wrap (Webril)
- Splinting material
- Elastic bandage

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The necessary postprocedural care should also be discussed. Obtain an informed consent for the reduction procedure as well as for the procedural sedation. Place the patient supine on a gurney. Apply procedural sedation. **The key to performing this procedure is to have the patient adequately sedated and their muscles relaxed.**

TECHNIQUES

ANTERIOR KNEE DISLOCATION REDUCTION

Reduction of an anterior knee dislocation is usually performed without difficulty using a modified traction-countertraction technique (**Figure 88-2**). Instruct an assistant to grasp the tibia and apply in-line traction while a second assistant grasps the thigh and applies countertraction. **It is extremely important to avoid putting pressure over the popliteal fossa as this could injure the structures traversing that space.** The EP then pushes the proximal tibia posteriorly (**Figure 88-2(1)**) while the distal femur is simultaneously lifted anteriorly into anatomic position (**Figure 88-2(2)**). **Do not allow the knee to become hyperextended during the reduction as this may further injure neurovascular structures.**

Some EPs feel that the reduction procedure may be easier to perform if the patient is in the prone position. Performing the procedure in the prone position is quite cumbersome, it is a difficult position to attain if other injuries are present, and it makes monitoring patients undergoing procedural sedation difficult. Therefore placing the patient in the prone position is not recommended.



FIGURE 88-2. Reduction of an anterior knee dislocation. An assistant applies inline traction to the tibia while a second assistant applies countertraction to the femur. The proximal tibia is pushed posteriorly (1) while the distal femur is pulled anteriorly (2) to reduce the dislocation.

POSTERIOR KNEE DISLOCATION REDUCTION

Reduction of a posterior knee dislocation is similar to that of an anterior knee dislocation. The two assistants provide in-line traction and countertraction while the EP grasps the proximal tibia and pulls it anteriorly into anatomic position (**Figure 88-3**).

MEDIAL KNEE DISLOCATION REDUCTION

Reduction of a medial knee dislocation is similar to that of the anterior knee dislocation. The two assistants provide in-line traction and countertraction while the EP grasps the proximal tibia and pulls it laterally into anatomic position.

LATERAL KNEE DISLOCATION REDUCTION

Reduction of a lateral knee dislocation is similar to that of the anterior knee dislocation. The two assistants provide in-line traction and countertraction while the EP grasps the proximal tibia and pulls it medially into anatomic position.

ROTARY KNEE DISLOCATION REDUCTION

Reduction of a posteromedial knee dislocation is similar to that of the anterior knee dislocation. The two assistants provide in-line traction and countertraction while the EP grasps the proximal tibia and simultaneously externally rotates and lifts it upward into anatomic position.

Reduction of a posterolateral knee dislocation should be performed in the Operating Room. These dislocations are irreducible using closed reduction techniques. The medial femoral condyle evaginates through the medial joint capsule in a process known as "buttonholing." This dislocation requires open reduction under general anesthesia.

ASSESSMENT

Immediately evaluate and document the neurologic and vascular status of the distal extremity after any attempts at reduction. Any diminished or absent sensation, motor deficits, and/or pulses require immediate angiography and operative intervention. Obtain postreduction radiographs to confirm proper anatomic reduction, to rule out any fractures not evident on the prereduction radiographs, and to rule out the displacement of any fracture fragments. Stress radiographs are recommended if injury to the collateral ligaments is suspected.

AFTERCARE

The postprocedural care of the knee joint is as important as the initial reduction. Immobilize the extremity in a posterior long leg splint with the knee in 15° of flexion. Administer intravenous and/or oral analgesics as necessary to control the patient's pain. All patients require admission to the hospital for observation and monitoring of the distal neurovascular status of the extremity. Arteriography should be obtained to exclude injury to the popliteal artery, especially if there is any irregularity in the dorsalis pedis or posterior tibial pulse before or after the reduction. Arteriography may not be necessary if the distal pulses are normal before and after the reduction; however, the vascular status should be closely monitored for 48 to 72 hours after the reduction.[6]

The mandatory use of arteriography to evaluate vascular injuries in patients with a normal postreduction physical examination may not be necessary.[13,14] These select patients who have a normal physical examination and a normal ankle brachial index may not require angiography and its associated complications. This is a decision that must be made in consultation with the Orthopedic Surgeon who will be managing the patient.

An inpatient magnetic resonance imaging (MRI) scan of the knee joint should be obtained to evaluate ligamentous injury. The patient may require reconstructive surgery on the knee joint. This is especially true if they are young, physically active, and well motivated to cooperate with rehabilitation therapy.[7]

COMPLICATIONS

Knee dislocations are true orthopedic emergencies because of the potential for associated vascular and neurological injuries. Complications are primarily related to injuries of the neurovascular



FIGURE 88-3. Reduction of a posterior knee dislocation. An assistant applies inline traction to the tibia while a second assistant applies countertraction to the femur. The proximal tibia is pulled anteriorly to reduce the dislocation.

structures crossing the popliteal fossa. These include popliteal arterial injury and peroneal nerve injury, as well as knee instability, knee arthrosis, knee stiffness, and chronic pain.[11,12]

Anterior knee dislocations have a high incidence (up to 40%) of associated vascular injuries usually involving the popliteal artery, and of these, up to one-half can result in amputation of the leg.[8] Nerve damage has been reported in the literature to occur in 20% to 40% of knee dislocations.[9] **These injuries and any associated fractures should not be missed. Pressure to the popliteal fossa during the reduction and hyperextension of the knee postreduction must be avoided to prevent iatrogenic neurovascular damage.** Injuries to neurologic and vascular structures can occur during the reduction. These include lacerations, traction injuries, and nerve or vascular entrapment between the tibial plateau and the femoral condyles.

Irreducible dislocations may be secondary to interposed soft tissue, ligamentous instability, buttonhole tears in the medial joint capsule, or entrapment of the medial femoral condyle. These patients require operative reduction under general anesthesia by an Orthopedic Surgeon.

SUMMARY

Knee dislocations occur after significant trauma to the knee joint. Fortunately, knee dislocations are rare events. They are associated with significant morbidity and require prompt reduction to restore the normal alignment of the bony structures. Arteriography to rule out damage to the popliteal artery and an MRI scan to rule out soft tissue injuries should be performed after the knee joint has been reduced and adequately splinted. All patients require admission for observation and eventual reconstructive surgery. Frequent neurovascular evaluation is extremely important during the hospitalization. Evidence of distal leg ischemia requires immediate surgical exploration.

89 Ankle Joint Dislocation Reduction

Jim Comes

INTRODUCTION

The foot and the ankle are the most frequently injured parts of the body. Fractures of the ankle associated with dislocations of the ankle joint (fracture-dislocations) are serious injuries that can lead to long-term morbidity. They occur most commonly in young people who participate in sports, in those suffering from falls, or in those involved in motor vehicle collisions. The ankle mortise and surrounding ligaments make the ankle joint strong and stable. As a result, isolated ankle dislocations are uncommon. Ankle dislocations are usually associated with malleolar fractures or a fracture of the tip of the tibia. They are open 25% of the time. While there are limited data on the mechanism of injury, most ankle dislocations lead to posterior or posteromedial displacement and occur from a force against a plantarflexed foot. Fracture-dislocations are often treated definitively in the Operating Room. Despite this, patients benefit from early analgesia and prompt reduction.

Ankle dislocations can be successfully reduced in the Emergency Department with the use of procedural sedation and longitudinal traction-countertraction.[1] Postreduction management invariably involves leg immobilization and consultation with an Orthopedic Surgeon. Some closed ankle dislocations may be managed nonoperatively with good long-term results from a closed reduction and casting for 6 to 9 weeks.[2–5]

ANATOMY AND PATHOPHYSIOLOGY

The ankle joint is composed of the talus, tibia, and fibula. The inferior articular surface of the tibia is concave in both the coronal and sagittal planes. The articular surface of the talus is broader anteriorly and longer on its medial and lateral aspects.[6] The ankle mortise limits rotation of the talus, making the ankle joint inherently stable.

There are three groups of ligaments that provide added stability to the ankle joint. It is stabilized laterally by the anterior talofibular, the calcaneofibular, and the posterior talofibular ligaments (**Figure 89-1**). It is stabilized medially by the deltoid ligament, which comprises a group of four adjoining ligaments: the anterior and posterior tibiotalar, the tibionavicular, and the tibiocalcaneal ligaments (**Figure 89-2**). The third group of ligaments stabilizes the tibia to the fibula and forms the tibiofibular syndesmosis. This includes the anterior and posterior tibiofibular ligaments.

Almost all ankle dislocations are associated with ligamentous ruptures, either partial or complete (**Figure 89-3**). They are often associated with malleolar and distal fibula fractures. While posterior or posteromedial ankle dislocations are the most commonly described dislocations of the ankle joint[4,7] (**Figures 89-3A & 89-4**). The most common ankle dislocations seen by the editor are lateral ankle fracture-dislocations (**Figure 89-3B**). Posterior ankle dislocations are associated with posterior marginal fractures of the tibia. An anterior ankle dislocation is rare and usually associated with a fracture of the anterior margin of the tibia (**Figure 89-3C**). The talus may also dislocate laterally or medially if the tibiofibular ligaments are disrupted or a fracture of one or both malleoli occurs. The medial and lateral ligamentous complexes are usually stronger than the malleoli. This results in one or both malleoli fracturing, rather than the ligaments tearing, with a lateral fracture-dislocation.[8]

Due to the low incidence of reported ankle dislocations without fractures, data on the mechanism of injury are incomplete.[9] A posteromedial ankle dislocation occurs when a force is applied against the posterior distal tibia with the foot plantarflexed. Anterior ankle dislocations occur from a forcible dorsiflexion of the foot (e.g., fall on the heel with the foot dorsiflexed) or from a force applied to the distal anterior tibia while the foot is fixed. Injury to the tibiofibular joint is variable, and the fibula may be dislocated posteriorly or anteriorly. Diastasis of the tibiofibular syndesmosis is uncommon. Lateral ankle dislocations are always associated with fractures of the malleoli. They occur from a force on the distal fibula with the foot fixed to the ground. Superior ankle dislocations are uncommon (**Figure 89-3D**). They occur when a force from above is driven through the leg and to the ankle (e.g., a fall from a height).

Physical examination often reveals the type of ankle dislocation. Prominence of the talus and a change in the length of the foot are common. Neurovascular injury is uncommon, although there is a higher incidence of this with open dislocations. Ankle dislocations are associated with a risk of vascular injury and the development of a compartment syndrome from severe swelling.[7] Most vascular injuries are to the dorsalis pedis or posterior tibial vessels and may be accompanied by damage to the adjacent superficial peroneal nerve or sural nerve, respectively.[1,6] Tibiotalar dislocations rarely result in avascular necrosis.

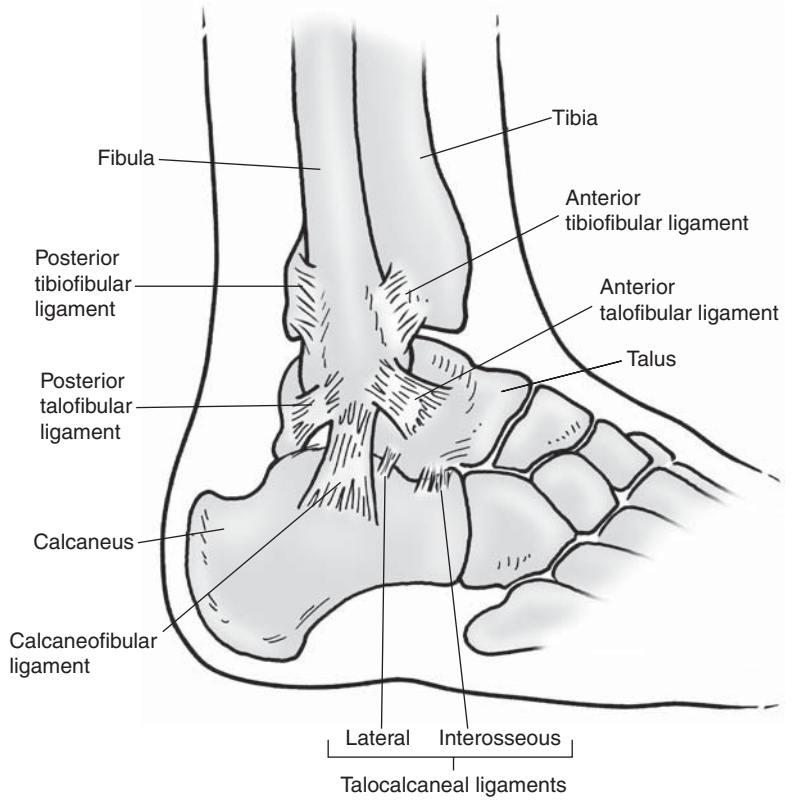


FIGURE 89-1. The bony and ligamentous structures of the lateral ankle.

INDICATIONS

All closed ankle fracture-dislocations and isolated dislocations should be reduced urgently not only to protect the soft tissues and decrease swelling, but also to minimize articular injury. Some authors recommend reduction prior to radiography.[10] **Any dislocation, open or closed, that has evidence of distal neurologic or vascular compromise must be reduced emergently.** Extreme lateral deviation may compromise the dorsalis pedis artery and requires prompt reduction.[10] All open dislocations require intravenous antibiotics, irrigation, surgical debridement, and reduction by an Orthopedic Surgeon in the Operating Room. However, reduction

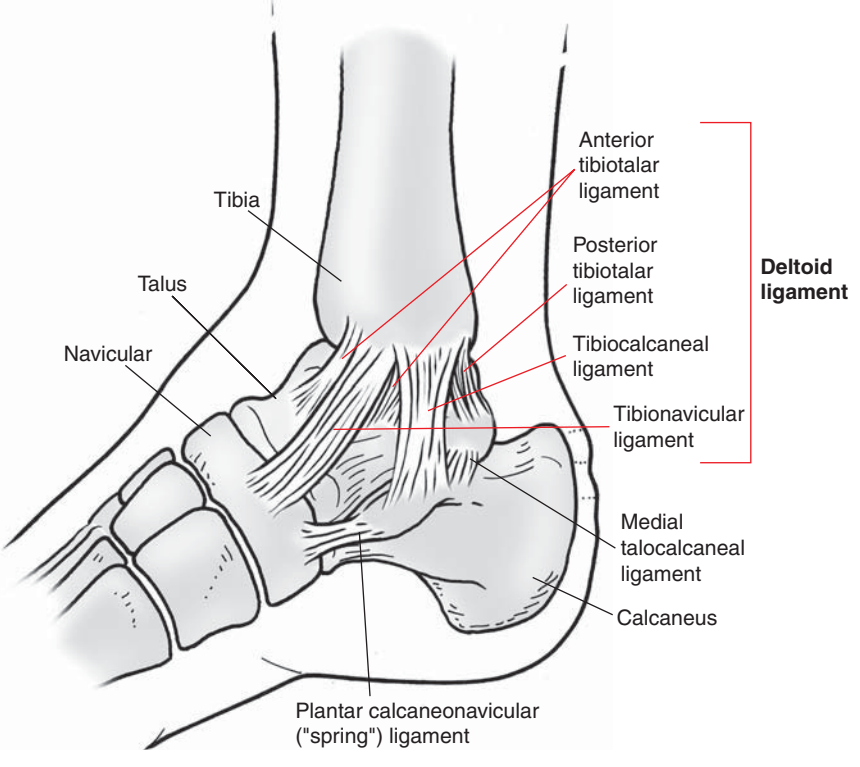


FIGURE 89-2. The bony and ligamentous structures of the medial ankle.

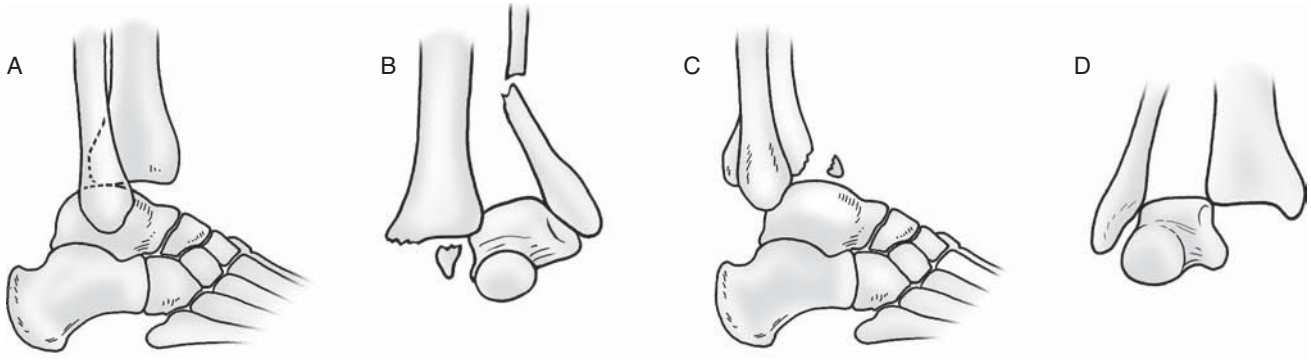


FIGURE 89-3. Types of ankle dislocations. **A.** Posterior. **B.** Lateral. **C.** Anterior. **D.** Superior.

should occur in the Emergency Department if the Orthopedic Surgeon or the Operating Room is not immediately available.[3]

CONTRAINDICATIONS

There are no absolute contraindications to reducing a dislocated ankle. Some authors would not recommend Emergency Department reduction of an open fracture-dislocation without evidence of neurovascular compromise or in a setting where immediate orthopedic and operative intervention was available.



FIGURE 89-4. Radiograph of a posterior ankle dislocation.

EQUIPMENT

- Local anesthetic solution
- 18 gauge needle
- 22 gauge needle, 2 in. long
- Equipment and supplies for procedural sedation (Chapter 129)
- Equipment and supplies for IV regional anesthesia (Chapter 127)
- Stockinette
- Compressive wrap (Webril)
- Plaster, fiberglass, or commercially prepared splinting material
- Elastic bandage

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the reduction procedure and the procedural sedation to the patient and/or their representative. Obtain an informed consent for both procedures. Place the patient supine with the affected foot at the edge of the gurney. Patients should be premedicated with an opioid analgesic prior to the procedure and ideally prior to radiography. Procedural sedation (Chapter 129) provides excellent analgesia, muscle relaxation, and sedation, allowing the reduction procedure to be more tolerable for both the patient and the physician. Intra-articular lidocaine has been reported as an effective alternative to conscious sedation for closed reduction of ankle fracture dislocations.[11] Please refer to Chapter 77 regarding the details of ankle arthrocentesis. An additional alternative is IV regional anesthesia (Bier block) of the lower leg (Chapter 127).

TECHNIQUES

The techniques described below to reduce ankle dislocations have three things in common. The hip and knee are flexed to relieve the tension on the gastrocnemius and soleus muscles. The foot is flexed (plantarflexed or dorsiflexed) to unlock or disengage the talus. Finally, the talus is maneuvered into its proper anatomic position.

LATERAL ANKLE DISLOCATIONS

Flex the patient's hip and knee by placing a pillow behind their knee. Grasp the calcaneus with one hand and the forefoot with the other hand (**Figure 89-5A**). Instruct an assistant to grasp the patient's calf. Apply distal traction to the heel while the assistant provides countertraction to the leg (**Figure 89-5A**). The next step is to rotate the

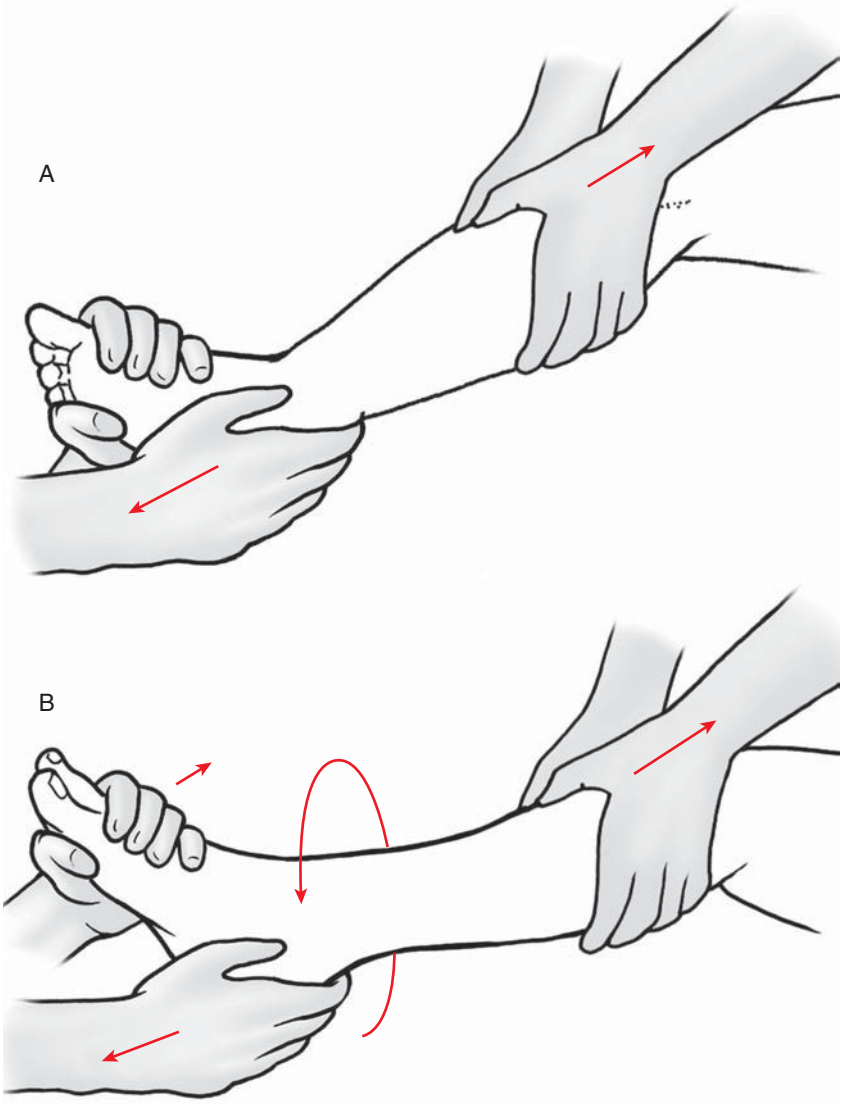


FIGURE 89-5. Closed reduction of a lateral ankle dislocation. **A.** The heel is distracted while an assistant provides countertraction. **B.** Simultaneously, medially rotate and dorsiflex the foot while distracting the heel.

foot medially so that the great toe is in alignment with the anterior tibia while simultaneously dorsiflexing the foot and distracting the heel (**Figure 89-5B**). The talus will reduce easily with a palpable and audible "clunk."

POSTERIOR ANKLE DISLOCATIONS

Flex the patient's hip and knee by placing a pillow behind their knee. Grasp the calcaneus with one hand and the forefoot with the other hand (**Figure 89-6A**). Instruct an assistant to grasp the patient's calf. Simultaneously apply distal traction to the heel and plantarflex the foot while the assistant provides countertraction to the leg (**Figure 89-6A**). The next step is to dorsiflex the foot while distracting the heel and a second assistant provides posteriorly directed pressure on the distal leg (**Figure 89-6B**). The talus will reduce with a palpable and audible "clunk."

ANTERIOR ANKLE DISLOCATIONS

Flex the patient's hip and knee by placing a pillow behind their knee. Grasp the calcaneus with one hand and the forefoot with the other hand (**Figure 89-7A**). Instruct an assistant to grasp the patient's calf. Simultaneously apply distal traction to the heel and dorsiflex the foot until the toes point upright while the assistant provides countertraction to the leg (**Figure 89-7A**). The next step is to push the foot posteriorly while distracting the heel and a second assistant provides anteriorly directed pressure on the distal leg (**Figure 89-7B**). The talus will reduce with a palpable and audible "clunk."

SUPERIOR ANKLE DISLOCATIONS

Superior ankle dislocations are associated with significant soft tissue and articular damage. Neurovascular injury is uncommon with these dislocations. Superior ankle dislocations should be reduced, splinted, and managed by an Orthopedic Surgeon. The only exception to this is if there is neurologic and/or vascular compromise of the distal extremity and no Orthopedic Surgeon is immediately available.

OPEN ANKLE DISLOCATIONS

The Emergency Physician occasionally reduces open ankle dislocations if neurologic and/or vascular compromise of the foot is present and an Orthopedic Surgeon is not immediately available. Copiously irrigate the wound with sterile saline before attempting the reduction. The technique to reduce an open ankle dislocation is the same as that for a closed ankle dislocation.

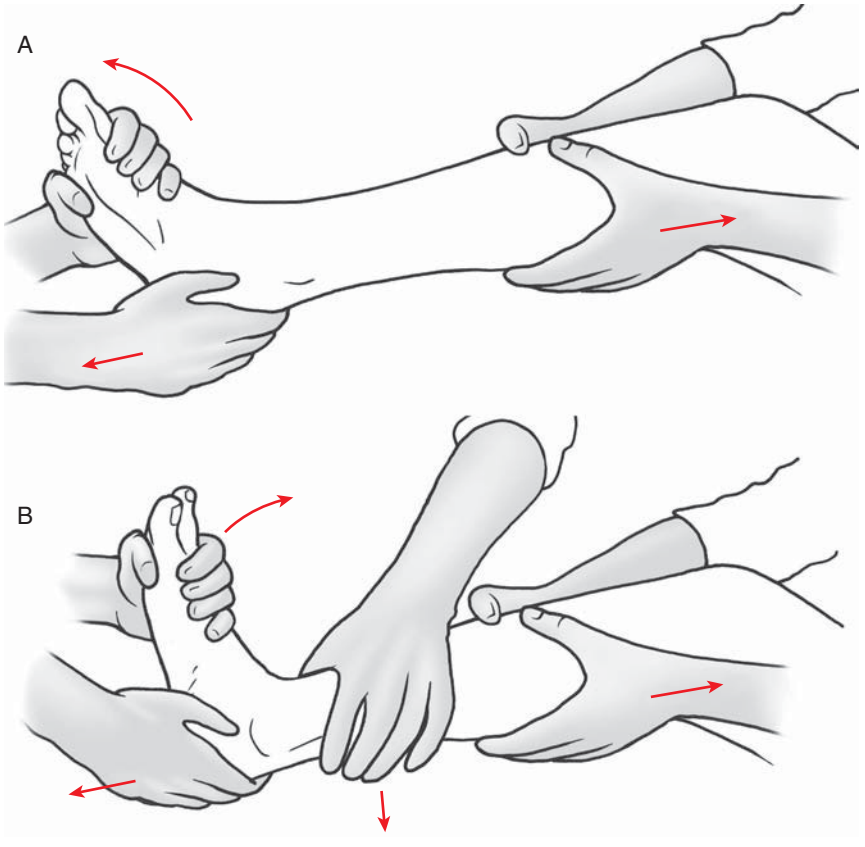


FIGURE 89-6. Closed reduction of a posterior ankle dislocation. **A.** The heel is distracted and the foot is plantarflexed while an assistant provides countertraction. **B.** The foot is dorsiflexed while the heel is distracted and a second assistant applies posterior traction on the distal leg.

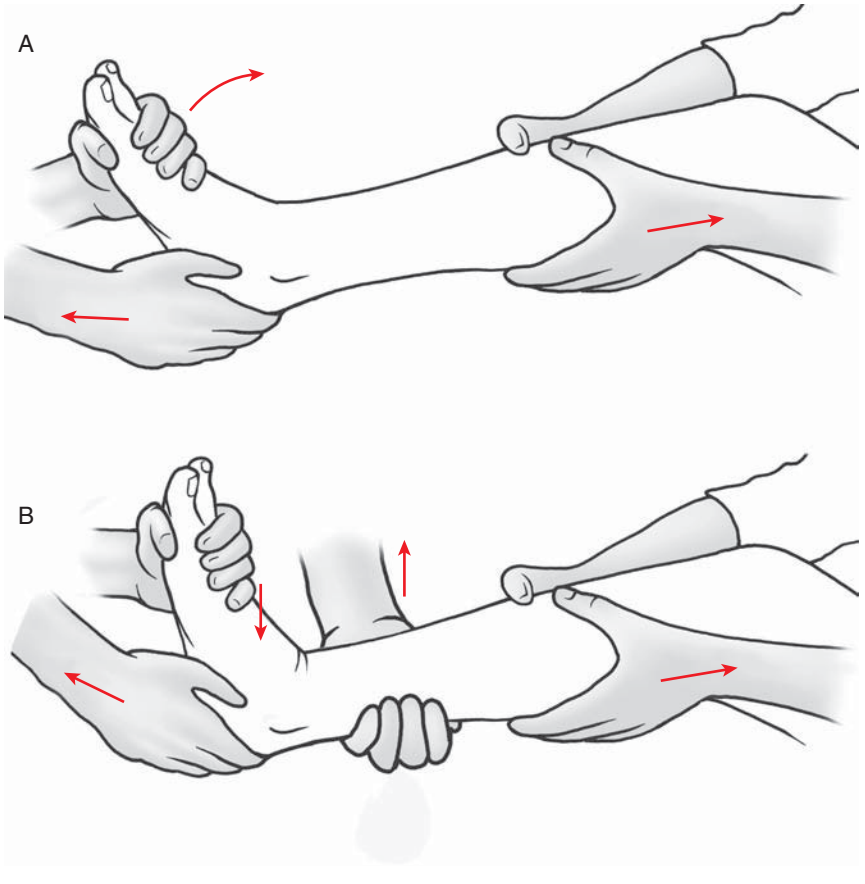


FIGURE 89-7. Closed reduction of an anterior ankle dislocation. **A.** The heel is distracted and the foot is dorsiflexed until the toes are upright, while an assistant provides countertraction. **B.** The foot is pushed posteriorly while the heel is distracted and a second assistant applies anterior traction on the distal leg.

ASSESSMENT

Verify and document the neurologic and vascular status of the foot before and after any attempts at reduction. Any diminution or the absence of normal neurologic or vascular signs requires emergent consultation with an Orthopedic Surgeon.

AFTERCARE

Splint the extremity. Apply a three-sided short leg splint from the base of the toes to just below the knee for posterior, lateral, and superior ankle dislocations that have been reduced. Immobilize the ankle in 90° of flexion and in a neutral position with respect to inversion and eversion.[7] Immobilize the reduced anterior ankle dislocation with the ankle in slight plantarflexion. The limb should be elevated, not bear weight, have frequent neurologic and vascular checks, and have frequent assessments for the development of the signs associated with a compartment syndrome.[7]

COMPLICATIONS

Most complications occur as a result of the fracture-dislocation and not the reduction procedure. This includes neurologic damage, vascular damage, and compartment syndromes. A posttraumatic peroneal tendon dislocation can occur and may be initially unrecognized. The patient usually becomes symptomatic after the acute stage, when the tendon subluxes and dislocates. There is a low rate of subsequently developing avascular necrosis and degenerative joint disease with isolated ankle dislocations.

Complications associated with the reduction procedure, if they occur at all, are usually neurologic and vascular injuries. These structures may become impinged, or trapped, in the relocated joint or on a fracture fragment. **Emergently consult an Orthopedic Surgeon if there is any diminished or absent function of any nerve or artery.**

SUMMARY

Ankle dislocations without fractures are uncommon yet serious injuries. Closed ankle dislocations can be reduced emergently and successfully with the use of procedural sedation. Open ankle dislocations should be irrigated in the Emergency Department and reduced rapidly after consultation with an Orthopedic Surgeon. Reduction, irrigation, and debridement are all likely to occur in the Operating Room if an Orthopedic Surgeon is immediately available. Any ankle dislocation with evidence of distal neurovascular compromise should be reduced immediately. All patients with ankle dislocations should have an Orthopedic Surgery consultation. The majority of closed ankle dislocations are managed nonoperatively with good long-term results.

90 Common Fracture Reduction

Eric F. Reichman and Robert M. Zesut

INTRODUCTION

Extremity fractures are a common reason for Emergency Department (ED) visits. If there is no neurologic or vascular compromise, most closed fractures can be managed conservatively in the ED with splinting and Orthopedic Surgeon follow-up. This chapter addresses four common fractures of the upper extremity that may require reduction by the Emergency Physician (EP). These include clavicular fractures, Colles fractures, displaced surgical neck fractures of the humerus, and supracondylar fractures of the humerus. **The reduction of fractures in the ED should involve consultation with an Orthopedic Surgeon prior to performing the procedure. The only exception to this is if neurologic or vascular compromise exists in the extremity.**

CLAVICULAR FRACTURES

INTRODUCTION

Clavicular fractures are common and represent approximately 5% of all fractures.[1–3] Most of these occur at the junction of the middle and distal third of the clavicle, just medial to the coracoclavicular ligament. The clavicular fracture is the most common fracture encountered in childhood and occurs most often as a result of a fall. These fractures are usually detectable clinically, with plain radiographs helping to confirm the diagnosis. Although these fractures are relatively common, there is a small but definite risk of associated complications.

ANATOMY AND PATHOPHYSIOLOGY

The clavicle is the only bony attachment of the upper extremity to the axial skeleton. It serves as a strut to support the shoulder girdle. It provides support and stabilization of the upper limb while allowing a broad range of movements. The clavicle is securely attached at both the acromioclavicular and sternoclavicular joints by ligaments (**Figure 90-1**). The great vessels of the upper extremity and nerves of the brachial plexus pass posteriorly to the clavicle at its midportion where it overlies the first rib. The proximity of these neurovascular structures, as well as the underlying lung, accounts for most of the potential complications of clavicular fractures.

The most commonly used classification for clavicular fractures was proposed by Allman.[4] This simple classification is useful clinically and mechanistically to the EP. Group I fractures are midclavicular and account for approximately 80% of clavicular fractures. These most often result from a shearing force applied to the lateral aspect of the shoulder. Group II fractures involve the distal third of the clavicle and account for approximately 15% of all clavicular fractures. These most often result from a direct blow to the top of the shoulder. Several additional subclassifications have been proposed for these fractures based on the location of the fracture and associated ligamentous injury. Operative repair is suggested for some of these subtypes. All distal clavicular fractures should therefore be referred for follow-up within 24 hours to an Orthopedic Surgeon.[1,2] Group III fractures represent about 5% of clavicular fractures and involve the proximal third of the clavicle. They often result from a direct blow to the chest.

Patients with clavicular fractures are easily identified clinically. The clavicle is almost entirely subcutaneous, allowing most fractures to be palpated. Presenting signs and symptoms include localized pain, ecchymoses, and edema. Physical examination findings include superior and posterior displacement of the proximal portion of the clavicle due to traction from the sternocleidomastoid muscle (**Figure 90-2**). The shoulder is often displaced inferiorly by the weight of the upper extremity and the force of gravity. Medial displacement of the shoulder may be seen due to traction from the pectoral and the latissimus dorsi muscles.

Most fractures are readily identifiable on standard anteroposterior radiographs. Some group II and III fractures may not be readily identifiable.[1] Additional views at a 45° angle cephalad (apical

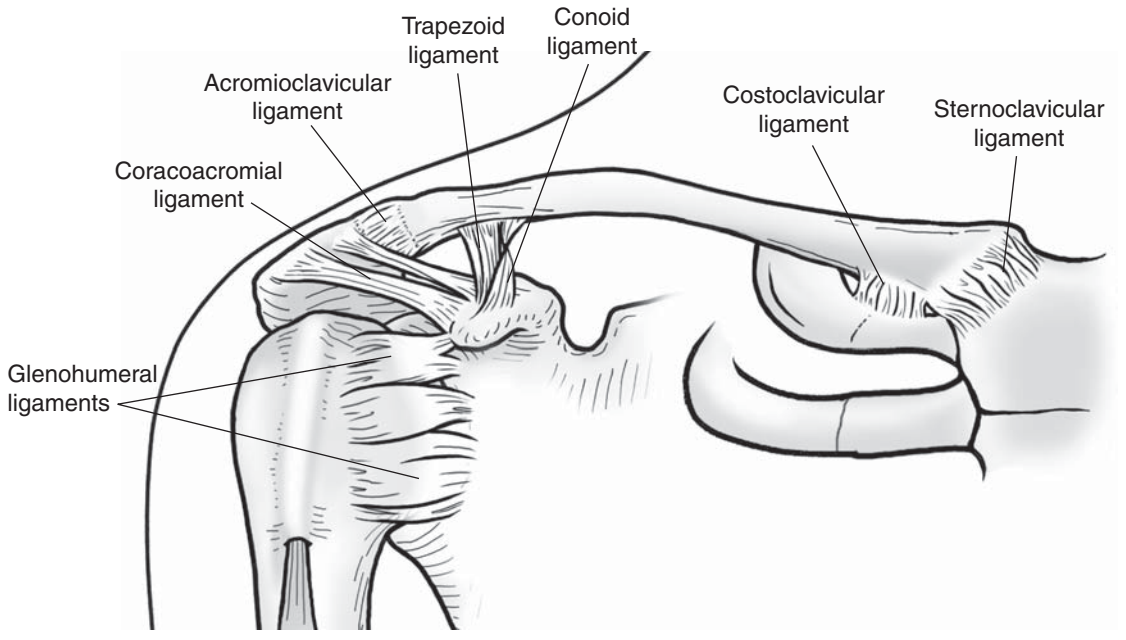


FIGURE 90-1. The clavicle serves as a strut between the torso and upper extremity; it is held firmly by the acromioclavicular and sternoclavicular ligaments. The brachial plexus and great vessels pass behind the middle third of the clavicle.

lordotic view) or 15° posteroanterior radiograph may be useful to assess displacement.[1,3,11] Evaluation of fracture union with spiral computed tomography may allow the best assessment of displacement. Computed tomography is usually required for adequate visualization of medial-end fractures, particularly those extending into the sternoclavicular joint.[12] Special views (e.g., cone views, tomograms, and upper rib films) may be required and are best determined in consultation with an Orthopedic Surgeon.

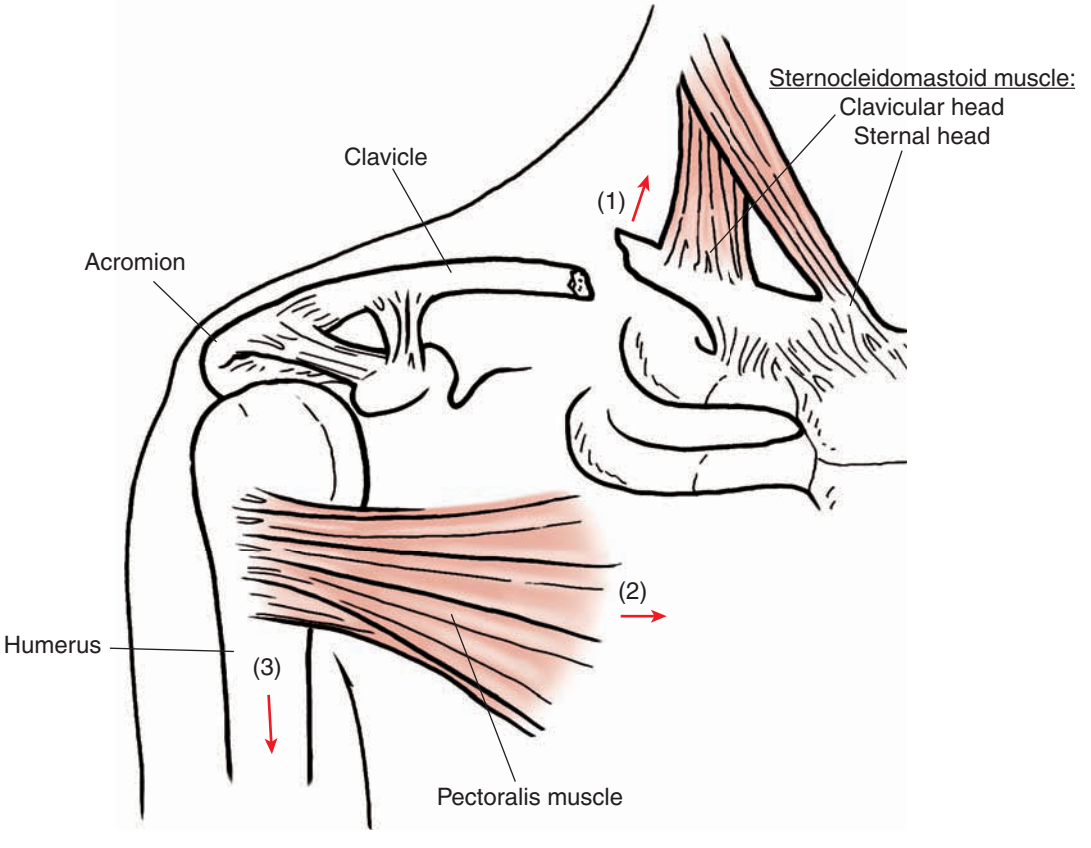


FIGURE 90-2. Displacement of the clavicle and shoulder after a clavicular fracture. The clavicular head of the sternocleidomastoid muscle displaces the proximal clavicular fragment superiorly and posteriorly (1). The pectoralis major and latissimus dorsi muscles pull the shoulder medially (2). The force of gravity displaces the distal clavicle and shoulder inferiorly (3).

Clavicular injury and pain in children present two concerns. First, nondisplaced greenstick fractures to the clavicle may not be radiographically visible for 7 to 10 days.[2,3] Clinical suspicion of a clavicular fracture with a negative radiograph should prompt conservative management. Follow-up should be arranged for 7 to 10 days after the injury to obtain repeat radiographs. Second, it may be unclear if the epiphyses are involved in some group II and III fractures.[2,3] **Any fracture through the epiphysis, or possibly through the epiphyses, requires an urgent referral to an Orthopedic Surgeon.**

INDICATIONS

Reduction of clavicular fractures is necessary in a few circumstances. **It is required if neurologic and/or vascular compromise is present in the affected extremity.** This includes medial fracture displacement producing superior mediastinal compromise. In these circumstances, an emergent attempt at closed reduction should be made.[11,13] Consider patients who are actively involved in athletics or have jobs that require overhead use of their arms (e.g., painters) for operative reduction by an Orthopedic Surgeon. Distal clavicular fractures that are displaced should be reduced. Otherwise, reduction is optional and at the discretion of the treating physician.

CONTRAINDICATIONS

Reduction of most clavicular fractures is not usually necessary in either the pediatric or adult patient.[1,2] A sling for simple arm support provides results comparable to the figure-of-eight reduction without the risk of brachial plexus injury or patient discomfort.[1–3] The sling may be additionally supported by a swath (**Figure 90-3A**) or a Velpeau wrap (**Figure 90-3B**). However, many physicians still prefer the use of a figure-of-eight strap (**Figures 90-3C & D**). The figure-of-eight splint still represents the treatment of choice in patients over the age of 10 years in the presence of greatly displaced fragments.[2,3] Despite this, there is no evidence that the figure-of-eight splint offers any advantage over a simple sling for midclavicular fractures. It is of note that the rates of compression of the neurovascular bundle, axillary pressure sores, and nonunion are higher in patients treated with the figure-of-eight splint.[11,12]

Contraindications to the reduction of a clavicular fracture include other injuries that represent a threat to life or limb. The patient's airway, breathing, and circulation must first be addressed and stabilized. Patients with open clavicular fractures require emergent consultation with an Orthopedic Surgeon, intravenous antibiotics, and hospital admission for possible open reduction and internal fixation. Reduction is also contraindicated if an expanding hematoma, indicative of a vascular injury, is observed. Finally, unfamiliarity with technique is a relative contraindication.

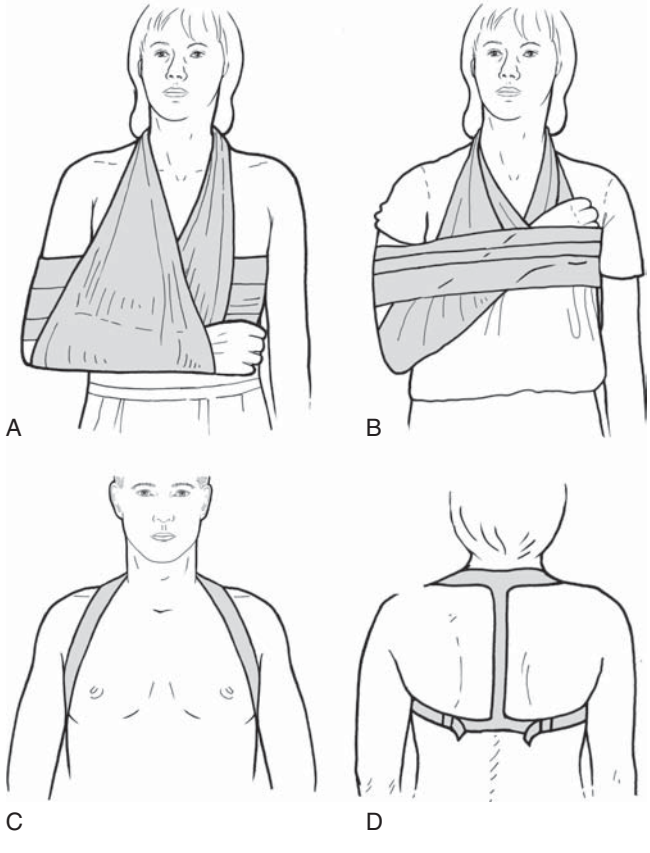


FIGURE 90-3. Treatment of clavicular fractures. **A.** Sling-over-swath immobilization. **B.** Velpeau sling immobilization. **C.** Anterior view of the figure-of-eight splint **D.** Posterior view of the figure-of-eight splint.

EQUIPMENT

- Figure-of-eight splint strap (commercially available)
- Sling
- Swath
- Kerlix rolls
- Elastic bandage

PATIENT PREPARATION

Explain the risks, and benefits of the reduction technique and aftercare to the patient and/or their representative. As with any procedure, informed consent should be obtained. Consider the administration of oral, intramuscular, or intravenous analgesics for patient comfort during the procedure. Procedural sedation is not needed or required for this fracture reduction.

TECHNIQUE

Sit the patient upright on the side of the stretcher with their feet on the floor. Alternatively, the patient may be standing upright. Stand behind the patient. Grasp and pull both of the patient's shoulders backward as if the patient were standing at attention. Instruct an assistant to apply the figure-of-eight splint while the patient is in this position. Apply the splint like a backpack and tighten the straps (**Figures 90-3C & D**). Reassess the neurologic and vascular integrity of the affected extremity after applying the splint.

ASSESSMENT

The neurologic and vascular integrity of the upper extremity should be assessed for all patients both initially, following any reduction attempts, and after the application of a figure-of-eight splint. Any neurologic and/or vascular compromise requires an emergent consultation with an Orthopedic Surgeon.

AFTERCARE

Patients with uncomplicated fractures should be referred to an Orthopedic Surgeon in 7 to 10 days. Patients with group II distal fractures and any fracture in a child potentially involving the epiphysis should have an urgent consultation with an Orthopedic Surgeon within 24 to 48 hours. Any patient with neurologic or vascular compromise, a pneumothorax, or signs of

vascular injury should be admitted to the hospital after an emergent consultation with an Orthopedic Surgeon.

Once the acute pain has subsided, the use of the sling can normally be discontinued and patients are encouraged to participate normal activities as pain allows. Most patients respond well to self-administered range-of-motion exercises. Recovery of the range of motion of the shoulder is usually swift, and supervised physiotherapy is very rarely required.[13]

General principles of orthopedic care are recommended. These include the application of ice, rest, nonsteroidal anti-inflammatory drugs, and narcotic analgesics as needed. Most patients find the figure-of-eight splint difficult to apply, extremely uncomfortable, and remove it shortly after its application. If the patient tolerates the splint, it should be tightened daily. The figure-of-eight splint should be worn until there is evidence of clinical union and the arm can be abducted without pain. This generally requires 3 to 5 weeks in children and 6 or more weeks in adults.[1,2] It may be more advantageous to apply a sling and swath or a sling and Velpeau wrap for patient comfort and compliance (**Figures 90-3A & B**). The outcomes of applying a figure-of-eight splint versus a sling are equivalent.[18,19] Alternatively, apply a shoulder immobilizer.

The sling is used to immobilize and elevate the elbow, forearm, and hand. It is also used to support the upper extremity. Slings are often used to support casts or splints of the upper extremity. These devices are simple, inexpensive, and effective. **It is imperative that the sling not be too short to allow the wrist and hand to hang over the sling.** This can result in an ulnar nerve neuropraxia.

The addition of a swath to a sling is used to immobilize dislocated shoulders that have been reduced and proximal humeral fractures (**Figure 90-3A**). The swath immobilizes the humerus against the torso to limit motion at the shoulder. A shoulder immobilizer may be substituted for a sling and swath.

The Velpeau wrap is a sling-and-swath technique that positions the forearm diagonally rather than horizontally (**Figure 90-3B**). The Velpeau wrap has no practical advantages over a sling and swath.

COMPLICATIONS

Complications of the reduction procedure include injuries to the brachial plexus, subclavian artery, and/or vein.[1,2] Commonly, these are the result of the initial injury and not the reduction procedure. **It is imperative to perform a neurologic and vascular examination prior to and after any attempt at reducing a clavicular fracture. Any neurologic or vascular deficit requires an immediate consultation with an Orthopedic Surgeon.**

SUMMARY

Clavicular fractures are common, easily diagnosed, and often treated in the ED. Fractures of the distal or medial third may be more challenging. Although the incidence of complications is low, a thorough search for resultant or concomitant injury is required. Any evidence of neurologic or vascular compromise requires an emergent consultation with an Orthopedic Surgeon.

COLLES FRACTURE

INTRODUCTION

A Colles fracture is a transverse fracture of the distal radial metaphysis with dorsal displacement and angulation of the distal fragment. The fracture usually occurs 2 cm from the distal end of the radius (**Figure 90-4**). The most common mechanism producing a Colles fracture is a fall on an outstretched hand.[5,6] The majority of fractures occur in patients 50 years of age and older.[5,6] This fracture is more commonly seen in women than in men.

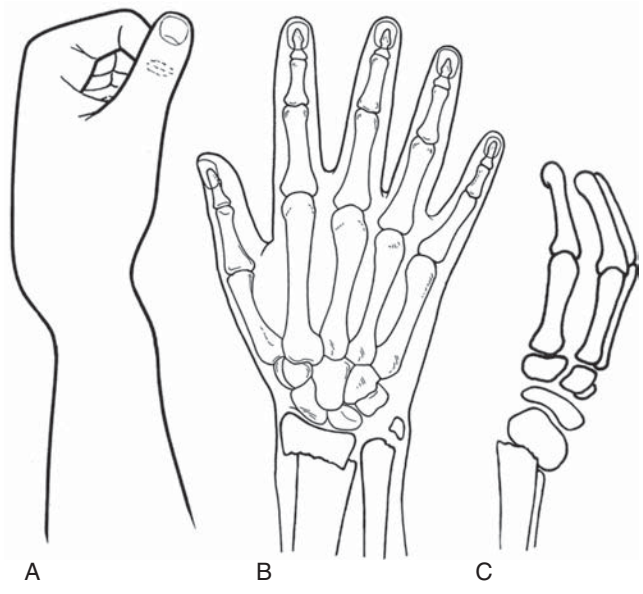


FIGURE 90-4. The Colles fracture. **A.** The dinner fork deformity, which is often seen. **B.** Anteroposterior view. **C.** Lateral view.

The Colles fracture is the most common fracture of the wrist.[5,6] Familiarity with its presentation, indications for reduction, and method of reduction are essential for the EP. Consult an Orthopedic Surgeon for the reduction of most fractures, due to the high incidence of long-term complications that may result, even when these fractures are appropriately managed and reduced.[5,6]

ANATOMY AND PATHOPHYSIOLOGY

The distal radius is involved in two important articulations. First is the distal radioulnar joint, which is responsible for pronation and supination of the forearm. The second is the wrist articulation. The distal radius normally displays approximately 15° to 30° of angulation relative to the ulna. It also has a volar tilt of up to 23°. It is important to maintain this anatomic position of the distal radius with the reduction of a Colles fracture so that the patient retains good function of the wrist and distal radioulnar joints.[6]

The Colles fracture can be associated with several other significant injuries. Up to 60% of patients have a fracture of the ulnar styloid process.[5,6] Other injuries include carpal fractures, distal radioulnar joint subluxations, flexor tendon injuries, median nerve injuries, ulnar neck fractures, and ulnar nerve injuries. A thorough physical examination and evaluation of the radiographs will uncover these injuries.

Standard radiographs include the anteroposterior and lateral views of the wrist. The Colles fracture is classically described as a "dinner fork" deformity when seen on lateral view (**Figure 90-4A**). Intraarticular involvement with the fracture is rare and should prompt an emergent consultation with an Orthopedic or Hand Surgeon in the ED for reduction.[6]

A variation of the Colles fracture is the Smith fracture (reversed Colles). The Smith fracture is similar to the Colles fracture except that the distal fracture fragment is displaced in a volar direction. This fracture most often results from a direct blow to the wrist while the hand is flexed. It is more commonly seen in young males. The management of these fractures is similar to that of the Colles fracture.

INDICATIONS

Nondisplaced Colles fractures can be placed in a splint or cast and the patient follow-up with an Orthopedic or Hand Surgeon on an outpatient basis. Displaced fractures should be reduced in the ED.[5,6] Simple Colles fractures may be reduced after consultation with an Orthopedic or Hand Surgeon. Many Orthopedic and Hand Surgeons prefer to reduce these fractures themselves, often prior to open reduction and internal fixation. **The fracture must be emergently reduced if the patient has any neurologic and/or vascular compromise.** The EP should reduce the fracture if the Orthopedic or Hand Surgeon is not immediately available. The goal is to relieve the neurologic and/or vascular compromise. Ideal positioning is not required as the Surgeon can later reduce the bony defect.

CONTRAINDICATIONS

Contraindications to the reduction of a Colles fracture include other injuries that represent a threat to life or limb. Airway, breathing, and circulation must first be addressed and stabilized. An Orthopedic or Hand Surgeon should reduce any fractures that involve the radioulnar or wrist joint. Complex, comminuted, or open fractures also require reduction by an Orthopedic or Hand Surgeon. Unfamiliarity with the reduction technique is a relative contraindication.

Any patient presenting with a Colles fracture should be evaluated for the presence of a compartment syndrome. **Any suspicion of a compartment syndrome necessitates having intracompartmental pressures measured. Elevated compartmental pressures require an emergent consultation with an Orthopedic, Hand, or General Surgeon.** Reduction and fasciotomies should be performed in the Operating Room. Refer to Chapters 74 and 75 for the details regarding a compartment syndrome and a fasciotomy, respectively.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Local anesthetic solution, 1% to 2% lidocaine
- 10 mL syringe
- 18 gauge needle
- Finger trap
- Compressive cotton bandage (Webril)
- Elastic wrap
- 8 to 10 pounds of weights
- Casting material (plaster, fiberglass, and prepackaged splints)
- Anesthesia and analgesia supplies

PATIENT PREPARATION

Obtain an informed consent for reduction of the fracture after explaining to the patient and/or their representative the indications, anticipated outcome, risks, benefits, and potential complications.

The patient should be given adequate anesthesia for the procedure. This can often be accomplished with a hematoma block. The procedure is briefly described here. Refer to Chapter 125 for a more complete discussion of this procedure. Clean the skin overlying the fracture of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the skin and allow it to dry. Place a subcutaneous wheal of local anesthetic solution over the area of the hematoma. Insert an 18 gauge needle through the anesthetized skin and into the hematoma. Aspirate blood from the hematoma site to confirm proper needle placement. Inject 5 to 10 mL of the local anesthetic solution into the hematoma surrounding the fracture. Although a hematoma block will provide adequate anesthesia in most patients, it may be incomplete. Adjunctive or alternative anesthesia includes intramuscular analgesics, intravenous analgesics, regional nerve blocks (Chapter 126), intravenous regional anesthesia (Chapter 127), and procedural sedation (Chapter 129).

TECHNIQUE

Place the patient supine on a stretcher. Perform a hematoma block as described above. Provide supplemental analgesia to the patient if required. Position the patient as in **Figure 90-5A**. Abduct the arm 90° and allow it to hang over the edge of the bed. Flex the elbow 90° with the hand pointing upright. Insert the thumb, index finger, and long finger into the finger trap (**Figure 90-5B**). Suspend 8 to 10 pounds of weights from the distal humerus (**Figure 90-5C**). Allow the patient to remain in this position for 5 to 10 minutes to distract and disimpact the fracture fragments.

The fracture reduction involves traction followed by manipulation of the distal radial fragment to reverse the action that resulted in the fracture (Figure 90-6). Place both hands around the patient's wrist with the thumbs at the base of the fracture site (**Figure 90-6A**). Displace the fracture fragment distally with your thumbs while maintaining traction with the finger trap and the weights (**Figure 90-6A**). This maneuver allows the distal fragment to become free from any contacts with the proximal radius, which may prevent its movement. Continue to manipulate the fragment distally while simultaneously manipulating it in a volar direction until the fragment assumes the proper anatomic position. In the case of a volar angulation or Smith fracture, these manipulations would simply be reversed to reduce the displacement. Slight ulnar deviation of the fragment is often necessary (**Figure 90-6B**). Remove the weights. Palpation of a smooth surface at the radial and dorsal aspects of the radius indicates an appropriate reduction. Remove the finger trap and apply a splint.

Immobilize the forearm with a sugar tong splint. Place the forearm in a neutral position, halfway between pronation and supination. Place the wrist in 15° to 20° of flexion and 20° of ulnar deviation. Unstable fractures are best splinted immediately after the reduction while the hand is still maintained in the finger trap for traction (**Figure 90-6C**). If a long arm cast is applied, be sure to bivalve it to prevent complications. A short arm splint or cast may be used if the fracture is stable and impacted or is stable in an elderly person who needs to maintain mobility of the elbow.

ASSESSMENT

All patients should be assessed both initially and following any reduction attempts for neurologic and vascular integrity of the extremity. Postreduction radiographs should be obtained to confirm proper bony positioning. The procedure may be repeated if the radiographs show an incomplete reduction. Bedside ultrasound is a reliable and convenient method of assessing the reduction.[20] It is noninvasive, does not use ionizing radiation, involves minimal contact, and does not require the patient to remain motionless.[14]

The goal is the restoration of the normal relationships and angles of the radius with congruity of the radiocarpal and radioulnar joints. The lateral radiograph should reveal a 23° angle of the radiocarpal joint in a palmar direction with no dorsal angulation. The

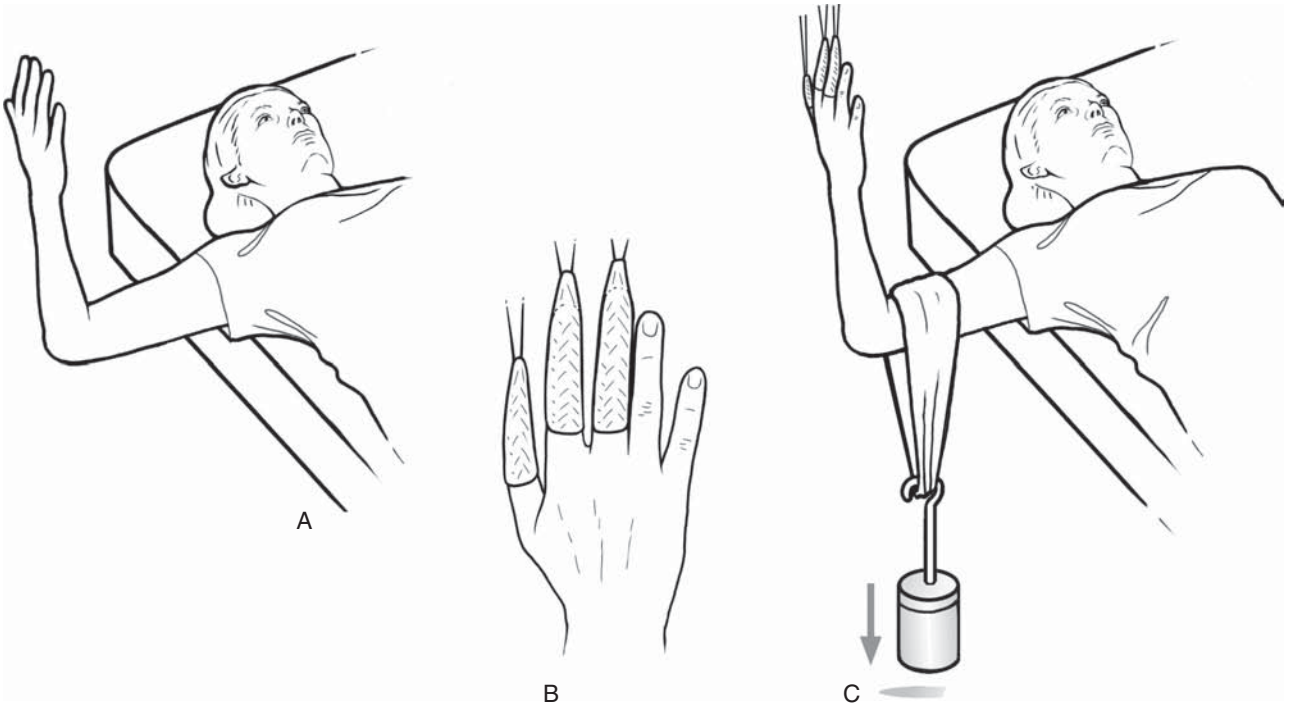


FIGURE 90-5. Patient positioning for the reduction of a Colles fracture. **A.** The arm is abducted 90° and the elbow is flexed 90°. **B.** The thumb, index finger, and long finger are placed in the finger trap. **C.** Weights are suspended from the distal humerus.

anteroposterior radiograph should reveal a radioulnar joint angle of 15° to 30° with the ulna in relation to the radiocarpal joint.

Positioning is not critical if the reduction was performed for neurologic and/or vascular compromise. The primary consideration is the relief of the compromised nerve and/or artery. The Orthopedic or Hand Surgeon can later reduce the bony defect that remains.

AFTERCARE

Patients with uncomplicated or nondisplaced fractures should be referred to an Orthopedic or Hand Surgeon in 24 to 48 hours. Patients with unstable fractures should be evaluated within 24 hours. **All patients should be given written instructions regarding the signs and symptoms of the splint or cast being**

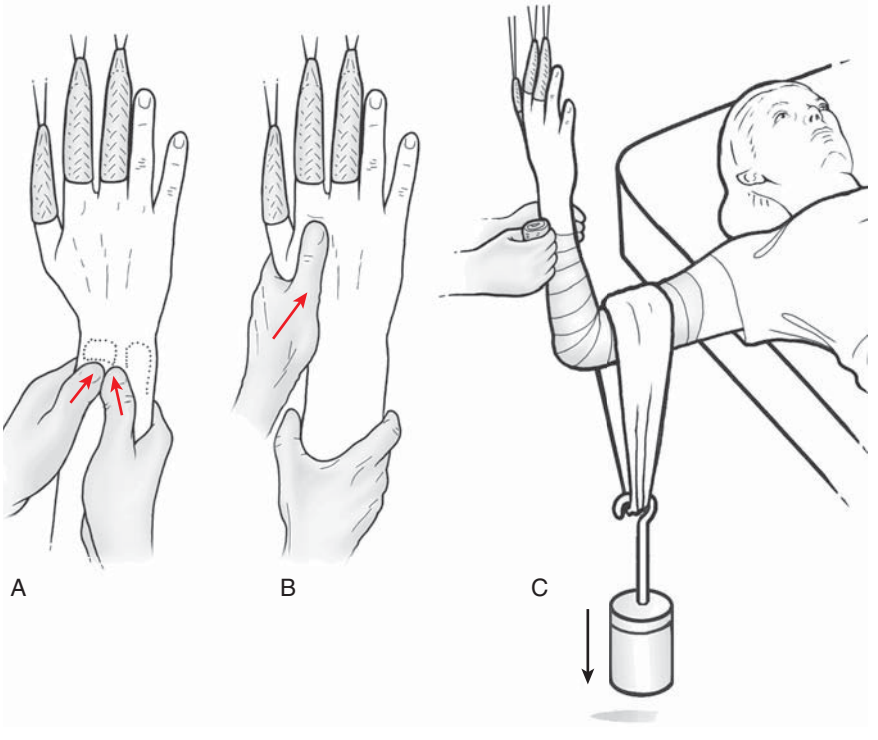


FIGURE 90-6. Reduction of a Colles fracture. **A.** Proper positioning of the EP hands. The arrows represent the application of a distally directed force. **B.** Application of an ulnar-directed force to reduce the radial deviation. **C.** The application of a splint to an unstable fracture. The finger trap and weights remain during the splinting.

too tight or a potential compartment syndrome. Any patient with an open fracture, evidence of neurologic and/or vascular compromise, or suspicion of a compartment syndrome should be admitted to the hospital after an emergent consultation with an Orthopedic or Hand Surgeon.

General principles of orthopedic care are recommended. These include rest, elevation of the arm, nonsteroidal anti-inflammatory drugs, and narcotic analgesics as needed. The patient should be instructed to exercise the fingers and shoulder to prevent weakness, muscular atrophy, and the ligaments surrounding these joints from becoming taut.

COMPLICATIONS

Complications of the reduction procedure include postreduction edema and bleeding into the forearm. These may contribute to the development of a compartment syndrome. Although infrequent, a neuropraxia of the median nerve is possible. Most complications result from the injury that produced the fracture and underlie the need for a good neurologic and vascular examination prior to any attempts at reduction. Any diminished or absent neurologic or vascular function requires an emergent consultation with an Orthopedic or Hand Surgeon. Incomplete reduction can result in future morbidity (i.e., pain, decreased range of motion, and deformity).

SUMMARY

The Colles fracture is the most common fracture of the wrist. Familiarity with its presentation and method of reduction are essential for the EP. Many Orthopedic and Hand Surgeons prefer to reduce these fractures. Consultation is advised prior to reduction unless the extremity has evidence of neurologic or vascular compromise. These fractures have a high incidence of long-term complications, even when appropriately managed and reduced.[5,6]

DISPLACED SURGICAL NECK FRACTURE OF THE HUMERUS

INTRODUCTION

Proximal humeral fractures are relatively common. Most patients presenting to the ED with a proximal humeral fracture are elderly and usually have osteoporosis. The most common mechanism of injury involves a fall on an outstretched hand with the elbow extended.[3,7] The EP can manage most of these fractures conservatively. However, the EP must have a basic knowledge of the types of proximal humeral fractures, those that should be managed by the Orthopedic Surgeon, and the indications for emergent reduction.

ANATOMY AND PATHOPHYSIOLOGY

The proximal humerus is composed of the articular segment, the greater and lesser tuberosities, and the proximal humeral shaft. This anatomic division is based on the epiphyseal lines and the development of the humerus.[2,3,7] The commonly used Neer classification utilizes the observation that proximal humeral fractures separate primarily along these epiphyseal lines.[2,3,7] Using this classification, it is the displacement of fragments, not the total number of fracture lines, that is important. Significant displacement is considered to be a separation of greater than 1 cm, angulation of more than 45°, or displacement of the greater tuberosity greater than 0.5 cm.[3,7] The classification separates fractures into one- to four-part fractures. The vast majority, approximately 80%, of proximal humeral fractures are one-part or minimally displaced fractures.[3,7] These fractures can be managed conservatively. Multiple-part fractures often require surgical intervention by an Orthopedic Surgeon. **A surgical neck fracture of the humerus is the only proximal humeral fracture that should be reduced by the EP.**

INDICATIONS

Surgical neck fractures of the humerus may be reduced in the ED after consultation with an Orthopedic Surgeon. **If the patient has neurologic and/or vascular compromise, the reduction should be undertaken emergently after consultation with the Orthopedic Surgeon.**

CONTRAINDICATIONS

Contraindications to the reduction of humeral fractures include other injuries that represent a threat to life or limb. Airway, breathing, and circulation must first be addressed and stabilized. An Orthopedic Surgeon should manage any open fracture, complex comminuted fracture, or multiple-part fracture as the patient often requires operative repair and reduction.[2,3,7] Unfamiliarity with the reduction technique is a relative contraindication. Children presenting with separation of the proximal humeral epiphyses require meticulous realignment. These fractures should be reduced by an Orthopedic Surgeon.[2]

EQUIPMENT

- Supplies and equipment for procedural sedation (Chapter 129)
- Compressive cotton bandage (Webril)
- Casting material (plaster, fiberglass, and prepackaged splints)
- Sling
- Elastic wrap

PATIENT PREPARATION

Obtain an informed consent for reduction of the fracture after explaining to the patient and/or their representative the indications, anticipated outcome, risks, benefits, and potential complications of the procedure. Adequate anesthesia for this procedure is best accomplished with procedural sedation. Obtain an informed consent for the procedural sedation procedure. Refer to Chapter 129 for complete details regarding procedural sedation.

TECHNIQUE

Place the patient supine. Apply procedural sedation. Completely flex the patient's elbow. Apply a distractive force along the long axis of the humerus by applying traction on the patient's elbow (**Figure 90-7A**). Simultaneously slightly adduct the arm across the chest (to allow relaxation of the pectoralis muscle), slightly flex the arm, and apply lateral pressure to the fracture site while distracting the humerus (**Figure 90-7B**). Slowly release the traction on the elbow as the fragments come into good reduction.

Apply a sugar tong splint from over the deltoid muscle, under the elbow, and up into the axilla (**Figure 90-8A**). Secure the splint in the usual manner with an elastic wrap. Apply a sling (**Figure 90-8B**). Place the arm slightly across the chest and apply a sling and swath in the event of an unstable proximal humeral fracture (**Figure 90-3A**). This can help to limit the pull of the pectoralis muscle on the fracture site.

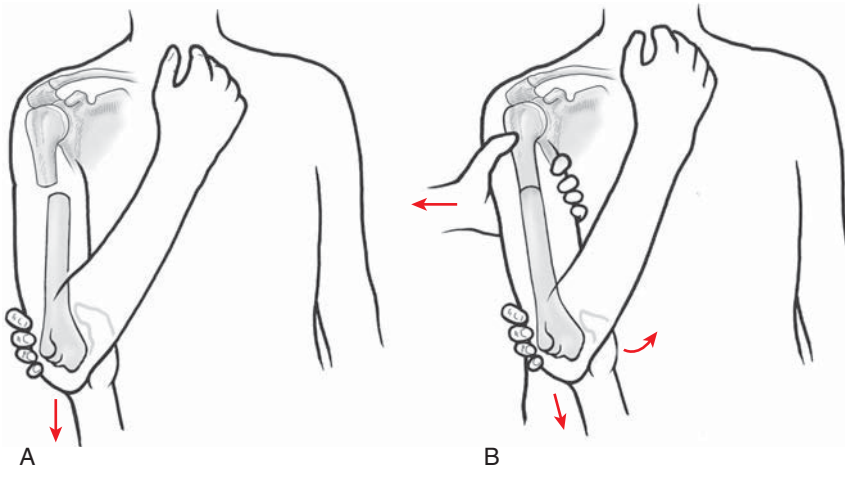


FIGURE 90-7. Reduction of a displaced surgical neck fracture of the humerus. **A.** The application of distal traction to the elbow. **B.** Lateral pressure is applied to reduce the fracture while maintaining distal traction, adducting the elbow, and slightly flexing the arm.

ASSESSMENT

All patients should be assessed both initially and following any reduction attempts for neurologic and vascular integrity of the extremity. Postreduction radiographs should be obtained to confirm proper bony positioning. The procedure may be repeated if the radiographs show incomplete reduction.

Positioning is not critical if the reduction was performed for neurologic or vascular compromise. The primary consideration is the relief of the compromised nerve and/or artery. The Orthopedic Surgeon can later reduce the bony defect that remains.

AFTERCARE

Patients with uncomplicated or nondisplaced fractures should be referred to an Orthopedic Surgeon in 24 to 48 hours. **All patients should receive written instructions on the signs and symptoms of the splint being too tight or a potential compartment syndrome.** Patients with unstable fractures should be evaluated within 24 hours. Any patient with an open fracture, evidence of neurologic and/or vascular compromise, or suspicion of a compartment syndrome should be admitted to the hospital after an emergent consultation with an Orthopedic Surgeon.

COMPLICATIONS

Complications of the reduction procedure include primarily neurologic and/or vascular compromise. However, most complications result from the injury that produced the fracture. This underlies the need for a good neurovascular examination prior to any reduction attempt.

SUMMARY

Proximal humeral fractures are common. While the EP can manage most of these conservatively, a displaced surgical neck fracture is the only proximal humeral fracture that should be reduced in the ED. Reduction is often reserved for patients who have evidence of neurologic and/or vascular compromise. Most of these injuries require open reduction and internal fixation in the Operating Room by an Orthopedic Surgeon. Close follow-up should be arranged for any patient discharged from the ED.

SUPRACONDYLAR FRACTURE OF THE HUMERUS

INTRODUCTION

Distal fractures of the humerus located within 2 cm or just proximal to the epicondyles are known as supracondylar fractures (**Figure 90-9**). Supracondylar fractures are classified as extension and flexion fractures.[8–10] These fractures are common in children under the age of 15 and are rare in people over the age of 20.[8–10] Supracondylar fractures are the most common elbow fractures seen in children.[15] The most common mechanism of injury involves a fall onto an outstretched hand with the elbow locked

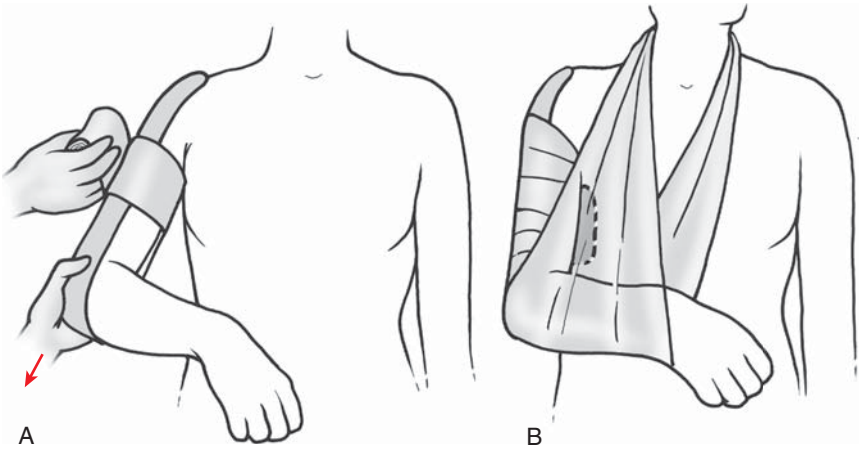


FIGURE 90-8. Immobilization of the reduced surgical neck fracture of the humerus. **A.** Application of a sugar tong splint. **B.** A sling is applied after padding is placed between the upper arm and the thorax.

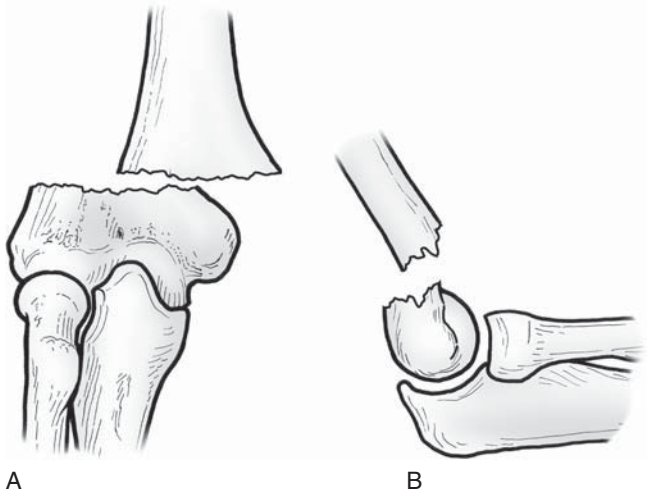


FIGURE 90-9. Supracondylar fracture of the humerus. **A.** Anteroposterior view. **B.** Lateral view.

in extension.[8–10] The same mechanism of injury in an adult often results in a posterior elbow dislocation. The bones of an adult are much stronger than those of a child, so that the ligaments rupture rather than the bone fracturing.[8,9] **These injuries have a significant incidence of associated neurologic and/or vascular injury. There is a significant incidence of a subsequent compartment syndrome.** All supracondylar fractures should be referred to an Orthopedic Surgeon for follow-up care.

ANATOMY AND PATHOPHYSIOLOGY

On presentation, the child will be holding the affected extremity with the elbow flexed 90° and the arm adducted.[8,10] Localized tenderness and swelling will be found upon examination. Extension fractures have posterior displacement of the distal fragment of the humerus that is aggravated by the pull of the triceps muscle.[8,10] The olecranon will be displaced posteriorly due to traction from the triceps muscle. The posterior displacement of the olecranon may mimic a posterior elbow dislocation. **Anterior angulation of the sharp proximal fragment (Figure 90-9B) may injure the brachial artery or median nerve (Figure 90-10). A thorough neurovascular examination is essential.** There will be loss of the normal olecranon prominence with flexion injuries. These fractures are frequently open and vascular injury is less frequent.[8,10]

The modified Gartland classification of supracondylar humeral fractures is the most commonly accepted and used system.[17] A Gartland type-I supracondylar fracture is nondisplaced or minimally displaced by <2 mm and is associated with an intact anterior humeral line. A type-II supracondylar fracture is displaced by >2 mm, and the posterior cortex is intact, but may be hinged. On a true lateral radiograph of the elbow, the anterior humeral line does not go through the middle third of the capitellum. Type-III fractures are displaced with no meaningful cortical contact. Gartland type-IV fractures are characterized by an incompetent periosteal hinge circumferentially and are defined by instability in both flexion and extension.[17] The EP's primary role in a supracondylar humeral fracture is to ascertain if there is any neurological and/or vascular compromise of the extremity distal to the fracture.

Radiological evaluation of supracondylar fractures is best appreciated on the lateral view. One-quarter of these fractures in children are of the greenstick variety.[8,10] The posterior fat pad sign and anterior humeral line should be closely examined. Initial radiographs may show no evidence of a fracture except for a posterior fat-pad sign.[15] Even without any radiologic signs, a child with localized tenderness in the supracondylar area should be treated conservatively with splinting and referral to an Orthopedic Surgeon.[8,10] The anteroposterior view allows an assessment of any displacement. Displaced fractures should be emergently referred to and reduced by an Orthopedic Surgeon.

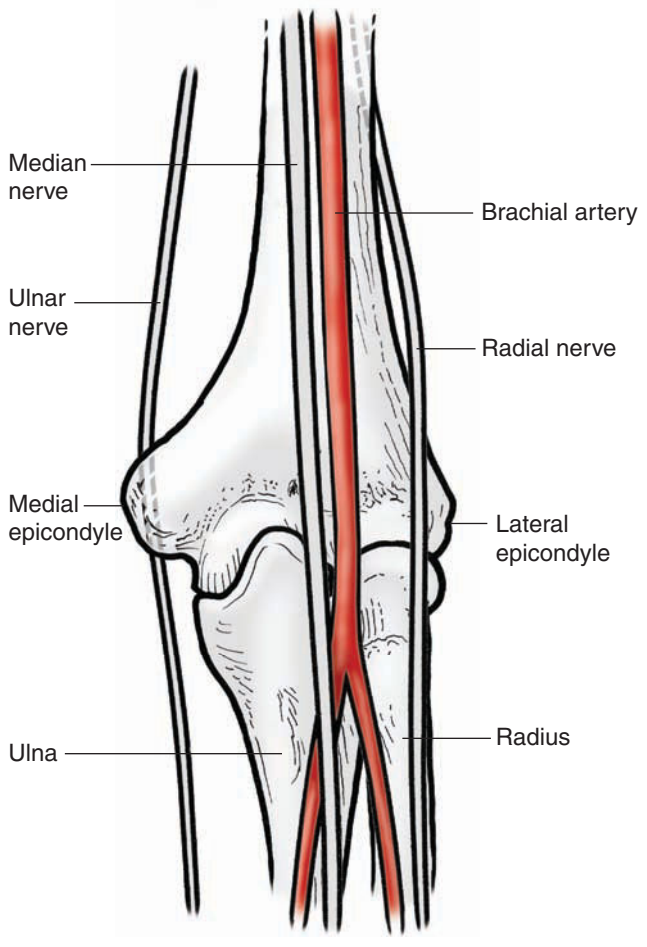


FIGURE 90-10. Major neurologic and vascular structures crossing the elbow.

INDICATIONS

The only indication for reducing a supracondylar fracture of the humerus emergently is neurologic and/or vascular compromise of the extremity distal to the fracture and an Orthopedic Surgeon is not immediately available.

CONTRAINDICATIONS

Contraindications to the reduction of a supracondylar fracture include other injuries that represent a threat to life or limb. The patient's airway, breathing, and circulation must first be addressed and stabilized. An Orthopedic Surgeon should manage any open or displaced fractures. Unfamiliarity with the reduction technique is a relative contraindication. If the EP is uncomfortable with the reduction procedure, simple traction on the extended elbow may be sufficient to restore neurologic and/or vascular integrity.

EQUIPMENT

- Supplies and equipment for procedural sedation (Chapter 129)
- Compressive cotton bandage (Webril)
- Elastic wraps
- Casting material (plaster, fiberglass, and prepackaged splints)
- Prepackaged splinting sheets
- Sling

PATIENT PREPARATION

Obtain an informed consent for the reduction of the fracture after explaining to the patient and/or their representative the indications, anticipated outcome, risks, benefits, and potential complications. Adequate anesthesia for this procedure is best accomplished with procedural sedation. Obtain an informed consent for this procedure in addition to the reduction procedure. Refer to Chapter 129 for the complete details regarding procedural sedation.

TECHNIQUE

Place the patient supine. Apply procedural sedation. Slightly abduct the affected extremity. Place the patient's hand in the midposition between pronation and supination with the thumb pointing upward (**Figure 90-11A**). Grasp the patient's elbow region with the dominant hand and grasp the wrist with the nondominant hand (**Figure 90-11A**). Instruct an assistant to stabilize the distal humerus (**Figure 90-11A**). Apply distal traction in line with the long axis of the arm by pulling on the wrist while simultaneously correcting any medial or lateral displacement at the elbow (**Figure 90-11A**). Supinate the patient's arm and correct any remaining medial or lateral displacement at the elbow while simultaneously distracting the wrist (**Figure 90-11B**). Place the thumb of the dominant hand across the joint line of the elbow with the fingers behind the olecranon process and slowly flex the elbow to just beyond 90° while distracting the elbow (**Figure 90-11C**). Splint the arm in this position. Avoid tight bandaging or splinting as significant swelling may occur up to 24 hours after the reduction. Excessive flexion or extension may compromise the limb's vascularity and increase compartment pressures.[16]

ASSESSMENT

All patients should be assessed both initially and following any reduction attempts for neurologic and vascular integrity of the extremity. Postprocedural swelling is common. Postreduction radiographs should be obtained to confirm proper bony positioning. The procedure may be repeated if the radiographs show incomplete reduction.

Positioning is not critical if the reduction was performed for neurologic or vascular compromise. The primary consideration is the relief of the compromised nerve and/or artery. The Orthopedic Surgeon can later reduce the bony defect that remains.

AFTERCARE

Patients with supracondylar fractures should be admitted to the hospital to be monitored for a delayed compartment syndrome, neurologic compromise, or vascular compromise. Any patient with an open fracture, evidence of neurologic or vascular compromise, or suspicion of a compartment syndrome should be admitted to the hospital after an emergent consultation with an Orthopedic Surgeon.

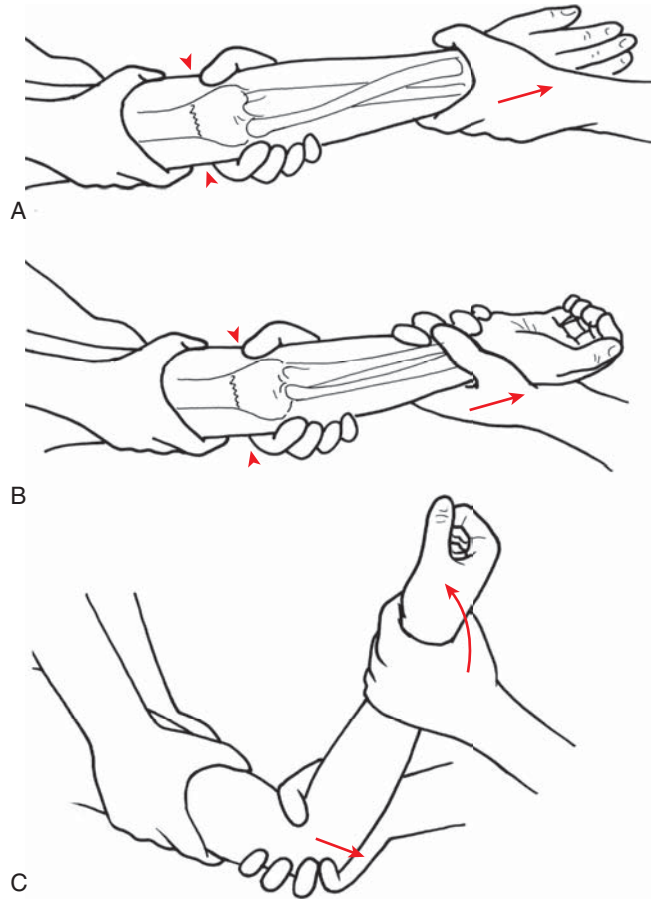


FIGURE 90-11. Reduction of a supracondylar fracture. **A.** Positioning of the hands of the EP and the assistant. Distal traction is applied (*arrow*) while reducing the medial or lateral displacement (*arrowheads*). **B.** The patient's hand is supinated while maintaining distal traction (*arrow*). Any remaining medial or lateral displacement is also corrected (*arrowheads*). **C.** The patient's elbow is flexed (*curved arrow*) just beyond 90° while maintaining distal traction (*straight arrow*).

COMPLICATIONS

Most complications result from the injury that produced the fracture and not the reduction. Complications of the reduction procedure include primarily neurologic and vascular compromise. This is most often a neuropraxia and may involve any of the three nerves crossing the fracture. The neurovascular structures crossing the fracture may become lacerated or entrapped during the reduction. **The necessity of an accurate and complete neurovascular examination prior to and after reduction cannot be overemphasized.**

SUMMARY

Supracondylar fractures of the humerus are common in children under the age of 15 and rare over the age of 20. The most common mechanism of injury involves a fall onto an outstretched hand with the elbow locked in extension. These injuries have a significant incidence of associated neurologic injury, vascular injury, and the subsequent development of a compartment syndrome. The only indication for the reduction of a supracondylar fracture of the humerus by the EP is neurologic and/or vascular compromise distal to the fracture.

91 Casts and Splints

Eric F. Reichman and Harold A. Sloas

INTRODUCTION

External immobilization of the extremities is the oldest form of fracture treatment. References to plaster use and various immobilization techniques are scattered throughout historical records. The use of plaster of paris (plaster) in fracture management dates back to the eighteenth century Turkish Empire. Plaster bandages became commercially available in 1931. Despite the development of plastic (i.e., fiberglass) casting products, the plaster bandage persists as the most economical and versatile material for immobilization techniques.[1]

Immobilization of an injured extremity begins at the scene of the accident. According to Advanced Trauma Life Support guidelines, the injured extremity must be aligned and immobilized after the appropriate management of any life-threatening problems.[2] Prehospital immobilization of fractures is invaluable for pain control, prevention of soft tissue injury, prevention of any new or further injury to neurovascular structures, and management of edema. External immobilization with splinting or casting is often the definitive management of injured extremities in the Emergency Department. Knowledge of and expertise in this therapeutic procedure is essential for any EP.

Splints are commonly used for the immobilization of upper and lower extremity injuries. A splint is a hard bandage that is not circumferential and prevents movement of the fracture site. Splinting may be the definitive management of certain injuries. Splints have the distinct advantage of being quick, easy to apply, and they are designed to accommodate postinjury swelling. The major disadvantages of splints are that they provide slightly less rigid immobilization than casting and require a Physician visit within a few days to be replaced with a cast.

Casts, which are generally circumferential, are better suited for the definitive treatment of fractures and ligamentous injuries. Casts provide superb immobilization and allow for the maintenance of a reduced fracture. The rigidity of a cast limits the amount of swelling and soft tissue edema in the first 24 to 48 hours after the injury and is therefore associated with an increased risk of developing a compartment syndrome. **Casts should be used with caution in the management of acute fractures. They are often split (i.e., bivalved) to allow swelling and prevent the development of a compartment syndrome before the patient is discharged from the Emergency Department.**

ANATOMY AND PATHOPHYSIOLOGY

Casts and splints rely on the principle of a three-point mold to maintain fracture reduction (**Figure 91-1**). **When applying a cast or splint, the application of directed force to the underlying bones should be uppermost in one's mind.** To obtain a three-point mold, place one point of contact over the convex side of the fracture site. The other two points of force are aimed in an opposite direction, proximal and distal to the fracture, and from the concave side. This is the classic teaching of Sir John Charnley, who noted that "a curved plaster is necessary in order to make a straight limb."[3] A skin-tight cast that closely follows the contours of the extremity will not maintain the fracture in alignment, as it does not apply appropriate pressure to the underlying bones.

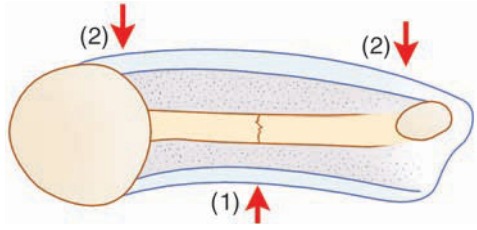


FIGURE 91-1. Three points of force are acting on the injured extremity in a well-applied cast or splint. One force is applied to the convex side of the fracture site (1). Two opposing forces are applied at sites proximal and distal to the fracture and on the concave side of the fracture (2).

Casts and splints also rely on hydraulic force to maintain limb length and alignment. One may think of the soft tissues surrounding the broken bones as constituting a flexible cylinder that contains the underlying fracture, hematoma, and edema. Axial loading of the bones will cause the soft tissue to expand and allow the limb to shorten. A well-applied cast or splint will resist the outward expansion from axial loading and provide additional support for the limb.[4]

Plaster is made of finely ground calcium sulfate that has been dehydrated by heat. The calcium sulfate is impregnated into muslin sheets containing dextrose or starch. The addition of various chemicals (e.g., alum, aluminum, copper, iron, magnesium, salicylic acid, or zinc) to the calcium sulfate alters the rate of hardening after the addition of water. Plaster grades include fast-setting and extra-fast-setting plaster, which are useful for different applications. Long cylindrical crystals form and interlock as the plaster sets to give strength to the cast. **For this reason, plaster should not be moved once it begins to set, as these crystals may fracture, causing the plaster to lose strength. Careful lamination of the plaster while it is still wet will add strength by enabling the formation of longer crystals.**

Crystal formation during the setting of plaster is an exothermic process that is initiated by the addition of water to the plaster. Using warm water will accelerate the chemical reaction, harden or set the plaster sooner, and decrease the setting time. Unfortunately, the use of very warm or hot water will also increase heat production while the plaster sets. The use of very thick splints or fast-setting plaster will also increase the heat produced during setting. Use cold water to activate the plaster, increase the setting time, and decrease the heat produced during setting. **Great care should be taken if warm water is used in applying a cast or splint to an anesthetized patient, unconscious or altered patient, or an insensate limb. The setting plaster may burn the skin in these cases as the patient will not notice the heat and pain associated with the exothermic reaction.** Rubbing and working with the plaster will also accelerate the setting process.[5]

The same principles described above regarding plaster apply to the use of fiberglass. The fiberglass splinting material consists of cloth impregnated with a plastic and spun glass resin and a water-activated catalyst.

INDICATIONS

SPLINTS

An injured extremity should be splinted as soon as possible after the injury. Splinting results in the reduction of pain, reduction of edema, relieves pressure on neurovascular structures, and the prevention of further soft tissue injury.[6] Any available material can be used to immobilize or realign the affected extremity in the

prehospital setting and in the Emergency Department. **A thorough neurologic and vascular examination of the extremity should be performed and documented before temporarily splinting the extremity. A thorough neurologic and vascular examination of the extremity should be performed and documented after temporarily splinting the extremity. The initial neurovascular examination, temporary splinting, and the postsplinting neurovascular examination should be performed before the patient undergoes radiographic studies.** Immobilize an extremity in the appropriate and definitive splint after diagnosing and stabilizing the fracture. **A thorough neurologic and vascular examination of the extremity should be performed and documented after the placement of the definitive splint.**

An extremity fracture is the most common reason for placement of a splint. A splint is also indicated following the reduction of a dislocated joint. The patient with ligamentous sprains or muscle strains will also receive significant pain relief with splint immobilization. Splints are placed following orthopedic or soft tissue surgery of the extremities.

CASTS

There are few reasons to immobilize an acutely injured extremity with a cast in the Emergency Department. Most injuries can be initially stabilized with a splint. Following reduction of certain fractures, placement of a cast will secure the bones in their proper alignment and allow for a primary union (e.g., distal radius, tibial shaft).[6,7] **Placement of a cast instead of a splint should be performed only if the patient has access to close follow-up or can return to the Emergency Department for a cast check within 24 hours.**

Patients with casts may present to the Emergency Department with various cast-associated problems. The cast may have become wet and lost its strength and integrity. The cast may no longer fit properly if the affected extremity has decreased in size from reduction of swelling. The cast must be removed and the affected area examined if the patient complains of persistent pain.[6,7] All these patients may safely be placed back in a cast. They may also be placed in an appropriate splint and follow-up arranged with an Orthopedic Surgeon for casting.

CONTRAINDICATIONS

SPLINTS

There are no absolute contraindications for the placement of a splint. Relative contraindications include soft tissue injuries or wounds that need regular care and evaluation. In this setting, the wounds should be appropriately dressed and padded and the splint constructed so that it can easily be removed and replaced. A "window" may also be cut in the splint as it is being applied to facilitate access to the wound. The splint should not place pressure over the wound.

CASTS

Do not cast an extremity that has the potential for significant edema or that may develop a compartment syndrome. An injured extremity with significant edema or soft tissue injuries should not be constrained by a cast. Similarly, infections of joint spaces or soft tissues must remain exposed for frequent evaluations. Any fracture that is not adequately reduced by closed manipulation should not be placed in a cast.[3,7] A cast should not be applied by someone unfamiliar with the technique and unable to manage the associated complications.

EQUIPMENT

- Bucket or basin to hold water
- Source of cool or tepid water
- Cotton cast padding (e.g., Webril), various widths
- Plaster strips or rolls, various widths
- Fiberglass strips or rolls, various widths
- Prefabricated splinting material, various widths
- Bias stockinette, various widths
- Cloth tape, 1 in. wide
- Bias stockinette, optional
- Elastic bandages (e.g., Ace wraps), various widths
- Slings, various sizes

The width of the cotton cast padding, plaster, and bias stockinette required will vary by the site of application. In general, 1 to 3 in. material can be used for the hands and digits, 3 to 4 in. wide material can be used for the upper extremity, and 4 to 5 in. wide material can be used for the lower extremity. Alternative materials include fiberglass strips and rolls instead of plaster strips. Elastic bandages (e.g., Ace wraps) can be substituted for bias stockinette. Prefabricated splinting material is also available, with the padding and fiberglass (or plaster) already assembled and covered with cotton material (e.g., Parker Splints or Orthoglass). **It is important to remember that all of the casts and splints described in this chapter can be constructed using plaster or fiberglass splinting material.**

Fiberglass rolls must be cut to the appropriate length with scissors while plaster can easily be torn by hand. The fibers are too strong to be torn by hand. Gloves should always be worn when handling fiberglass because the resin will stick to skin and is exceedingly difficult to remove.[4–6] Otherwise, the same principles described for plaster apply to fiberglass.

PATIENT PREPARATION

Whether reducing a fracture or simply manipulating the extremity to place a cast or splint, make sure that the patient has received appropriate analgesia. Conduct a thorough examination of the skin overlying the site of injury. **It is inexcusable to miss the diagnosis of an open fracture. All skin wounds must be inspected and explored.** Exploration of the wound is undertaken cautiously with a sterile probe or gloved finger according to wound size. Fractures may puncture the skin from the "inside-out," resulting in an innocuous appearing pinhole in the skin. These are grade I open fractures and carry with them a 5% risk of infection.[8] Cover any open fractures with sterile saline-soaked gauze until formal irrigation and debridement can be undertaken in the Operating Room. Do not examine open wounds repeatedly due to the risk of increased contamination. Administer tetanus prophylaxis as indicated. Administer the appropriate intravenous broad spectrum antibiotics for an open fracture if present.

Document a thorough neurologic and vascular examination of the injured extremity before and after any splinting or casting. A change in the neurologic or vascular status of an extremity may be the result of the fracture reduction, the splint or cast application, or a compartment syndrome. The fracture may have to be reduced and held in position while a splint or a cast is applied. If no reduction is needed, splint the affected extremity in a position of stability. Techniques for achieving and maintaining fracture reduction are beyond the scope of this chapter.

GENERAL SPLINTING CONSIDERATIONS

The general considerations and techniques common to the application of all splints are discussed in this section.[14,15] It describes the techniques for splints utilizing cotton cast padding, plaster, and bias stockinette. Many alternative materials are available and may be substituted, such as fiberglass for plaster or elastic wraps for stockinette. Prefabricated splint materials that incorporate padding may also be used. The techniques described in these chapters are applicable for all splinting materials. Where alterations in technique are required, they are so noted.

Splints are constructed of cotton padding overlaid by splinting material (i.e., strips of plaster or fiberglass) and subsequently held in position by an overwrap of bias stockinette or an elastic bandage. Splint padding should be thick enough to provide protection for the skin from the plaster. **The splint or cast will be unable to provide sufficient immobilization of the fracture to maintain a reduction if the padding is too thick.** One to two layers of cotton cast padding are sufficient over the fracture site. Three to four layers of cotton cast padding are required at the proximal and distal extents of the splint to distribute the stresses. Thinner padding can be used when maintenance of fracture reduction is a priority (e.g., with a fracture of the distal radius).

Plaster strips are available in precut slabs measuring either 4 by 15 or 5 by 30 in. The precut strips have the advantage of speed and ease of application. Alternatively, plaster and fiberglass are available in rolls of various widths ranging from 2 to 8 in. The rolls of splinting material may be rolled out to the precise length desired and cut appropriately. The rolls of splinting material are useful for splints requiring long strips, such as coaptation splints. **The ideal thickness for most upper extremity splints is 10 sheets or layers of plaster or five to six layers of fiberglass. The use of 15 sheets or layers of plaster or 8 to 10 sheets of fiberglass is preferable for lower extremity splints.** The strength of the splint depends on the number of layers as well as the lamination of the layers during their application.

A piece of cotton cast padding may be used as a template for the length of the required splinting material. Roll a piece of cotton cast padding over the desired location of the splint to determine the length of the splinting material required (**Figure 91-2A**). Roll out the splinting material to the appropriate lengths and cut them slightly shorter than the template.

An alternative is to cut the splinting material approximately 1 to 2 in. longer than necessary so that the ends may be folded back on themselves. This will prevent any contact of the sharp splint ends with the patient's skin. Prefabricated splinting material covered with padding has jagged ends and once it has been cut it begins to harden immediately; even prior to the addition of water. These sharp ends will rub against the patients exposed skin, even through cotton cast padding or bias, and for that reason should be folded back. To avoid premature hardening of the prefabricated splinting material, keep it inside of the protective foil and seal it with tape or the manufacturer provided clips.

Bias stockinette may be applied to the extremity for extra padding and comfort. This may also be omitted depending on EP preference. Prepare strips of cotton cast padding. **The strips of cotton cast padding should always be longer and wider than the plaster.** This prevents the plaster from touching the skin and causing a pressure sore, abrasion, or burn. Padding is especially important at the proximal and distal edges, as this is where significant pressure originates. Apply additional pieces of padding over pressure points and bony prominences (e.g., the olecranon). **Additional padding may also be created by folding a loose piece of cotton cast padding back on itself several times and placing it over the individual prominences.** Alternatively, cotton cast padding may be applied directly by wrapping the pressure point or bony prominence circumferentially as is done in cast application.

Begin applying the splint once the padding and splinting material have been cut to the appropriate lengths. Be sure that all required materials have been collected before dipping the splinting material in water to activate it. Only a limited amount of time, less than 10 minutes, is available for splint application and molding once the splinting material is wet. Completely immerse all of the splinting material in a bucket of tepid, clean tap water. Keep the splinting material submersed until no more bubbles arise from under the water (**Figures 91-2B & C**). At this point, the splinting material can absorb no more water. Suspend the splinting material over the bucket and lightly squeeze out the excess water by running your fingers down its length (**Figure 91-2D**). **It should only take two or three passes of the fingers to remove the excess water. Do not wring the plaster strips like a dish rag, as that will cause loss of plaster into the bucket!** Lay the splinting material on a clean flat surface. Run your hands over the splinting material to laminate the individual strips into one slab. Laminating the strips together adds significant strength. Lay the splinting material onto the cotton cast padding (**Figure 91-2E**). Fold the edges of the cotton cast padding over the splinting material to cover all the edges completely. Apply the splint to the extremity.

An alternative and more commonly used method that is preferred by many is to apply the cotton cast padding circumferentially over the extremity, overlapping each layer by 50%, and then applying the wet splinting material. In this fashion, the splinting material will "stick" to the cotton cast padding. **Smooth the splinting material with the broad aspect of your hand and not your fingers to help minimize irregular indentations.**

The cotton cast padding should be facing the patient and no splinting material should directly contact the skin regardless of the method used. Secure the splint with a wrap of bias stockinette or an elastic bandage. The wrap must be applied under minimal tension when you are using an elastic wrap to affix the splint. The elastic may cause increasing pressure over time. Gently apply strips of tape to the end of the wrap to secure the bias stockinette or the elastic bandage. **Tape should never be applied circumferentially, as this can impede expansion of the splint due to underlying swelling and create a tourniquet effect. Application of the tape under tension before the splint is completely hard will cause indentations in the splinting material and result in pressure points on the underlying skin.**

The splinting material may be molded at this point to achieve greater conformity to the extremity or better reduction of the fracture. **It is paramount to use only the palms and not the fingertips when molding the finished splint. Finger pressure induces deformity in the splint that will result in skin breakdown under those defects. All molding must stop once the splinting material begins to harden.** The plaster is quite fragile, and cracks that weaken the splint may be propagated. Apply 1 in. wide tape in a spiral fashion to secure the bias or elastic wrap after the plaster has hardened.

If using prefabricated splinting materials, cut it to length, remove it from the sealed foil, and wet it to activate the splinting materials. Briefly pass the prefabricated splinting material under cool water. Place the wet prefabricated splinting material on a towel and roll it up. This will remove any excess water. **The splinting material should not be soaked or placed in a bucket of water. It requires only one pass under the running water.** The prefabricated splinting material should not be squeezed dry as









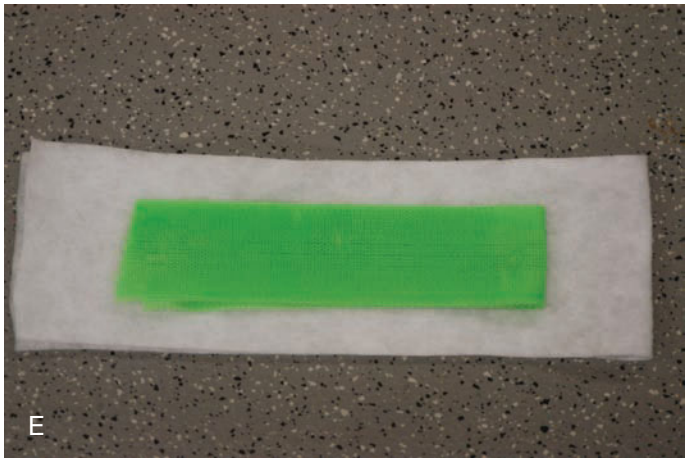


FIGURE 91-2. Preparing the splint. **A.** Cotton cast padding to measure the length of material needed. **B.** Plaster is submersed in tepid water and air bubbles arising from it. **C.** Fiberglass is submerged in tepid water and air bubbles arising from it. **D.** Suspend the lengths of wet splinting material over the bucket and gently squeeze out the excess water. **E.** The splinting material is placed on the cotton cast padding.

this tends to deform the splinting material and result in a poorly molded final product.

Apply the splint and mold it to the extremity. **It is paramount to use only the palms and not the fingertips when molding the finished splint. Finger pressure induces deformity in the splint that will result in skin breakdown under those defects.** Any excess length of splinting material should be folded back on itself so that the cut ends do not come in contact with the patient's skin. The distal part of any extremity should always be left visible so that the EP may recheck a neurovascular exam. The patient will also be able to visualize any changes in color that may occur latter. It is held in place by circumferentially wrapping the splinting material with an elastic bandage. **The elastic bandage should be applied relatively loosely so it will not induce increased compartment pressures.**

GENERAL CASTING CONSIDERATIONS

The general considerations and techniques common to the application of all casts are discussed in this section.[3,5,6,10] **Casting requires careful circumferential turns of material instead of longitudinal layers of material, as for splints.** Casts are constructed of cotton cast padding overlaid with either fiberglass or plaster bandages (i.e., casting materials). The four areas that require particular attention and are discussed in this section are the application of padding, padding pressure points, application of casting material, and molding the cast.

Begin by organizing the required supplies. Cast application requires the same material as that used in splinting (i.e., water, cotton cast padding, stockinette, and casting material). The width of the padding and casting material depends on the size of the









FIGURE 91-3. Preparing to place a cast. **A.** Apply an initial layer of tubular stockinette. **B.** The stockinette has been unrolled over the extremity. **C.** Begin and end the layering of the cotton cast padding at a site distal and proximal to where the casting material will end. Unroll the cotton cast padding in a circumferential manner, covering each preceding layer by one-third to one-half of its width. **D.** The cotton cast padding tears easily to provide additional layers of padding over bony prominences.

extremity. Generally, the 4 to 6 in. wide rolls of casting material are used for lower extremity casts while 3 or 4 in. wide rolls are used for the upper extremity. **Use the widest casting material available and possible in order to limit the number of turns of the fiberglass or plaster roll over joints and other curved surfaces.** Place all materials on a tray near the bedside, including a bucket of tepid water. An assistant designated to dip and drain the casting material and help with patient positioning is immensely helpful.

Prepare the patient. Position the extremity and the patient appropriately for cast placement. The patient is frequently able to assist in the process. Cover the patient with gowns or towels to keep casting material off their clothes.

Apply tubular stockinette to the extremity (**Figures 91-3A & B**). The stockinette is not a necessary component of casting, but many EP use it as a first layer.[5] It provides a smooth covering over the skin that wraps neatly over both ends of the cast. Roll up the stockinette. Place it over the distal extremity as if you were putting on a sock (**Figure 91-3A**). Unroll the stockinette up the leg (**Figure 91-3B**). Care must be taken to apply the stockinette gently. **Do not create tension in the stockinette by pulling it tightly. Eliminate any creases or redundancy of material by trimming any overlapping folds with a scissors.** For upper extremity injuries, cut a small hole one-third of the way from the end of one side of the stockinette to allow the thumb to pass through.

The primary layer of padding is provided by the cotton cast padding. **Casts and cast padding should be applied from distal to proximal.** Begin wrapping the cotton cast padding at a point that will be distal to the start of the plaster (**Figure 91-3C**). This initial band of padding is essential for protection against the cast edge. Keep the roll of padding in contact with the skin so that the material conforms easily to the contours of the extremity as it unrolls. Unroll the padding in a circumferential manner around the extremity. **The cotton cast padding must be laid down neatly and cleanly with no kinks or creases.** Each turn should overlap one-third to one-half of the previous turn. Tear off the extra cotton cast padding to eliminate excess material as you turn angles (e.g., ankle, heel, elbow, or thumb). **Lay the torn edges down by rubbing the padding smoothly.** Continue applying the padding, ensuring that it extends beyond the proximal end of where the cast edge will be to ensure skin protection at the cast edge. Excess length can easily be torn away after the cast is applied and hardened. Typically, two layers of cotton cast padding are adequate for protection between the skin and the casting material.

Pressure points occur over bony prominences or where excess padding has created an unnatural prominence. Palpate the obvious bony prominences to get a sense of whether or not there is adequate padding after the application of the two layers of padding. If the area feels vulnerable, place torn off pieces of cotton cast padding onto the exposed areas (**Figure 91-3D**). **Do not over-pad bony prominences, as excess layering can also lead to excess pressure.** Two to three layers of padding are adequate for most pressure points and bony prominences. Rub the torn edges of the padding so that they fuse smoothly to the underlying padding.

Place the rolls of casting material in a bucket of tepid water so that they are standing on end. Let the casting material remain submersed as long as air bubbles rise out from the center of the roll (**Figures 91-2B & C**). Remove the rolls of casting material when all bubbles stop rising. Hold the casting material in both hands and squeeze some of the water out (**Figure 91-4**). **Do not wring the roll. Do not eliminate all the water from the roll.** Squeeze it gently. The remaining water in the roll is necessary for smoothing and molding the casting material into one solid unit. In general, casts should be applied with "wetter" material and splints with "drier" material as less time is required to apply a splint.



FIGURE 91-4. Hold the casting material roll in both hands and gently twist each end to squeeze out the excess water. Keeping the free end of the casting material folded over will facilitate access after it has been removed from the water.

Apply the casting material (**Figure 91-5**). Place the roll of casting material on the extremity (**Figure 91-5A**). Unroll the casting material in a circumferential fashion around the extremity. **Never lift the roll of casting material off the extremity!** Continue each consecutive wrap around the extremity by overlapping the casting material by approximately 50%. The free border of the casting material will have excess material in it as the extremity changes in size. Grasp this excess casting material with the thumb and index finger of the nondominant hand (**Figure 91-5B**). Pull it outward to create a tuck or a fold. Wrap this fold around the extremity (**Figure 91-5C**) and smooth the fold down against the extremity. This fold will barely be noticeable in the final product. As one roll of casting material ends, another should begin with a small amount of end-to-end overlap. Do not make consecutive folds at the same site as this will create bumps and add bulk to the cast.

Continuously mold and smooth the casting material with wet hands as each layer is applied. **This action ensures continuity of casting material throughout the cast and forms a smooth cast that conforms to the contours of the extremity. Use only the palmar surface of the hands and proximal digits to mold and smooth the casting material (Figure 91-5D). Excessive use of the fingertips will produce irregular indentations and pressure points.** Molding around irregular bony areas is best accomplished with two hands simultaneously rubbing the casting material. **Do not allow excessive time to pass between applying each layer of the casting material, as lamination between layers may not occur. This will weaken the cast considerably.**

A cast thickness of 1/4 in. is felt to be adequate. This usually requires four to five layers of plaster or three to four layers of fiberglass. Allow the cast to set and dry with no further manipulations by the EP or the patient. The time for drying is variable depending upon the casting material used, the water temperature, and the thickness of the cast. Typically, let the casting material set over a period of 10 to 15 minutes. Fold the free ends of the cotton cast padding and the stockinette over the edges of the cast as it sets (**Figure 91-6**). This prevents the rough edges of the casting material from irritating and abrading the skin. Secure the edges of the cotton cast padding neatly with tape or thin strips of casting material.

It is a common practice to bivalve the cast with a cast saw if the potential for increased swelling of the extremity is a concern (**Figure 91-7**). Cut completely through the length of the cast in two









FIGURE 91-5. Apply the casting material to form the cast. **A.** Lay the roll of casting material on the extremity and unroll it. **B.** As the limb changes in girth, there will be excess plaster. Use the nondominant hand to pull on the excess material. **C.** Fold the excess material back onto the extremity in a neat tuck. Each tuck should be laid down smoothly with a molding of the hand. **D.** The casting material is laminated smooth with a continuous motion of the palmar surface of the hand and the proximal fingers.



FIGURE 91-6. Fold the free ends of the cotton cast padding and the stockinette over the edges of the casting material to finish the cast.



FIGURE 91-7. Splitting of the cast can be achieved with a cast saw that cuts through the thickness of the fiberglass or plaster. Cut the underlying protective material with a scissors.

spots 180° apart (i.e., medial and lateral or anterior and posterior). This simple maneuver provides some room for edema without compromising the integrity of the reduction or the strength of the cast. **The underlying cast padding must also be split. Splitting the plaster alone will not reduce the pressure sufficiently.**

UPPER EXTREMITY CASTS AND SPLINTS

COAPTATION SPLINT

A coaptation ("to bring together") splint is used primarily in the acute setting for humeral shaft fractures that are nondisplaced or minimally displaced. This splinting technique allows for motion of the hand and wrist while limiting shoulder and elbow mobility. The cotton cast padding should extend from the nape of the neck to the axilla to avoid skin breakdown. The patient should then be placed in a sitting position to minimize splint displacement during the actual application process. The length of the splint extends from the axilla, around the 90° flexed elbow, along the outer arm, over the deltoid muscle, and over the acromion process (**Figure 91-8**). **It is critical that the splinting material extend over the deltoid muscle and the acromion process.** The shoulder portion can be held down by applying 3 in. wide tape over the portion of the splint that covers the acromion. Secure the splint with an elastic bandage that covers the entire splint. The major pitfall is making the splint too short and having it fall off! A splint that is too long will not provide proper immobilization. Always leave plenty of length over the shoulder. Padding is required to minimize axillary irritation. The disadvantages of this splint include the possibility of fracture displacement and extremity shortening. The splint should be replaced with a functional brace or cast after a short period of immobilization for pain control.[4]



FIGURE 91-8. The coaptation splint. The overwrap has been omitted for easier visualization of the splint.



FIGURE 91-9. The sugar tong splint. Leave the metacarpal joints free for flexion and extension. The overwrap has been omitted for easier visualization of the splint.

SUGAR TONG SPLINT

Sugar tong splints may be used for mid-forearm fractures, distal forearm fractures, and some wrist fractures. They are most commonly recommended for minimally displaced and distal ulnar and radial fractures (i.e., Colles and Smiths fractures). This splint immobilizes the elbow and wrist joints to prevent supination and pronation of the forearm (**Figure 91-9**). The splint begins at the palm, just proximal to the metacarpophalangeal (MCP) joints. It has the distinct advantage of allowing the MCPs to remain free preventing stiffness in those joints. Measure the required length of splinting material along the volar surface of the hand (starting just proximal to the MCP joints) and forearm, around the elbow, and back on the dorsal surface of the forearm ending just proximal to the MCP joints. **The MCP joints should be left completely free to prevent stiffness.** Early mobilization of the fingers will help to reduce swelling. Apply cotton cast padding from the MCP joints to just proximal to the elbow. The ulnar styloid process and the olecranon process are two bony prominences that need extra padding for comfort and prevention of pressure sores. The free ends of the splint also need added protection to minimize hand discomfort. Apply the splint. **Mold the splinting material with great caution to prevent closure of the sides of the splint, thus forming a closed cast.** Fold and/or cut the volar and dorsal splinting material to ensure that the finger MCP joints are freely mobile (**Figure 91-9**).

POSTERIOR LONG ARM SPLINT

Distal humeral fractures and proximal forearm fractures can be immobilized in a posterior long arm splint (**Figure 91-10**). It is also useful for fractures of the radial head and neck, olecranon fractures, and severe ligamentous injuries to the elbow. The posterior long arm splint extends from the axillary crease area, behind the elbow, distally to incorporate the wrist joint, and ending at the MCP shafts (**Figure 91-10**). This splint immobilizes the elbow in a range of 45° to 90° with the forearm in supination, pronation, or neutral



FIGURE 91-10. The posterior long arm splint. The forearm and wrist are in a neutral position. The padding and overwrap have been omitted for easier visualization of the splint.



FIGURE 91-11. The radial gutter splint with the hand in the "safe" position.[9]

positioning depending upon the type of injury. The wrist can also be in a flexed, extended, or neutral position. **The metacarpals should not be immobilized in this splint unless the distal forearm or wrist fracture is comminuted.** Despite the many possibilities, the posterior long arm splint is usually applied with the elbow flexed 90°, the forearm neutral, and the wrist neutral (**Figure 91-10**).

RADIAL GUTTER SPLINT

The radial gutter splint is used for the treatment of stable phalangeal and metacarpal fractures of the index or middle fingers. The splinting material extends from the pulp of the distal fingers to the proximal forearm (**Figure 91-11**). It is helpful to measure and cut a hole in the middle of the splinting material to allow for the insertion of the thumb prior to wetting the splinting material. Place cotton cast padding between the index and middle fingers prior to applying the splint to prevent skin maceration. Mold the width of the splinting material around the radial aspect of the index finger, middle finger, hand, and forearm to create a stabilizing force. The ulnar aspect of the hand and forearm is left entirely free. The hand is immobilized in what is considered a "safe" position with the wrist dorsiflexed 20°, the MCP joints flexed 60° to 90°, and the interphalangeal (IP) joints extended or slightly flexed at 10°[9] (**Figure 91-11**). This is also known as the "position of comfort." It can be described as if the patient were holding a can of soda. The fingertips should be visible to allow for repeat neurovascular examinations.

ULNAR GUTTER SPLINT

This splint is used for the treatment of stable metacarpal and phalangeal fractures of the ring and small fingers (**Figure 91-12**). The long axis of the plaster extends from the pulp of the distal fingers to the proximal forearm. Place cotton cast padding between the ring and little fingers to prevent any maceration (**Figure 91-12A**). The width of the plaster must wrap around the ulnar aspect of the hand and forearm. Mold the splint around the forearm, hand, fourth finger, and fifth finger. The radial side of the hand is left entirely free. The hand is immobilized in the "safe" position with the wrist dorsiflexed 20°, the MCP joints flexed 60° to 70°, and the IP joints extended or slightly flexed at 10°[9] (**Figure 91-12B**). The fingertips should remain visible to allow for repeat neurovascular examinations.

VOLAR SPLINT

The volar splint can be used for the treatment of wrist fractures, radial styloid fractures, ulnar styloid fractures, metacarpal fractures, middle phalangeal fractures, and proximal phalangeal fractures. This splint remains only on the volar surface of the hand and forearm, as the name suggests. The splint begins at the proximal forearm and ends just proximal to the MCP joints (**Figure 91-13**). The splint can be modified and extended to include the fingers





FIGURE 91-12. The ulnar gutter splint. **A.** Padding is necessary between any fingers that are immobilized together. **B.** The final product with the hand in the "safe" position.[9]



FIGURE 91-13. The volar splint. The overwrap has been omitted for easier visualization of the splint.

for phalangeal fractures with the wrist dorsiflexed 20°, the MCP joints flexed 60° to 90°, and the IP joints extended or slightly flexed at 10°.

DORSAL ("CLAM DIGGER") SPLINT

The dorsal splint can be used in place of a volar splint for injuries of the distal forearm, wrist, or hand. The splint runs along the dorsal surface of the forearm and hand, from the proximal forearm to the ends of the digits. As with the volar splint, the wrist is extended 15° to 20°, the MCP joints are flexed 60° to 90°, and the IP joints are extended or slightly flexed to a maximum of 10°.

The dorsal splint maintains better control of the MCP and IP joints, assuring that the hand remains in the "safe position," when compared to the volar splint. Pad the splint adequately to prevent pressure sores, since the dorsal surface of the hand lacks the intrinsic fat pads of the palm.

THUMB SPICA SPLINT

Scaphoid fractures, navicular fractures, carpometacarpal subluxations and dislocations of the thumb, and collateral ligament injuries of the thumb can all be immobilized in a thumb spica splint (**Figure 91-14**). This splint extends to the proximal forearm. It can be extended proximally to include the elbow joint if required. It is positioned on the forearm, like a radial gutter splint, but only the thumb is immobilized. There are several methods to forming a thumb spica splint. One can simply lay the plaster over the radial aspect of the forearm and thumb. It is useful to cut one side of the splint into a shape that conforms to the thumb to facilitate the placement of the splint material around the thumb (**Figure 91-14A**). Cutting a wedge out of one side of the plaster will allow for easier splinting of the thumb without excess material







FIGURE 91-14. The thumb spica splint. **A.** One technique of thumb spica application with the splinting material cut to conform to the thumb. **B.** Cutting the splinting material facilitates this different technique of thumb spica application. **C.** The final product with the wrist dorsiflexed 20° and the thumb positioned as if a glass were being held in the hand.

collecting in the first web space (**Figure 91-14B**). Position the thumb as if a glass were being held in the hand with the wrist in 20° of dorsiflexion (**Figure 91-14C**).

FINGER SPLINTS

Immobilization of the finger lends itself to great creativity in the field of splinting. Finger splints may be adequate for immobilization of stable finger fractures, reduced dislocated joints, or ligamentous strains. Splint the finger in full extension if it involves an extraarticular fracture of the distal phalanx. Splint the finger in slight flexion if it involves the strain of a joint or ligament. The finger can be splinted in isolation, or it can be immobilized with the adjacent finger for additional stability. Applying a single-digit or two-digit splint allows neighboring joints to remain mobile. Splinting material is rarely used for finger splints in the modern Emergency Department setting. The creation of foam-padded metal or plastic splints has facilitated immobilization of the affected digit. Nonetheless, small strips of cut splinting material can still be used to stabilize any finger injuries. **The juxtaposition of the affected finger with its neighboring finger requires padding between the digits to prevent skin maceration and breakdown.**



FIGURE 91-15. The short arm cast. **A.** Flex the elbow 90°. The patient can help position the wrist and fingers in a position of function. **B.** Tubular stockinette is applied to the entire arm in anticipation of a long arm cast. **C.** Cotton cast padding is applied to the forearm. Adequate padding is also needed at the thumb, as it will remain exposed and mobile. **D.** Cut one side of the casting material as it is wrapped around the thumb. Less bunching of excess material occurs with quick cuts of the casting material. **E.** An additional length of casting material (four to five layers) can be applied along the ulnar length of the cast. This serves as reinforcement if additional strength is necessary. **F.** Mold the cast with the palmar aspect of the hands.





FIGURE 91-15. (*continued*) **G.** The wet casting material and underlying padding are cut and folded back to fully expose the thumb. **H.** The "okay" sign of a properly exposed thumb.

SHORT ARM CAST

The short arm cast is used for stable fractures of the metacarpals, the carpal bones, the distal radius, and the radial or ulnar styloid processes (**Figure 91-15**). The short arm cast begins at the proximal forearm and extends to include the palm and the dorsum of the hand. The metacarpophalangeal and elbow joints are left exposed to allow for full motion at these joints. Flex the patient's elbow 90° (**Figure 91-15A**). Place the wrist in the desired position. The extent of flexion and ulnar-radial deviation of the wrist is determined by the underlying injury. The forearm can be in a neutral, pronated, or supinated position. Apply bias stockinette (**Figure 91-15B**). Apply cotton cast padding (**Figure 91-15C**). Ensure that extra padding is applied to the bony prominences of the base of the thumb and the ulnar styloid.

Apply the casting material. Roll the casting material over the padding from the hand to the forearm. A quick trim of the casting material will allow for a better fit as it passes around the thumb (**Figure 91-15D**). **Provide adequate space for the thumb so that its motion is not limited.** The application of additional layers to the anteromedial surface will strengthen the cast (**Figure 91-15E**). Mold the cast with an anterior–posterior force applied to the forearm and not up and down strokes (**Figure 91-15F**). Use smooth, rapid, and repetitive motions to mold and laminate the casting material. Trim the casting material while it is still wet to even out the thumb opening and the cast ends (**Figure 91-15G**). Ensure that all protective padding is pulled out from under the casting material to protect the skin from the sharp edges (**Figure 91-15G**). The patient should be able to touch the tips of the thumb and index fingers when the cast is properly applied (**Figure 91-15H**).

LONG ARM CAST

A short arm cast can easily be extended into a long arm cast if needed. Simply extend the cast proximally with the elbow in 90° of flexion. Extend the padding and the casting material to the proximal humerus, ending two or three finger breadths distal to the axilla (**Figure 91-16**). Be careful to provide adequate padding around the axilla or the patient will complain about the sharp cast edge.

LOWER EXTREMITY SPLINTS AND CASTS

ANKLE (SHORT LEG) SPLINT

The ankle splint helps to immobilize isolated ankle injuries with the joint at a 90° angle (**Figure 91-17**). This splint is commonly used for ankle fractures and sprains. It can also be helpful for certain stable fractures of the foot. This splint can be applied as a posterior splint or a lateral to medial stirrup splint.[13] Combining the two techniques can provide additional support for the ankle and is known as a trilaminar splint. The first part (posterior splint) provides posterior support to the foot and ankle. The second part creates a medial-to-lateral stirrup-like splint around the sides of the ankle for additional stability.

Place the patient prone with their knee flexed 90° and the foot pointing upward (**Figure 91-17A**). Place the posterior support of splint material from the proximal posterior calf, passing under the heel, and along the plantar surface of the foot (**Figure 91-17B**). It



FIGURE 91-16. The short arm cast is extended into a long arm cast. The axilla needs adequate padding for protection of its sensitive skin.



FIGURE 91-17. The ankle splint. **A.** Stockinette is applied and the leg is positioned. **B.** The splinting material is applied posteriorly. **C.** A stirrup splint is applied around the medial to lateral ankle. **D.** Fold the corners and smooth out the splint. **E.** An elastic wrap is applied over the splint after folding back the stockinette. The foot is maintained in this position until the plaster sets.

can be extended distal to the toes to provide protection. Place the foot 90° to the tibia and in neutral rotation.

For a "stirrup" support of the ankle, begin by applying splinting material onto the length of the medial aspect of the proximal calf, over the medial malleolus, under the heel, and up the lateral aspect of the ankle and calf (**Figure 91-17C**). The stirrup portion should be long enough to go from mid-tibia to mid-fibula when wrapped under the affected foot. Fold and smooth the edges of the stirrup around the heel (**Figure 91-17D**). Keep the ankle flexed 90° with the foot neutral while the splint material sets (**Figure 91-17E**).

LONG LEG SPLINT

This splint is commonly used for knee and tibial injuries prior to and after surgical fixation. It is basically a longer extension of the short leg splint described above. Posterior, medial, and lateral lengths of splinting material are used to stabilize the leg while the anterior aspect of the leg is left exposed. Measure the extremity from the gluteal crease distally to the tips of the toes. It is important to add an additional 1 to 2 in. to the measured length so that the splinting material can be folded back on itself to protect the patient from the sharp ends. The application of medial and lateral splinting material begins at the upper thigh just below the level of the gluteal crease and travels down the knee, calf, and under the ankle. The posterior portion of splinting material begins at this same level and travels down the posterior aspect of the leg, behind the knee, curving around the heel, and ending just beyond the ends of the toes. Flex the foot 90° to the tibia, flex the knee 10° to 30°, and mold the splint. Failure to keep the ankle at 90° will allow the Achilles tendon to shorten and stiffen. A pillow may be placed under the knee to maintain 20° to 30° of flexion while the splint hardens.



FIGURE 91-18. Positioning and splinting of the patient with an Achilles tendon injury.

SPLINT FOR ACHILLES TENDON RUPTURE

Rupture of the Achilles tendon can be managed surgically or conservatively with immobilization. Surgery is often delayed and the patient will require immobilization. Position the patient as if placing an ankle splint or have the patient sit up with the affected extremity hanging over the gurney's edge. Position the foot in 20° to 30° of plantarflexion (**Figure 91-18**). This is a position that the foot will naturally relax into. Place a posterior splint on the lower extremity extending from the proximal calf to the distal aspect of the toes. Cut out wedges of plaster in order to minimize buckling at the malleoli as the splint material wraps around the heel.

SHORT LEG CAST

The short leg cast is used for stable ankle fractures and stable fractures of the hindfoot, midfoot, and forefoot (**Figure 91-19**). Place the patient either supine or sitting on the edge of the gurney. Place a padded block under the distal thigh if the patient is supine. Instruct an assistant to hold the patient's toes to help keep the lower extremity in a good position. Holding the leg by the toes may allow the force of gravity to disrupt fracture alignment. Care must be taken to prevent this outcome. The patient can sit upright on the edge of the gurney with the affected leg hanging down freely if no assistant is available.



FIGURE 91-19. The short leg cast leaves the knee and tibial tuberosity exposed. The finger is pointing to the tibial tuberosity.

The short leg cast begins at the proximal calf, below the knee, and extends down to the toes (**Figure 91-19**). The knee and tibial tuberosity are left entirely free to allow for full flexion and extension. The toes can be left entirely exposed or the cast can provide a hard sole of support and protection beneath the toes. Apply cotton cast padding with extra attention to the areas of bony prominence such as the fibular head, the lateral malleolus, and the medial malleolus. Apply the casting material from the calf to the toes as if applying a short arm cast. Mold the casting material around the Achilles tendon, away from the malleoli and to conform to the plantar arch. Cut the wet casting material under the metatarsal heads to expose the toes or leave it long to support the entire toes.

Converting a short leg non-weight bearing cast to a walking cast requires small adjustments to the existing cast. Supplement the arched foot of the short leg cast with additional casting material to form a flat surface. **Apply a preformed heel after the cast has completely dried to prevent any indentation.** Place the walking heel in the midsagittal plane of the foot with the center aspect lining up with the anterior calf. Secure the heel in place with copious casting material wrapped around the foot and ankle (**Figure 91-20**).



FIGURE 91-20. Converting the short leg cast into a walking cast. A walking heel is secured with an additional casting material over-wrappings.



FIGURE 91-21. The long leg cast.

LONG LEG CAST

The long leg cast can be used for immobilization of distal femoral or proximal tibial fractures (**Figure 91-21**). The cast extends from the metatarsal heads to several finger breadths below the groin. The leg is immobilized with the knee in slight flexion and the foot 90° to the tibia with no internal or external rotation (**Figure 91-21**). Extending the short leg cast up to the groin is a safe and stepwise technique of forming a long leg cast. Be sure to provide sufficient overlap of casting material at the junction between the two casts. Inadequate overlap will weaken the integrity of the cast. Support the knee in slight flexion while the casting material sets. Make sure that there is adequate padding around the proximal free edge of the cast to protect the groin.

KNEE IMMOBILIZERS

Knee immobilizers can be made using splinting material and are indicated for ligamentous injuries. Measure the extremity starting 10 in. above the patella to 10 in. below the patella. Double that length and cut the splinting material. Fold the splinting material end-to-end. Make a cut in the folded side extending from one edge to the middle of the folded side to create a hinge. Apply cotton cast padding starting 10 in. above the patella to 10 in. below the patella. Place the hinged portion of the splinting material 10 in. below the anterior patella with the cut ends extending proximally up both the medial and lateral leg. Secure the splinting material with a loose fitting elastic bandage.

AFTERCARE

The most feared complication of a splint or cast application is the development of a compartment syndrome. The aftercare is geared toward edema reduction and patient education. Instruct the patient regarding the early signs of a compartment syndrome. This includes increased pain, pain with passive motion, paresthesias, pallor, decreased or altered sensation, as well as delayed capillary refill. The patient should return to the Emergency Department immediately if they develop any of these symptoms, if the digits become cold or blue, or if the patient has other concerns. The extremity should be maintained above the level of the heart for the first 48 to 72 hours after the injury. Ice should be applied to the surface of the cast or splint for at least 15 minutes three times a day. The cold therapy will be transmitted through the cast or splint and result in significant reduction of edema. Active motion of the fingers and toes should be encouraged to help reduce edema in the extremity. **The cast or splint must be kept completely dry.** Should bathing be desired, instruct the patient to place two plastic bags over the extremity and tape the proximal edge to the skin of the extremity. Sufficient pain medication should be supplied to last the patient until their follow-up visit with an Orthopedic Surgeon. This should include nonsteroidal anti-inflammatory drugs supplemented with narcotic analgesics. A sling may facilitate mobilization for some upper extremity injuries.

COMPLICATIONS

The most common complications associated with the application of a cast or splint include plaster sores, compartment syndrome, joint stiffness, thermal injury, infection, and allergic reactions. The following section focuses on the prevention of these complications.[4,6,10]

PLASTER SORES

Plaster sores result from ischemic necrosis of the skin underneath a cast or splint. The skin begins to exhibit necrosis after only 2 hours of continuous pressure. **Great care should be taken in applying a cast or splint and only molding it with the broad surfaces of the hands. Molding with the fingers can result in indentations and localized areas of pressure. The cast or splint should never be allowed to rest on a hard or pointed surface until it is completely dry.** Points of contact on the hard surfaces may cause impressions that result in increased pressure. Extra padding over bony prominences may decrease the incidence of plaster sores.

Complaints of pain should be taken very seriously. The cast or splint should be split or removed immediately and the skin examined. If the pressure point is not addressed rapidly, the pain will often subside as the skin becomes necrotic. This oversight often results in a foul smelling pressure sore under the cast or splint when the patient returns for follow-up. Cast and splint treatment may be rife with complications for patients with limited sensation from underlying medical conditions (i.e., diabetes, paraplegia, and myelomeningocele). **Great care should be taken and extra padding used when casting or splinting these individuals.**

Common areas of pressure necrosis also include the proximal and distal ends of the cast or splint. These are areas of stress concentration. **Great care should be taken in padding the ends of the cast or splint during the application. No plaster or fiberglass should ever touch the skin directly. If the edges of the splint are sharp or too long, they should be folded out and away from the patient.**

COMPARTMENT SYNDROME

A compartment syndrome is a significant complication from the application of a cast or, less commonly, a splint. The rigid immobilization prevents soft tissue expansion from edema and decreases the amount of fluid needed to raise compartment pressures.[11] In cases of acute fractures, casts should be used with caution and always split in the direction perpendicular to the force needed to maintain the reduction. **For example, after casting a distal radius fracture where a dorsal mold is needed to maintain the reduction, split the cast longitudinally on the volar and dorsal surfaces (i.e., bivalved) to allow for mediolateral spread of the plaster.** Splinting greatly reduces the chance of iatrogenic-induced compartment syndromes because unlike casting, splints do not harden circumferentially.

It is not sufficient to split only the plaster. The plaster and underlying cotton cast padding must be split to visualize the skin underneath. Making a single longitudinal cut (i.e., univalving) in

the cast can also decrease the compartment pressure. Univalving the cast can decrease intracompartmental pressures by 30%.[12] Spreading the cast 1 cm after cutting it can lower the pressure 60%.[12] Splitting the cotton cast padding will decrease the pressure by 70%.[12]

JOINT STIFFNESS

Joint stiffness is a significant complication of joint immobilization with casts and splints. Sometimes the immobilization is unavoidable, as the incorporation of the ankle and the knee in a long leg cast. **Every effort should be made to decrease adjacent joint immobilization as soon as it is safe and practical.** For example, by converting a long leg cast into a short leg cast.

Immobilize the extremity in a position of function as long as this does not interfere with the maintenance of fracture reduction. For example, take great care not to immobilize the ankle in plantarflexion when applying a lower extremity splint or cast. This mistake is commonly seen when a long leg cast is placed. This pitfall may be avoided by the stepwise application of the cast. First apply the cast to the foot and ankle with the ankle held 90° to the tibia. Second, extend the cast proximally to become a short leg cast and mold the reduction. Finally, extend the cast up the thigh as needed. An additional benefit is the reduction of anterior compartment pressures of the leg when the foot is held in 0° to 37° of dorsiflexion.

Great care should also be taken in splinting the upper extremity. **Every effort should be made to leave the fingers mobile at the metacarpophalangeal joints.** Immobilization of the metacarpophalangeal joints in extension results in shortening of the collateral ligaments and thus limits flexion. **Immobilize the metacarpophalangeal joints in 90° of flexion if they must be immobilized.** This position keeps the collateral ligaments in a lengthened position and allows a rapid return to function.

THERMAL INJURY

Thermal injury may result from the exothermic reaction of plaster or fiberglass as it sets (i.e., dries). The heat generated during the setting increases as the number of layers (i.e., thickness) increases as well as the temperature of the water increases. Also important is the ability to dissipate the heat generated by the drying plaster or fiberglass. Placing a cast or splint on a plastic pillow as it dries will result in reflection of the heat and an increased temperature within the cast or splint. The use of cloth pillows or towels under the cast or splint allows for some dissipation of the heat. Optimal heat dissipation occurs by exposing the cast or splint to circulating air.

Sufficient cotton cast padding must be used to protect the skin. Plaster and fiberglass must never touch the skin directly. The incidence of thermal injury can be decreased by using cool water and as thin a layer of plaster or fiberglass as possible to accomplish stable immobilization of the extremity. Great care should be used in the application of a cast or splint to anesthetized patients, insensate limbs, or confused patients.

INFECTION

Infection secondary to a cast or splint is uncommon and is usually related to open wounds or exposed surgical pins underneath the plaster. Fresh water should be used to wet the plaster. Do not use standing or previously used water, as it is an excellent culture medium. All wounds should be dressed with sterile gauze and cotton cast padding prior to applying the cast or splint. Windows can be created over wound sites to allow for regular care and evaluation. Patients should be instructed to keep casts and splints clean and dry so as to prevent skin maceration.

ALLERGIC REACTIONS

Allergic reactions to cotton, fiberglass, and plaster have been reported but are exceedingly rare. Orthopedists and orthopedic technicians may develop a contact dermatitis from continued exposure to plaster over many years. Gloves should be worn for plaster and fiberglass application.

SUMMARY

The initial management of orthopedic trauma is a fundamental aspect of Emergency Medicine. Fractures and dislocations of the extremities are routinely handled in the Emergency Department with prompt Orthopedic follow-up or consultation. The application of external immobilization can be the definitive or temporizing management of the injured extremity. The application of splints accounts for the majority of immobilization of injured extremities. Cast application plays a role in maintaining bony alignment following closed reductions of fractures.

Clear benefits of external immobilization include pain relief and the reduction of further soft tissue injury from bony fragments. Immobilization of the fracture decreases motion and traction on the nerve-rich periosteum.[4,7] The immobilization of fracture ends protects adjacent neurovascular structures from injury and helps prevent bony fragments from penetrating the skin. External immobilization also reduces the area available for hemorrhage and decreases bone bleeding.[4] Early immobilization leading to fracture stabilization is also important in reducing the morbidity associated with long bone fractures.[12] Finally, the closed treatment of fractures facilitates the body's natural processes of repair. External periosteal and internal intramedullary callus formation is optimized in the setting of bony alignment that has been secured by casting or splinting.

The application of splints is an essential skill for any Emergency Physician. The application of a cast in the Emergency Department is appropriate in some select situations. The casting or splinting of an extremity is simple, easy to perform, and relatively quick.

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SECTION 7

Skin and Soft Tissue Procedures

92 General Principles of Wound Management

Lisa Freeman Grossheim

INTRODUCTION

An acute wound can be defined as an unplanned disruption in the integrity of the skin, including the epidermis and dermis. **The goals of wound management are to restore tissue continuity and function, minimize infection, repair with minimal cosmetic deformity, and be able to distinguish wounds that require special care.** The principles of wound management should be emphasized over the repair technique. Appropriate wound management prior to approximating the wound will allow it to heal with minimal complications. This includes wound cleansing, debridement of the wound edges, wound approximation, and prevention of secondary injury.

HEALING OF WOUNDED TISSUE

PHASES OF WOUND HEALING

The response of tissue to an injury is described in three phases. The first phase is coagulation and inflammation. The second phase is the proliferative phase. The final phase is the reepithelialization or remodeling phase.

Phase I consists of coagulation and inflammation. It occurs in the first 5 days. This phase is also known as the vascular phase. A fibrin clot forms a transitional matrix that allows for the migration of cells into the wound site over a period of 72 hours. Inflammatory cells (i.e., neutrophils, monocytes, and macrophages) kill microbes, prevent microbial colonization, break down soluble wound debris, and secrete cytokines. The cytokines signal synthetic cells, such as fibroblasts, to initiate phase II. Most sutured wounds develop an epithelial covering that is impermeable to water within 24 to 28 hours.

Phase II is the proliferative phase. It occurs during days 5 to 14 after the injury. Fibroblasts proliferate and synthesize a new connective tissue matrix that replaces the transitional fibrin matrix. Granulation tissue consisting of fibroblasts, immature connective tissue, epidermal cells that have migrated, and abundant capillaries forms within the wound. Fibroblasts release collagen, a protein substance that is the chief constituent of connective tissue. **At 5 days, the tensile strength of the wound itself is 5% that of normal skin. Collagen formation peaks at day 7.**

Phase III is known as the remodeling, reepithelialization, or maturation phase. It occurs from day 14 and lasts until there is complete healing of the wound. The new granulation tissue is being converted into a scar. The scar consists of a rich matrix with decreasing cell density, decreasing vascular density, and increasing thickness of collagen fiber bundles packed in parallel arrays.[1] **The wound will have 15% to 20% of its full strength at 3 weeks and 60% of its full strength at 4 months.** Tensile strength continues to increase up to 1 year after wounding. The skin will eventually regain only 70% to 90% of its original tensile strength.

FACTORS AFFECTING NORMAL REPAIR

The most common causes of improper wound healing are tension on the wound edges, necrosis and/or ischemia of the tissues from local conditions (e.g., crush injuries and contusions decrease blood flow and lymphatic drainage, which alters local defense mechanisms), or shock. Hypovolemia is the major deterrent to wound healing in patients with hemorrhage and shock, hemorrhage from inadequate hemostasis, infection, or retention of foreign bodies. Systemic conditions such as malnutrition, immunosuppression, shock, diabetes secondary to microangiopathy, decreased oxygen and nutrient delivery to the wound, renal insufficiency, cytotoxic drugs, vitamin deficiency, trace metal deficiency, and collagen vascular disease can result in poor wound healing. Polymorphonuclear leukocyte function is known to be impaired from hyperglycemia, jaundice, uremia, cancer, or chronic infections.

Drugs and medications can contribute to good wound healing or affect it adversely. Malnutrition, lack of protein, and lack of vitamins (e.g., vitamins A and C) may inhibit or prolong healing. Zinc deficiency, which is reversible, may play a role in retarding the healing process.[3] Anti-inflammatory drugs (e.g., colchicine, aspirin, and glucocorticoids) disrupt macrophage function, collagen synthesis, and polymorphonuclear neutrophil concentrations. Pretreatment or early introduction of glucocorticoids results in retarded wound repair by slowing cell proliferation.[4]

SCAR FORMATION

Some 6 to 12 months are required to form a mature scar. This explains why scars should not be revised until 12 months have passed. A wider scar, inadequate wound closure, or a wound dehiscence may occur in areas with increased skin tension or if the wound is in an area of excessive motion (e.g., over joints). **Adequate immobilization of the approximated wound (but not necessarily the entire anatomic part) is mandatory after wound closure for efficient healing and minimal scar formation.** Contractures can develop when a scar crosses perpendicular to a joint crease. These patients may require physical therapy to prevent the loss of range of motion secondary to contractures.

Hypertrophic scars result from full-thickness injuries. **Hypertrophic scars are characterized by a thick and raised scar that remains within the boundaries of the original injury.** They must often be corrected by surgical intervention.[1]

Keloids are hypertrophic scars (i.e., thick and raised) that exceed the boundaries of the initial injury. They can develop from superficial injuries and appear to have a genetic basis. Surgical intervention rarely resolves keloids. They may be prevented or minimized by the local application of pressure dressings, Silastic dressings, glucocorticoids, and calcium channel blockers.[1]

The repair procedure may result in more scar tissue. Absorbable suture materials contribute to the formation of suture marks because of their increased reactivity, whereas nonabsorbable materials do

not. Wounds that are approximated too tightly can result in tissue ischemia and more scar tissue formation.

WOUND CLOSURE TECHNIQUES

PRIMARY INTENTION

Primary intention involves surgically approximating the wound edges shortly after the time of injury. The skin's greatest strength is in the dermal layer. The best repair results when the entire depth of the dermis is accurately approximated to the entire depth of the opposite dermis. **Accurate approximation of the epidermis gives a cosmetically appealing effect to the repair but does not contribute to its strength. Wound eversion and the use of buried sutures can greatly improve healing by primary intention.**

SECONDARY INTENTION

Secondary intention involves allowing the wound to heal without any surgical intervention. The wound is left open and allowed to heal from the inner layer to the outer surface. It is a more complicated and prolonged healing process than primary intention. Infection, excessive trauma, tissue loss, or imprecise approximation of tissue can result due to healing by secondary intention. Wound contraction by granulation tissue containing myofibroblasts is the major influence on this type of healing. Wound contraction becomes more significant when the dermis is lost.

Concave skin wounds heal with the best results. These areas often heal better by secondary intention than by primary intention. Such concave areas include the inner ear, the nasal alar crease, the nasolabial fold, the temple, and the concave areas of the pinna. Flat surfaces can also heal well by secondary intention, although surgical intervention may be best. Some examples include the forehead, the side of the nose, and periorbital areas. Wounds on convex surfaces are not optimal for healing by secondary intention. Convex surfaces include the malar cheek, the tip of the nose, and the vermilion border of the lip.[2]

TERTIARY INTENTION

Tertiary intention, or delayed primary closure, can often decrease infection rates. Wound closure by tertiary intention is accomplished 3 to 5 days following the initial injury. It is a combination of allowing the wound to heal secondarily for 3 to 5 days and then primarily closing the wound. It is the safest method of repair for wounds that are contaminated, dirty, infected, traumatic, associated with extensive tissue loss, at high risk for infection, and for wounds that are "too old" to close. The ultimate cosmetic result is the same as that of primary wound closure. This method may not be suitable for young children, having to return a second time for an uncomfortable procedure.

During the interim period, instruct the patient to apply wet-to-dry dressing changes twice a day. Upon the patients return, assess the wound for any signs of infection. Anesthetize and clean the wound. Scrub the wound base and edges with saline-moistened gauze and irrigate the wound to remove any dirt, debris, and granulation tissue. Suture the wound to approximate and evert the wound edges. The postprocedural wound care is the same as if the wound was closed primarily.

WOUND INFECTION

Wound infections occur as a result of the patient's resident flora and the environment. It is related to wound age, the amount of devitalized tissue, and the tissue concentration of pyogenic bacteria. A wound infection exists when there are bacterial densities of more than 10,000 organisms per gram of tissue.[5] Bacteria slow wound healing by secreting proteases that directly injure the tissue in the wound.[2] They also secrete other factors that lead to excess inflammatory cells in the wound, which also injures the tissue.[2]

PATIENT EVALUATION AND ASSESSMENT

HOST HISTORY

A thorough and accurate history and physical examination are essential for optimum wound management. Documentation of the patient's age, prior tetanus immunization history, systemic illnesses, medications, allergies (such as to latex or local anesthetics), and the circumstances of the injury are essential to good wound management. These principles are emphasized because the presence of disease processes (such as diabetes mellitus, chronic malnutrition, alcoholism, hepatic or renal insufficiency, asplenism, malignancies, and extremes of age) may impair host defenses or complicate wound healing.[6,7] **Second, the wound itself is often less important than an associated injury to an adjacent structure or cavity. Associated injuries can easily be missed without a specific directed search for their presence.**

TETANUS PROPHYLAXIS

A thorough history must be obtained concerning the patient's tetanus immunization status. Important factors to consider in assessing the risk of developing tetanus include prior immunization history, the type of wound, the degree of wound contamination, the time from injury to treatment, and the presence of underlying medical disease.

Wounds may or may not be prone to tetanus (**Table 92-1**). The administration of tetanus prophylaxis is based upon the patient's immunization history and the risk of developing tetanus (**Table 92-2**). Current guidelines state that tetanus toxoid (Td) may be deferred in patients with "clean, minor" wounds who have completed a primary series or received a booster dose (Td 0.5 mL IM) within 10 years. Consider tetanus immune globulin (TIG 250 to 500 U IM) in addition to Td for patients at risk of developing tetanus. Elderly patients without documentation of a primary series, patients from nonindustrialized nations, and those from rural or

TABLE 92-1 Characteristics of Tetanus-Prone and Non-Tetanus-Prone Wounds

Clinical feature	Tetanus-prone wounds	Non-tetanus-prone wounds
Contaminants (feces, foreign body saliva, and soil)	Present	Absent
Devitalized tissue	Present	Absent
Infection	Present	Absent
Ischemic or denervated tissue	Present	Absent
Mechanism of injury	Burn, crush, bullet	Sharp and smooth (knife or glass)
Wound age	>6 h	<6 h
Wound depth	>1 cm	<1 cm
Wound type	Abrasion, avulsion, crush, irregular, stellate	Linear or straight

TABLE 92-2 Tetanus Prophylaxis

Immunization history	Tetanus-prone wounds	Non-tetanus-prone wounds
History of adsorbed Td	Td and TIG	Td and TIG
Unknown or less than three doses	Td, TIG, and complete the series	Td and complete the series
Fully immunized, >5 years and <10 years since last dose	Td	None needed
Fully immunized; ≤5 years since last dose	None needed	None needed
Fully immunized, ≥10 years since last dose	Td and TIG	Td

Td, tetanus and diphtheria toxoids; TIG, tetanus immune globulin.

inner-city areas may never have received tetanus immunization and should be considered for TIG.

MECHANISM OF INJURY

Severity of injury as well as associated injuries can be anticipated by determining the precise mechanism of injury. This will often indicate additional soft tissue injury, the presence of a foreign body, or the amount of contamination present.

Soft tissue injuries are rarely surgical emergencies. The patient's general condition should be attended to, with priority given to observing the ABCs (airway, breathing, and circulation) of Emergency Medicine. The skin margins of a laceration can be tacked together with well-placed atraumatic sutures and the wound covered with a moist pressure dressing until the time is more opportune for definitive repair.

Important questions and answers that must be documented are exactly how the injury occurred, when and where the injury occurred, and what contaminants were present or involved. If the injury involves the hand, what position was the hand in at the time of the injury, what kind of work does the patient do, and which is the patient's dominant hand? Complicated wounds, such as those caused by animal or human bites, chemical exposure, or high-pressure injection may require a more extensive evaluation and consultation with the appropriate specialist.

CLASSIFICATION OF WOUNDS

Wounds are described and classified based upon their cause and the type of injury. Abrasions are the result of grinding or abrading forces on the skin. The epidermis and/or dermis is disrupted but not removed in its entirety. Crush injuries are due to compressive forces. The patient sustains a large amount of kinetic energy that results in microvascular disruption, edema, and devitalized tissue. Crush wounds are 100-fold more likely to become infected than lacerations because of the much lower bacterial loads required for infection.[8]

Lacerations are wounds that are caused by shear forces that result in a tearing of the tissue. They are subclassified as avulsion, shear, or tension lacerations. Avulsion lacerations are injuries where there is sharp trauma at an angle that removes the epidermal and possibly also the dermal layer of skin. The injury creates a skin flap. Shear lacerations are produced by a sharp force, usually perpendicular to the skin surface, that results in a tidy or clean wound. These wounds are usually caused by knives, glass, or sharp metal objects. There is little tissue damage, and this type of wound is not prone to infection. Tension or tensile lacerations are injuries with jagged or contused edges that are created by a compressive force. These wounds pose a greater risk for infection than shear lacerations.[8]

Punctures result in a wound that is deeper than it is wide. The skin opening is small and the depth of the wound is often unknown. Such wounds are made by discrete and thin objects, and they carry a high risk for infection. Irrigation is mandatory for puncture wounds; however, the pressure must not be so high as to drive contaminants deeper into the wound.

The wound may also be clinically classified based upon an estimate of microbial contamination and the subsequent risk of infection. Clean wounds are those that occur under aseptic technique. These are usually surgical incisions that are elective in nature and preceded by a thorough skin cleansing and decontamination process. Clean-contaminated wounds are those associated with the usual and normal flora of the region. There is no contamination from foreign bodies or pus. Contaminated wounds are those that are traumatic (e.g., lacerations, open fractures), less than 12 hours old, or associated with a break in aseptic technique. Most wounds seen in the Emergency Department are of the contaminated type. They may be associated with the introduction of "dirt" or foreign bodies into the wound. Dirty wounds are those that are heavily contaminated (e.g., soil or feces), occur through infected tissue, are over 12 hours old, are associated with retained foreign bodies, or associated with devitalized tissue.

TIME OF INJURY

This is probably the most pertinent factor of the history. After 3 to 6 hours, the bacterial count in a wound increases dramatically. Few studies have been conducted to determine the maximal time in which lacerations can be closed without resulting in infectious complications. One study performed in an underdeveloped country indicated that wounds might be closed up to 18 hours postinjury.[9] Lacerations of the face and scalp that are reasonably clean may be closed primarily up to 12 to 24 (or even 48) hours postinjury with little risk of infection because of the excellent circulation in these areas. Other lacerations may generally be closed primarily if they are less than 6 to 12 hours old provided that they are not heavily contaminated or located in high-risk areas (i.e., hand or foot). The infection rate rises rapidly after 12 hours.

WOUND ASSESSMENT

A complete examination and documentation of the laceration is necessary. This includes noting the location and depth of the laceration, the presence of any gross contamination, the presence of an obvious foreign body, and any associated injuries.

Assessment of soft tissue wounds involves an examination of the surrounding tendons as well as the vascular and neurologic structures; bony injuries and foreign bodies should also be sought. Emergency Physicians must possess a working knowledge of functional anatomy, particularly of the face and distal upper extremity.

Hemostasis can be achieved by direct pressure with a gauze sponge or gloved finger for simple lacerations. Suturing the wound best controls bleeding of the scalp. Extremity wounds, particularly of the wrist and hand, should have a pneumatic tourniquet applied after the extremity is elevated for 1 minute to promote venous drainage. Inflate the cuff above the patient's systolic blood pressure for 20 to 30 minutes at a time. A blood pressure cuff may be substituted if a pneumatic tourniquet is not available. For more severe bleeding, there are several commercial tourniquets available, as well as new hemostatic agents such as Quick Clot.[37–39] **Vascular**

structures (with the exception of small arterioles, small venules, and vessels within muscles) should not be clamped and may require special techniques for hemostasis.

Wounds may cross tissue planes, opening them and creating potential pockets or dead spaces. Elimination of the dead space has been advocated in the past to decrease the probability of this area becoming a nidus for infection. This once traditional practice of obliteration of dead space to avoid infection of a nonvascularized space or to prevent hematoma formation is now considered controversial. Studies in animal models have found the incidence of infected wounds to be consistently proportional to the number of suture layers.[10,11] Leaving dead space open resulted in lower rates of infection than obliterating it with sutures.[10,11] Studies in 1994 and 1996 concluded that buried absorbable sutures increase the infection rate and the degree of inflammation in contaminated wounds and do not significantly increase the degree of inflammation in noncontaminated wounds.[12] Sutures placed in fat contribute no strength to the repair and fail to prevent hematoma formation and infection. **Deep absorbable sutures may be placed to repair the periosteum, muscles, or fascia or to minimize tension on skin sutures. Use only enough subcutaneous sutures to restore anatomic and functional integrity.** In most wounds, however, leaving potential space may be preferable to attempting to obliterate it.

It is important to explore the deep structures through a full range of motion in order to detect partial tendon lacerations or joint capsule disruption. **Tendons can be evaluated by inspection, but individual muscles must also be tested for full range of motion and full strength.**

A distal neurologic and vascular examination should be performed on extremity injuries. Capillary refill should be checked distally and take less than 2 seconds. Neurologic assessment involves checking distal muscle strength and sensation. **Check two-point discrimination prior to the administration of anesthesia for hand and finger lacerations.** Two-point discrimination at 5 mm on the radial and ulnar aspects of the finger pads is the most efficient method of assessing median and ulnar nerve function. Two-point discrimination should be less than 1 cm at the fingertips. A crush injury may be associated with decreased two-point discrimination and may take several months for recovery. Numbness may also be the first sign of a developing compartment syndrome. Nerve lacerations can be repaired immediately or the wound can be loosely approximated and repair of the lacerated nerve delayed.

Obvious as well as questionable fractures should receive a radiograph of the area. Bone injuries require checking the overlying skin to exclude an open fracture. An open fracture is an indication for surgical debridement and repair except in the case of a distal phalanx fracture, which can be treated with copious irrigation, oral antibiotics, and detailed discharge instructions.

WOUND FOREIGN BODIES

Failure to identify foreign bodies in wounds may lead to complications such as an increased risk of infection, delayed wound healing, and loss of function.[36] Foreign bodies and foreign matter greatly enhance the infectivity of a given bacterial inoculum.[13] Retained foreign bodies are a common complication of simple wound repair. **Perform a thorough inspection to attempt to diagnose the presence of a foreign body.** Missed foreign bodies are the second leading cause (14%) of lawsuits brought against Emergency Physicians.[14] Some foreign bodies cause an inflammatory reaction (e.g., wood, thorns, splinters, cloth, teeth, and rubber from shoes or foam insoles), while others do not (e.g., metal, glass, most plastics, and pencil graphite).

Wound exploration, irrigation, and radiography may be needed when the clinical setting suggests a possible foreign body. **Spread the tissue during exploration. Do not cut tissue and risk neurovascular injury.** Puncture wounds have not been proven to benefit by coring or probing to determine the depth of the wound. Imaging may be required to detect retained foreign bodies. Retained wood, thorns, and plastic are often detectable only by wound exploration and may not be visible on plain radiographs. Radiographs will identify retained metallic fragments and more than 90% of glass foreign bodies if the glass does not have a low lead content and the fragments are at least 2 mm long.[15,16] Wound markers can be used during radiography. Radiographs obtained in two planes can help localize the object for recovery. Glass may penetrate at an angle and be buried deeper than it appears. The use of ultrasound is controversial because of its lack of specificity, lack of sensitivity, and operator dependency.

Foreign bodies that do not cause an inflammatory reaction are often not removed from lacerations. This is especially true if there are multiple fragments or if excessive tissue disruption will result with attempted removal. **The patient should be made aware of any retained foreign bodies at the time of discharge, their benign presence, why removal was not attempted, the possibility of later infection, and the fact that they may eventually self-extrude. This must also be documented in the medical record.** If the wound is in a complex area, such as the palm, it may be necessary to gain consultation for immediate or delayed removal. The wound can be approximated loosely and immobilized for comfort and to avoid further tissue disruption, antibiotics prescribed, and arrangements made for appropriate out-patient follow-up in 24 to 48 hours.

Soils have varied levels of contamination potential. Sandy soils present a low risk of wound contamination. Clay-containing soils are pyogenic because they impair host defense mechanisms and promote inflammation. Organic soils contain *Clostridium tetani* and a more concentrated bacterial inocula. Soil contaminants, when present, can be removed by copious irrigation. These contaminated wounds should be left open and allowed to heal by secondary or tertiary intention.

HIGH-RISK WOUNDS

Many wounds require special consideration in deciding upon the method of closure, the type of suture to use, and the use of antibiotic prophylaxis. These include wounds contaminated by saliva, feces, vaginal secretions, soil, and organic material. **Wounds in immunocompromised patients or patients taking immunosuppressive drugs may require antibiotics and longer times for the sutures to remain before removal.** Hand wounds, including bite wounds, and foot wounds require special care. Wounds greater than 6 to 12 hours old, other than wounds on the face, may require delayed closure. Puncture wounds may require radiographs, incision and exploration, and antibiotic prophylaxis. Wounds accompanied by excessive tissue damage and devitalization or crush injuries are prone to infection. Wounds with retained foreign bodies may require radiographs, exploration, and removal. Major tissue defects may be closed with advanced wound closure techniques. Wounds overlying sites of active infection require antibiotics and delayed closure. These topics are covered further on in this chapter and in other chapters of this book (see Chapters 95 through 98 for details).

SKIN AND WOUND PREPARATION

ANESTHESIA

Wounds must be anesthetized with either local or regional techniques prior to cleansing and repair. Local anesthesia distorts wound edges; therefore regional nerve blocks should be used where appropriate (e.g., the hand, face, ear, nasal cartilage, palm, sole). Refer to Chapters 123 through 129 for a complete discussion of local

anesthetic agents, regional anesthesia, topical anesthesia, nitrous oxide anesthesia, and procedural sedation.

Lidocaine (Xylocaine) in a dose not to exceed 4.5 mg/kg is an effective and standard local anesthetic agent. Lidocaine anesthesia lasts approximately 60 to 90 minutes. If a longer period of anesthesia is required, bupivacaine may be used. It provides approximately 120 to 180 minutes of anesthesia. The addition of a 1:100,000 dilution of epinephrine to lidocaine or bupivacaine will prolong the duration of anesthesia, promote hemostasis, allow a larger dose to be used, and reduce systemic absorption of locally infiltrated local anesthetic solution. Epinephrine is a potent vasoconstrictor and should not be used near end organs such as the fingers or toes. It may decrease blood flow and induce ischemia. Epinephrine should also be avoided near the tip of the nose, the ear, and the penis.

Animal model studies have consistently shown that epinephrine increases the incidence of infection in contaminated wounds. This may be due to vasospasm-induced local ischemia. Epinephrine should not be used to enhance local anesthesia in contaminated wounds. Consider the use of regional anesthesia or procedural sedation in these patients.

The pain of local anesthetic injection can be reduced. The use of a 27 or 30 gauge needle, slower and deeper infiltration (into the dermis), warming the local anesthetic solution, and the addition of bicarbonate to lidocaine (9 mL lidocaine to 1 mL of bicarbonate) may decrease the pain of anesthetic injection.[21–26] Other strategies involve anesthetizing as much tissue as possible through a single site, starting proximally on the extremity and moving distally. Infiltration of the local anesthetic solution through the wound edges is less painful than through intact skin.

Most "allergic" reactions are actually vasovagal or other adverse responses. Allergies to "caines" are attributed to what is often a vasovagal or other side effect. True allergies to local anesthetics are rare and are generally seen only with the ester class of local anesthetics. If an allergy to lidocaine (an amide class of local anesthetic) is suspected, the use of an ester class of local anesthetic is suggested. An alternative is the use of cardiac lidocaine, the prefilled syringes used in codes and cardiac arrests, which contains no preservative. It is felt that the preservative in lidocaine is responsible for the allergic effect. Another alternative is to use a 1% to 2% solution of diphenhydramine (Benadryl). This provides adequate but not ideal anesthesia. The most common complication of local anesthesia infiltration is hypotension and bradycardia as a result of a vasovagal reaction.

Topical anesthesia is an attractive alternative to injection, particularly in the management of pediatric patients with simple wounds. Lidocaine, epinephrine, and tetracaine (LET) gel or tetracaine, adrenaline, and cocaine (TAC) are two agents that can be used as effective local anesthesia.[27] Both of these agents contain epinephrine and should not be used on areas involving an end artery or contaminated wounds. TAC involves expense and incorporates problems with the use and maintenance of a controlled substance. TAC also has the potential for toxicity, especially when applied to mucosal surfaces. EMLA (eutectic mixture of local anesthetics) cream, also used for local anesthesia, has been found to provide effective anesthesia for extremity lacerations. EMLA is a combination of 2.5% lidocaine and 2.5% prilocaine suspended in an oil-in-water emulsion. Studies have found that it takes longer to obtain optimal anesthesia with EMLA than with TAC.[28]

SKIN CLEANSING

Meticulous preparation of the skin surrounding the wound and the actual wound, irrigation, and wound debridement are tantamount to good wound healing. The goal is to remove bacteria, foreign matter, and tissue debris. Wounds should be adequately anesthetized prior to cleansing and/or local exploration. Adequate light, anesthesia, and equipment are a must in order to avoid inadequate debridement, a retained foreign body, or a wound hematoma that can result in a necrotizing soft tissue infection.

Disinfecting the intact skin surrounding the wound and ridding it of foreign bodies, debris, and particulate matter is the initial step in wound preparation. This technique can be accomplished by scrubbing the skin with povidone iodine, chlorhexidine, or poloxamer 188 (Shur Clens) skin-prep solutions. **Do not expose the wound itself to these solutions.** Povidone iodine and chlorhexidine solution are bactericidal and work as it dries. Its toxicity to wound tissue is controversial. Shur Clens has no tissue toxicity but also has no antibacterial activity. A wide area surrounding the wound should be prepped with an antimicrobial agent, preferably povidone iodine or chlorhexidine solution.

HAIR REMOVAL

Hair removal is often unnecessary prior to closing wounds, can be embarrassing for the patient after discharge from the Emergency Department, and may increase the risk of wound infection. Shaving can cause minimal soft tissue trauma and wound infections.[17] **Eyebrows should never be shaved, as they can grow back unpredictably or not at all.** Simple scalp lacerations can be exposed by using antibiotic ointment (or lubricating gel) to move the hair away from the wound margins prior to placing sutures.

WOUND IRRIGATION

Wound cleansing and preparation have been proven to be the foundations of proper wound management and the prevention of wound infections. Irrigation removes contaminants, reduces infection, and improves visualization. There are two concerns regarding wound irrigation: the pressure required for adequate cleansing of the wound and the means to irrigate the wound safely while protecting the healthcare worker from the threat of human immunodeficiency virus and hepatitis B (by contamination of their own skin surfaces, mucosal surfaces [eyes, nose, or mouth], or minor open skin wounds).

Irrigation pressures of 5 to 8 pounds per square inch (psi) are felt to be adequate to cleanse a wound that is not heavily contaminated. This surface pressure can be generated by the combination of a 35 mL syringe and a 19 gauge angiocatheter held 2 cm from the wound surface.[18,40–42] Unfortunately, this process can be quite messy (**Figure 92-1**). High-pressure irrigation, which generates



FIGURE 92-1. Wound irrigation with an angiocatheter on a syringe. This process is quite messy and can result in an occupational exposure. (Photo courtesy of Zerowet Incorporated.)

peak pressures of 25 to 40 psi, has been a controversial issue in the Emergency Medicine literature. The theory is that high pressures may cause tissue disruption and increase infection rates. High-pressure irrigation should be reserved for highly contaminated wounds. High-pressure irrigation may drive contaminants deeper into puncture wounds and should be avoided.

Though there are a variety of irrigation fluids, the optimal type is unknown. Normal saline is the most commonly used irrigant. The volume of irrigation fluid to be used has not been well established. The use of 100 to 300 mL has been suggested in the literature. Heavily contaminated wounds require larger amounts of irrigant. Anecdotal recommendations suggest using 50 mL/cm for clean wounds and 100 mL/cm for dirty wounds. Heavily contaminated wounds may have to be scrubbed (after adequate anesthesia) with fine-mesh gauze or a micropore sponge using a 1% solution of povidone iodine or poloxamer 188. Tap water can be used for irrigation with no increased incidence of infection, especially when a large volume of irrigant is required.[43–47] Soaking of wounds is discouraged as a poor substitute for the preparation of contaminated or clean wounds. **Do not soak wounds in any fluid.** Soaking does not reduce bacterial contamination or decrease infection rates. It may actually increase infection rates. **Do not use undiluted povidone-iodine, hydrogen peroxide, or detergents in the wound as they cause tissue toxicity.**[48]

Numerous commercially available devices are available to irrigate a wound (**Figure 92-2**). The Combiport (Moog Medical Devices, Salt Lake City, UT) is a wound irrigation device that inserts directly into the port of an intravenous fluid bag (**Figure 92-2A**). Squeeze the bag of saline and direct the stream of fluid through the device and into the wound. Wound Wash Saline (Church & Dwight, East Princeton, NJ) is sterile normal saline within a pressurized can (**Figure 92-2B**). Direct the tip of the can toward the wound, press the button, and direct the saline stream into the wound. This is also available at retail stores for patients to use at home for wound care. The company offers a convenient chart that uses wound depth and base characteristics to determine how much saline to use to irrigate the wound. The can controls the pressure (6 to 13 psi), so that tissue is not devitalized during the irrigation. Unfortunately, using this method is quite messy as the saline and wound materials (e.g., tissue fluid, blood, and debris) splash all over.

The Emergency Physician should use barrier protection to shield their face, eyes, skin, and submucosal surfaces during the irrigation process. There are several barrier devices on the market that decrease the splatter of irrigation fluid[19] (**Figure 92-2**). Some of these devices are preattached to a wound irrigation device. Others can be attached to a wound irrigation device. The Zerowet Supershield (Zerowet Inc., Palos Verdes Peninsula, CA) is a dome-shaped device that attaches to a syringe (**Figure 92-2C**). The Combiguard Irrigation Splash Guard (Moog Medical Devices, Salt Lake City, UT) is similar in function to the Zerowet Splashield and has a slightly different shape. The Combiguard can attach to a syringe or the Combiport Wound Irrigation Device (**Figure 92-2D**). The Igloo Wound Irrigation System (Bionix Medical Technologies, Toledo, OH) is a similar device that provides a multiport shower effect to deliver the irrigation solution (**Figure 92-2E**). The Irrijet (Cooper Surgical, Trumbull, CT) is a spring-loaded, self-refilling system that

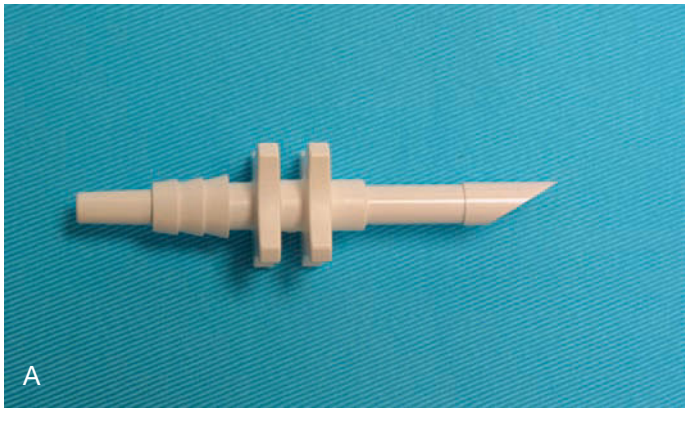
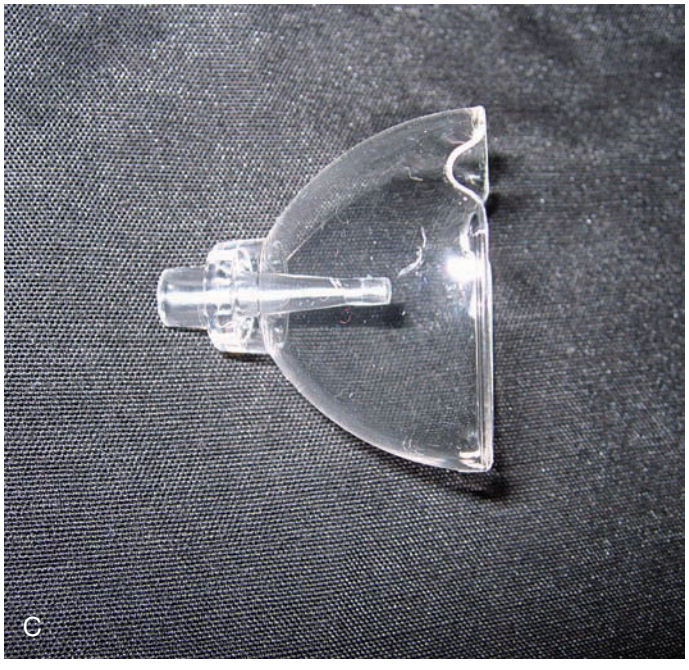
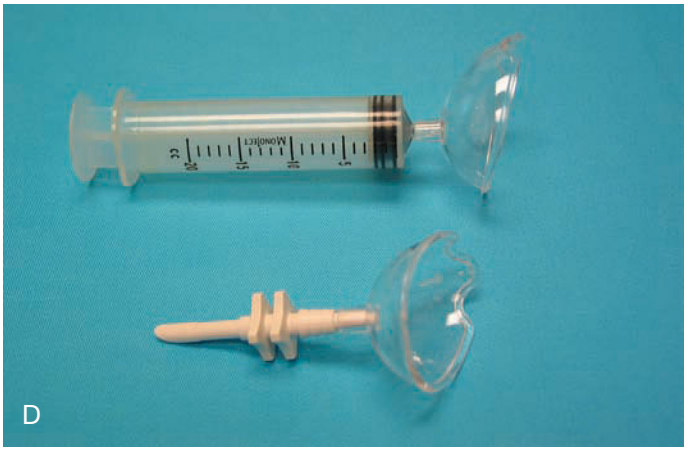




FIGURE 92-2. Commercially available wound irrigation devices. **A.** The Combiport Wound Irrigation Device (Moog Medical Devices, Salt Lake City, UT). **B.** Wound Wash Saline (Church & Dwight, East Princeton, NJ).









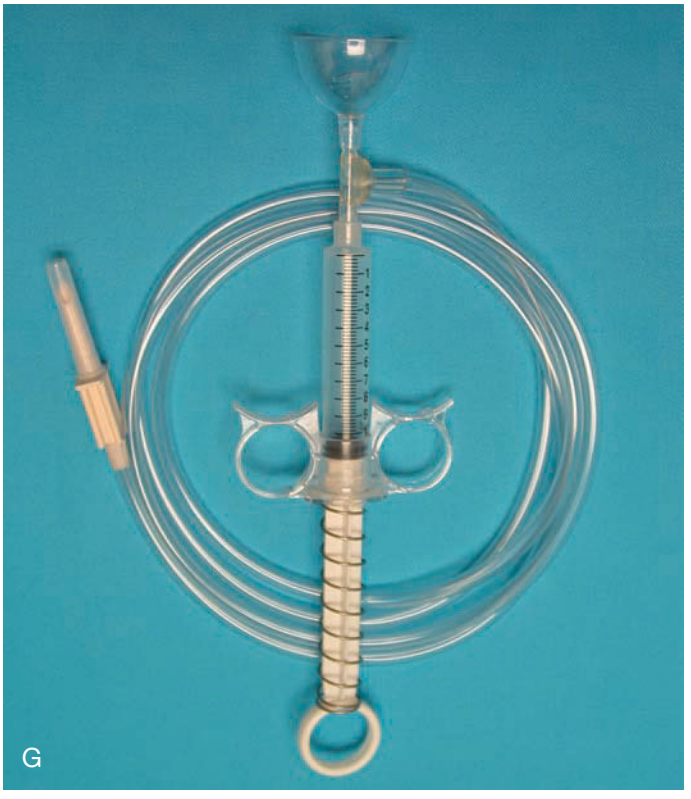


FIGURE 92-2. (*continued*) **C.** The Zerowet Supershield (Zerowet Inc., Palos Verdes Peninsula, CA). **D.** The Combiguard (Moog Medical Devices, Salt Lake City, UT) attaches to the Combiport or a syringe. **E.** The Igloo Wound Irrigation System (Photo courtesy of Bionix Medical Technologies, Toledo, OH). **F.** The Irrijet (Cooper Surgical, Trumbull, CT). **G.** The Canyons Wound Irrigation System (Wolf Tory Medical Inc., Salt Lake City, UT).

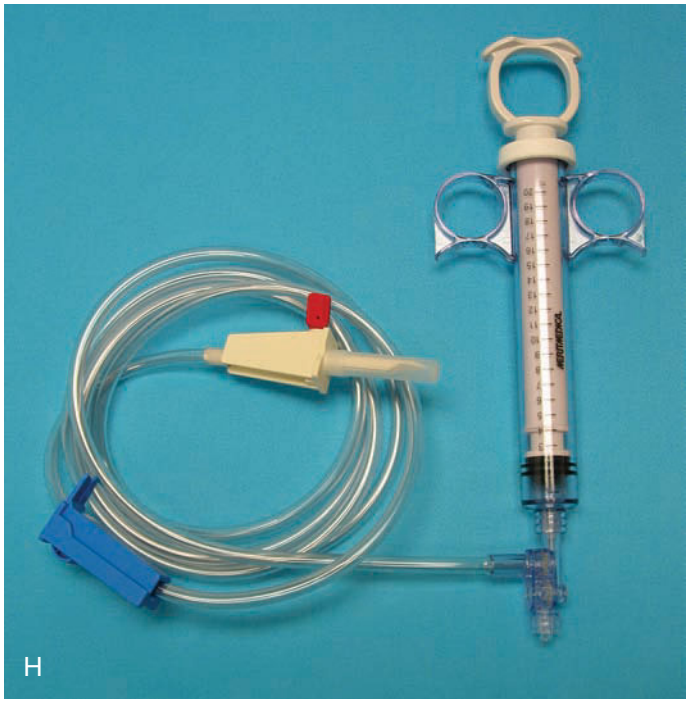








FIGURE 92-2. (*continued*) **H.** The Squirt Wound Irrigation Kit (Merit Medical Systems Inc., South Jordan, UT). **I.** The Klenzalac (Zerowet Inc., Palos Verdes Peninsula, CA). **J.** The Splashcap (Splash Medical Devices, Atlanta, GA). **K.** The Irrisept (Photo courtesy of Irrisept, Gainesville, FL).

is operated with one hand (**Figure 92-2F**). A Splashield or Splash Guard can be attached to the Irrijet. The Canyons Wound Irrigation System (Wolfe Tory Medical Inc., Salt Lake City, UT) is a similar device with the exception of using the built-in Zerowet Splashield (**Figure 92-2G**). The Squirt Wound Irrigation Kit (Merit Medical Systems Inc., South Jordan, UT) is a manually operated system that may be used alone or attached to the Splashield, Combiguard, or an angiocatheter (**Figure 92-2H**). The Klenzalac (Zerowet Inc., Palos Verdes Peninsula, CA) is a similar device with the exception of using the built-in Zerowet Splashield (**Figure 92-2I**). The Splashcap (Splash Medical Devices, Atlanta, GA) attaches to a bottle of sterile saline (**Figure 92-2J**). The Irrisept (Irrisept, Gainesville, FL) attaches to a proprietary bottle containing a saline and chlorhexidine mixture (**Figure 92-2K**).

WOUND DEBRIDEMENT

Debridement creates straight and clean wound edges that are easier to repair by removing tissue that is devitalized, contaminated by bacteria, or contaminated by foreign matter and may impair the ability of the tissue to resist infection. Successful wound closure may require the transformation of a ragged laceration, the removal of devitalized tissue, or the removal of contaminated tissue in order to convert a traumatic wound into a surgical wound. Devitalized and necrotic tissue must be removed in order to remove a nidus for bacterial growth and wound infection.[20]

Close approximation of the wound requires that debridement of jagged edges not be too vigorous in order to avoid widening the scar and making it difficult to close. Wounds of the face or areas that are devoid of redundant tissue require conservative debridement. Debridement to simplify wound closure is not always the answer for a superior cosmetic result in the repair of irregular wound edges. The meticulous repair of complex wound edges can often provide a superior cosmetic result.

Debridement can be accomplished mechanically, hydrodynamically, or with a combination of both methods. Tissue must be removed mechanically with a #11 or #15 scalpel blade or a scissors (**Figure 92-3**). Superficial debris and contaminants can be removed with a pulsatile stream of normal saline solution during the irrigation process. **Debridement must be performed using aseptic technique. Scrubbing is not a substitute for debridement of heavily contaminated tissue. Wound edges should be handled delicately or gingerly in order to avoid further soft tissue damage and devitalization of injured tissue.**

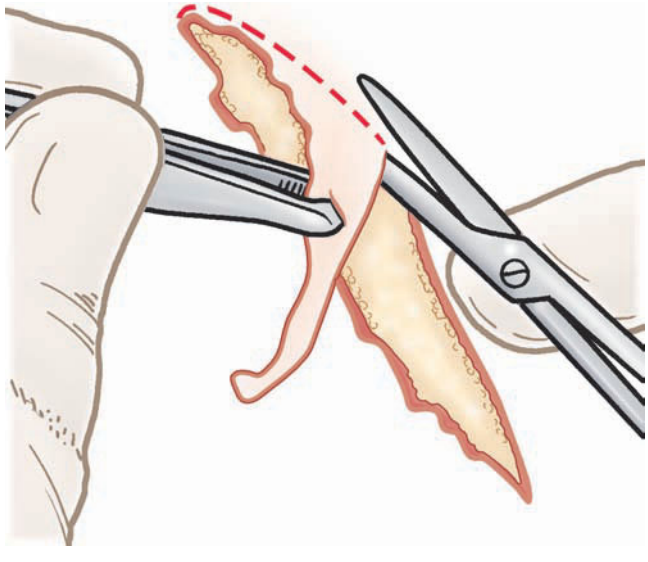


FIGURE 92-3. Wound debridement. Removal of the wound edges with a scissors (or a scalpel).

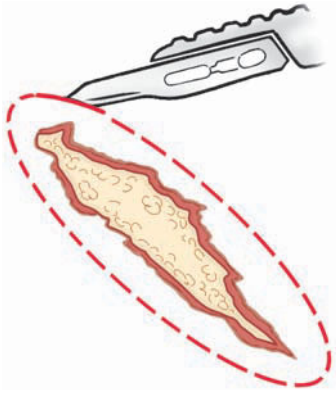


FIGURE 92-4. Wound excision. Removal of an ellipse of tissue that contains the wound results in smooth, clean edges that can be approximated.

WOUND EXCISION

The entire wound may be excised in areas of excess tissue or tissue laxity if no blood vessels, nerves, tendons, or joints lie within or at the base of the wound (**Figure 92-4**). The excision of a wound creates smooth, clean edges that may be approximated with sutures. This is especially useful in wounds that are heavily contaminated. Most wounds are excised with an elliptical incision (**Figure 92-4**). Other types of wound excision are discussed in Chapters 95 and 96.

Carefully plan the excision before removing any tissue. Mark the edges of the proposed incision with a marking pen. The long axis of the ellipse should be two-and-a-half to four times as long as the greatest width of the ellipse. Removal of too much tissue will produce a large defect that may not be possible to close primarily. Remove the tissue using aseptic technique, preventing any contamination of the new wound edges.

WOUND UNDERMINING

The undermining of tissue creates a "flap" that involves the separation of the skin and superficial subcutaneous tissue from the deeper subcutaneous tissue and fascia (**Figure 92-5**). The process of undermining tissue minimizes skin tension, allows for eversion of the approximated skin edges, and relieves the extrinsic tension from sutures. **Undermining is performed when the wound cannot be closed due to a tissue defect or if a wound is under tension.** This procedure requires the Emergency Physician to be familiar with the local anatomy so that no blood vessels, nerves, or tendons are injured in the process. **Do not undermine contaminated wounds.** Undermining large areas can separate the skin from its underlying blood supply and result in a diminished blood flow that predisposes the area to infection and necrosis. Undermining may be useful on the forehead, scalp, arm, forearm, thigh, calf, and torso. **Never undermine wounds on the palms, soles, and face.**

Undermine tissue at the dermal-epidermal junction or within the subcutaneous adipose tissue. The amount of undermining necessary to close a laceration is approximately double the width of the gap of the laceration at its widest point. A 1 cm wide laceration should be undermined for 1 cm on both sides of the wound, including the ends (**Figure 92-5**). The use of a Mayo scissors versus a #15 scalpel blade to undermine tissue is based on physician experience

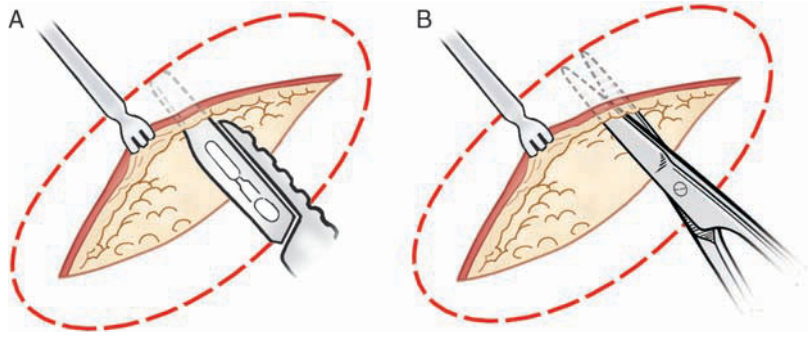


FIGURE 92-5. Wound undermining. **A.** Sharp undermining with a #15 scalpel blade. **B.** Blunt undermining with a Mayo scissors.

and preference. A Mayo scissors is recommended as it may cause less secondary injury, especially in experienced hands.

EMERGENCY DEPARTMENT VERSUS OPERATING ROOM MANAGEMENT OF WOUNDS

Laceration repair may sometimes have to be performed in the operating room. Indications for operating room repair of lacerations include those associated with open fractures, major or complex wounds involving devitalized tissue, heavily contaminated wounds, wounds with associated injuries (e.g., visceral, neurovascular, fracture, and tendon), perineal wounds, large or complicated soft tissue injuries, compartment syndromes, wounds with extensive amounts of necrotic or ischemic tissue, the total local anesthetic solution required would exceed toxic tissue levels, and high-pressure injection injuries.

ANTIBIOTIC PROPHYLAXIS

Despite the best wound care and management, the rate of infection has been determined to be approximately 1% to 12%. Not all wounds result in infection. Most uncomplicated wounds heal without the need for antibiotics. Wounds associated with an increased risk for infection are those of the extremities (especially the lower), complex wounds, or wounds over 3 to 5 cm in length. The use of antibiotics for traumatic wounds is controversial. Prophylactic antibiotics are not indicated for uncomplicated minor wounds with a low chance of becoming infected. It has not been proven that oral antibiotic administration following injury actually reduces the probability of infection. However, the use of topical antibiotics can decrease the rate of wound infection.[34] Useful preparations include bacitracin, triple antibiotic ointment, or silver sulfadiazine.

It is necessary to identify those patients who may benefit from early antibiotics. Antibiotic therapy should be considered in the following situations: where wounds are heavily contaminated or associated with major soft tissue injury; open fractures, intraoral lacerations, wounds associated with active infection; when there is a delay in care that results in a prolonged time from debridement or treatment (>3 hours); when the patient is immunocompromised or has cardiac valvular disease; when there are bites to the hand or face, deep puncture wounds, or lacerations to lymphedematous tissue; or when the patient has prosthetic joints (**Table 92-3**).

SUTURES

SUTURE TYPES

Proper size suture material can be summarized as the smallest suture needed to approximate the edges of a wound. This will reduce tissue damage caused by the suture, and the resulting scar will be minimized. The tensile strength of the suture should never exceed the tensile strength of the tissue, or it can pull through and damage the tissue. The sutures should be at least as strong as the normal tissue through which they are being placed.

The size of the suture material is related to the diameter of the suture. As the number of 0s in the suture size increases, the diameter of the strand decreases. For example, size 5-0, or 00000, is smaller in diameter than size 4-0, or 0000. The smaller the size, the less tensile strength the suture will have.

Suture description entails numerous characteristics. Sutures can be classified into two major groups based upon the number of strands of which they are composed. Monofilament sutures are made of a single strand of material. They encounter less resistance passing through tissue and resist harboring organisms that may cause suture-line infections. Multifilament sutures consist of several filaments, or strands, that are twisted or braided together. This affords greater tensile strength, pliability, and flexibility. Unfortunately, bacteria can migrate between the filaments and into the wound.

Another classification is based on the ability of the body to break down and absorb the suture material. Absorbable sutures are digested by body enzymes or hydrolyzed in body tissue. Nonabsorbable sutures are not digested by body enzymes or hydrolyzed.

Absorbable suture can be made of natural or synthetic material. Natural absorbable suture is classified as surgical gut (plain or chromic). Plain surgical gut is composed of collagen from bovine or sheep intestine. It is rapidly absorbed, maintaining its tensile

TABLE 92-3 Antibiotic Prophylaxis for High-Risk Wounds[35]

Situation	Antibiotic of choice	Days of treatment
Open fractures	First Generation Cephalosporin Add an aminoglycoside for more extensive injuries	1–3
Intraoral injuries	Penicillin VK or Clindamycin	5
Human bites	First dose: parenteral ampicillin sulbactam or Ertapenem, then Augmentin Or Clindamycin plus fluoroquinolone (Bactrim in children) Or Augmentin	3–5
Dog/cat bites	First dose: parenteral ampicillin sulbactam or carbapenem or clindamycin, then clindamycin plus fluoroquinolone Or Augmentin	3–5

strength for only 7 to 10 days, and is completely absorbed within 70 days. Chromic gut is treated with a chromium salt solution to resist body enzymes. It retains its tensile strength for 10 to 14 days and is absorbed over 90 days.

Synthetic absorbable sutures include polyglactin 910 (Vicryl, Ethicon) and polyglycolic acid (Dexon). They were developed because of the tissue reaction, suture antigenicity, and unpredictable rates of absorption of natural absorbable sutures. These sutures are braided synthetic materials that retain 50% of their initial strength at 4 weeks. The synthetic absorbable sutures retain their tensile strength long enough to ensure the security of the subcutaneous layers after the removal of percutaneous sutures.

Nonabsorbable sutures are made of silk, nylon, polypropylene, cotton, linen, or metal. They can be monofilament or multifilament in construction. Nylon is the most commonly used suture in the Emergency Department. It is used to approximate lacerations at the skin surface. Silk may occasionally be used in the mouth. It causes significant tissue reactions that result in inflammation and granuloma formation as the body "fights off" this natural fiber. The other types of nonabsorbable sutures are generally not utilized in the Emergency Department.

Several factors must be considered in choosing suture material. Choose sutures that match the healing properties of the tissues. Approximate slow-healing tissues (e.g., fascia and tendons) with nonabsorbable sutures or a long-lasting absorbable suture. Foreign bodies in potentially contaminated tissues may result in an infection. Multifilament sutures can act as a foreign body and may convert a contaminated wound into an infected one. Multifilament sutures should generally be avoided. Use monofilament sutures or absorbable sutures that resist harboring infection. Use the smallest inert monofilament suture materials (such as nylon or polypropylene), avoid using skin sutures alone (use subcuticular closure whenever possible), and use sterile skin closure strips for apposition when possible. **Use the smallest possible size of the chosen suture type that is capable of closing the wound to help minimize scarring.**

NEEDLES

Needles are generally of two types, tapered and cutting (**Figure 92-6**). Cutting needles have sharp ends and sharp edges that act as a cutting instrument (**Figure 92-6A**). The cutting needle is commonly used for tougher tissues such as subcutaneous, intradermal, and cutaneous (skin) closure. In addition to the two cutting edges, conventional cutting needles have a third cutting edge on the inside concave curvature of the needle. This needle type may be prone to "cutout" of tissue because the inside cutting edge cuts toward the edges of the incision or wound.

Reverse cutting needles are as sharp as the conventional cutting needle except that the third cutting edge is located on the outer convex curvature of the needle (**Figure 92-6B**). Reverse cutting needles have more strength than similar-sized conventional cutting needles. The danger of tissue "cutout" is greatly reduced. The hole left by the needle leaves a wide wall of tissue against which the suture is to be tied.

Taper point needles have a pointed end (**Figure 92-6C**). The rest of the needle is a smooth, rounded tube with no cutting edges. This type of needle is commonly used in surgery to close tissues with minimal trauma. It is used for all tissues except skin.

Two other types of needles are often available but not used in the Emergency Department. The blunt point needle has a smooth tip and tapered body (**Figure 92-6D**). It is used for suturing friable tissue and blunt dissection. The taper cut needle has a cutting tip and a tapered body (**Figure 92-6E**). It is a combination of the tapered point and cutting needle. It is used to place sutures through tough tissues. Numerous other needles are available, as are modifications of the five basic needle types. These needles are used by Surgeons for specialized tissues.

Always keep some general principles in mind when suturing. **Needles should be pulled through tissue using a needle driver and never a hemostat.** A hemostat or other clamp can damage the needle. Avoid injury to yourself and others. **Keep all open needles in a place so that they will not injure you or your assistant.** Account for and discard all suture needles in a "sharps" container. Following these two steps will dramatically decrease the chance for a needle-stick injury.

NEEDLE DRIVERS AND HANDLING SUTURES

Always use a needle driver when suturing. The use of a hemostat or other type of "clamp" can damage the needle and cause it to bend or break in the tissue. Needle drivers are generally made of steel with a jaw designed to hold the needle securely without damaging it. They come in numerous sizes and shapes. Choose a needle driver that is an appropriate size for the needle that is to be grasped. A 4.5 to 6 in. long needle driver is appropriate for Emergency Department use. Grasp and remove a clean needle from its package with your hands,

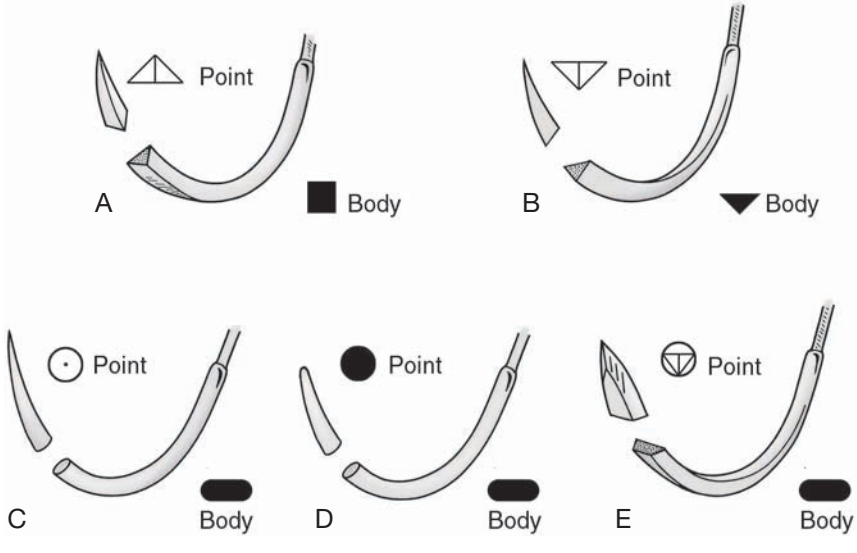


FIGURE 92-6. Common types of suture needles. **A.** The cutting needle. **B.** The reverse cutting needle. **C.** The taper point needle. **D.** The blunt point needle. **E.** The taper cut needle.

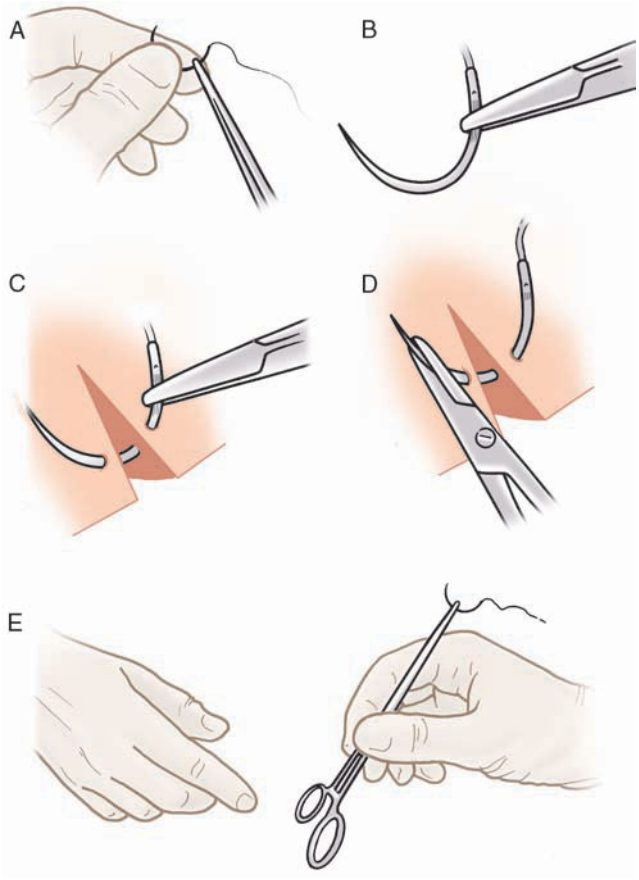


FIGURE 92-7. Using a needle driver. **A.** Grasp the proximal one-third to one-half of the needle. **B.** Always use the tips of the jaws to grasp the needle. **C.** Drive the needle through the tissue following the natural curve of the needle. **D.** Grasp the distal needle proximal to the cutting edges. **E.** Correct method to pass a needle driver armed with a needle.

forceps, or a needle driver. Securely grasp the proximal one-third to one-half of the needle with the needle driver (**Figure 92-7A**). **Do not grasp the distal one-third of the needle.** This can damage its cutting surfaces. **Always use the tips of the needle driver to grasp the needle (Figure 92-7B).** Grasping a needle with the base of the jaws may damage the needle.

Use the needle driver when pushing the needle through the tissue to place a suture (**Figure 92-7C**). **Apply the force in a direction following the curve of the needle. Do not twist or force the needle to push the point through the tissue and out the other side.** Use a larger needle if the first one is too short or too small. **Do not use a needle that has become dull and difficult to pass through the tissue.** Obtain a new needle and continue the procedure. Grasp the distal tip of the needle with a needle driver when it emerges from the tissues (**Figure 92-7D**). **Always grasp the needle proximal to its distal third to prevent damage to the cutting edges.**

Always use caution when handing a needle driver armed with a needle to another person. Grasp the needle driver between the thumb, index, and middle fingers (**Figure 92-7E**). Hand the base of the needle driver to another person. **Do not blindly pass the needle driver. Do not pass the needle driver over a third party without their knowledge of the transfer. Never grasp the distal end of an armed needle driver.**

Typical needle drivers contained within most disposable, commercially available laceration repair trays are not ideal. The suture often snags on the jaws or hinge when performing an instrument tie.



FIGURE 92-8. Examples of snag-free needle drivers. From left to right: The Centurion SnagFree (Centurion Healthcare Products, Howell, MI), the SutureCut needle driver (SutureCut LLC, Lexington, KY), and the Olsen-Hegar needle driver (Henry Schein Inc., Port Washington, NY).

Some needle drivers are designed to be snag-free (**Figure 92-8**). Two of these, the Centurion SnagFree (Centurion Healthcare Products, Howell, MI) and the SutureCut (SutureCut LLC, Lexington, KY) needle drivers, are available both as individual disposable instruments and in disposable laceration repair trays.

Suturing lacerations can take a significant amount of time. Much of this time is spent tying knots or switching between instruments (i.e., the needle driver and scissors). Two needle drivers are designed to also cut suture. This decreases the total time required to repair a laceration as well as avoiding the constant switching between instruments. The SutureCut (SutureCut LLC, Lexington, KY) and the Olsen-Hagar (Henry Schein Inc., Port Washington, NY) needle drivers cut the suture in their specially designed joint located at the base of the jaws.

We are all not fortunate to have suture-cutting needle drivers in our laceration repair trays. A needle driver and scissors can be simultaneously held in the same hand to improve efficiency (**Figure 92-9**). While awkward at first, this technique is easy to learn. Grasp a scissors with the tip pointing ulnarly (**Figure 92-9A**). Insert your middle finger through the adjacent ring on the handle. Grasp a needle driver in the same hand with the tip pointing radially (**Figure 92-9A**). Insert your thumb and ring finger through the rings on the handle of the needle driver. Grasp a suture needle with the needle driver. Place a stitch and tie it. Remove your thumb from the ring of the needle driver and place it in the open ring of the scissors. Use the thumb to open and close the scissors. Cut off the excess suture (**Figure 92-9B**). Place your thumb back into the ring of the needle driver and place the next stitch. Repeat this process until the laceration is closed.

WOUND CLOSURE

The goal of wound closure is approximation of the skin under minimal tension while achieving eversion of the wound edges (Chapter 93). Wound eversion slightly raises the wound edges to keep the epidermal cells from migrating into the dermal layers, therefore leaving a flat scar (**Figure 92-10**). Sutures should be placed closely enough to approximate wound edges, but not so tight as to cause tissue necrosis. The time from the injury to the

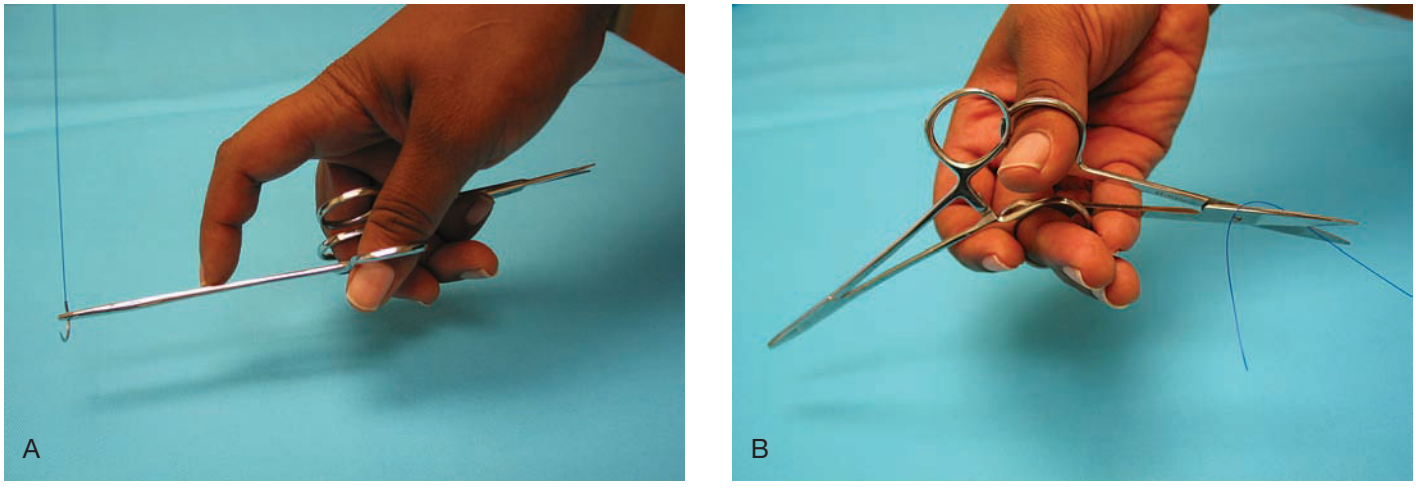


FIGURE 92-9. A one-handed method to simultaneously hold a needle driver and scissors. **A.** Placing a stitch. **B.** Cutting the suture.

presentation and the mechanism of injury will indicate whether the laceration mandates delayed closure instead of primary closure and whether tetanus prophylaxis is required. With the exception of patients who are immunocompromised or taking immunosuppressive therapy, those with high-risk wounds should be considered for delayed closure.

SINGLE-LAYER VERSUS MULTILAYER CLOSURE

The greatest strength of the skin (and of the wound) is contained within the dermis. The better the coaptation of the dermal edges, the narrower the scar will be. The best results occur when the entire depth of the dermis is accurately approximated to the entire depth of the opposite dermis. Dermal closure is best performed with synthetic monofilament absorbable suture that requires enzymatic degradation (e.g., Vicryl). Chromic or plain catgut suture dissolves much more rapidly by means of hydrolysis.

Close the wound in multiple layers if the goal is cosmesis. Close the wound with a minimal number of sutures in a single layer if the goal is a functional result. Do not suture through fat and muscle. Fat has no tensile strength. Sutures placed tightly in fat can cause ischemia and necrosis in the wound and increase the risk of a wound infection. Muscle fibers do not support sutures. Muscle is best treated by repair of the overlying fascia and immobilization to prevent motion and to allow coaptation of the muscle fibers.

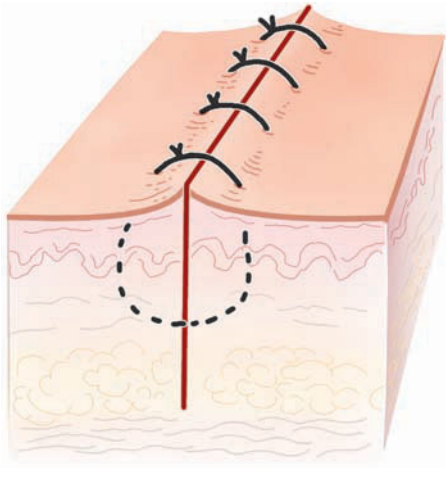


FIGURE 92-10. Eversion of the wound edge signifies proper suture placement and knot tension.

STERILE GLOVES

It is a common practice to wear sterile gloves when repairing a laceration. The advantages of sterile gloves include a better fit, improved tactile sensitivity, and improved dexterity. The use of sterile gloves for laceration repair costs significantly more than using nonsterile, clean gloves from a box. Clean, nonsterile, powder-free, boxed examination gloves can be used for uncomplicated wound repair in the Emergency Department. No clinically important differences in infection rates has been found when comparing sterile gloves to clean gloves.[49,50]

The use of clean gloves from a box is not always ideal. Clean gloves come in a limited number of sizes (i.e., extra small, small, medium, large, and extra large). The fit and feel of clean gloves may not be as comfortable for the Emergency Physician. Clean gloves may have more manufacturing defects when compared to sterile gloves.[51] These defects can result in the loss of personnel protection and the potential to contaminate the wound. Others have shown clean gloves to have comparable quality to sterile gloves.[52–54] A box of clean gloves that has become wet can harbor mold.[55] While the use of clean gloves in uncomplicated wound repair is acceptable, the decision is physician dependent.

WOUND CLOSURE PROCEDURE

Clean any dirt and debris from the skin. Scrub the skin surrounding the wound with an antiseptic skin cleanser (e.g., povidone iodine or chlorhexidine). Anesthetize the wound with a 27 to 30 gauge hypodermic needle and local anesthetic solution. Irrigate the wound with normal saline. Use a mask with a face shield to prevent exposure to the patient's blood and tissue fluid. Debride and undermine the wound as necessary. Irrigate the wound again to remove exposed debris and devitalized tissue. Repair the wound with sutures or pack it with saline-soaked fine-mesh gauze for delayed closure. Clean the repaired wound with normal saline and apply a dressing for comfort and protection. Consider the application of a splint for wounds across joints or muscle lacerations.

Write a procedure note describing the sterile preparation of the wound, the type and volume of anesthesia administered, the type of suture(s) used in the repair, the layers repaired, the type of repair

(interrupted vs. continuous), and how the procedure was tolerated by the patient. Any complications should also be noted.

AFTERCARE

Wound care has become a specialty involving sophisticated research in many areas, including dressings and the environment in which wounds heal best. Clean the area surrounding the repaired wound with normal saline to remove any antimicrobial agents and blood. It has been demonstrated that optimal growth of fibroblasts in tissue culture occurs at low partial pressures of oxygen (5 to 10 mmHg). Epidermal cell growth is inhibited at oxygen levels higher than that in surrounding air. It has been shown clinically that hydrocolloid dressings are capable of maintaining low oxygen tension independent of the underlying disease process.[29] The application of an occlusive dressing has been shown to increase the rate of wound healing by approximately 40%, as well as preventing environmental trauma and keeping bacteria out of the wound.

Dressings, regardless of the type used, should produce a moist but not macerated wound that is free of infection, toxic chemicals, and foreign material while maintaining an optimum temperature and pH. Layered dressings of nonadherent gauze, such as Xeroform, covered with dry gauze can be used for large sutured lacerations and abrasions. This dressing draws exudate into a layer that can be replaced without disturbing the underlying wound. Shear wounds or hematomas may require gauze that is fluffed and formed into a pressure dressing. Dressings of antibiotic ointment with a standard adhesive bandage (e.g., Band-Aid) provide adequate healing and protection for smaller repaired lacerations. The topical application of topical antibiotics to the suture line after wound closure may help to protect against exogenous bacterial contamination. No studies have shown that topical antibiotic ointments have an effect on the final outcome of a wound. Despite this, their use is still recommended because they keep the wound surface moist and their use has not been shown to have any negative effects. The use of paper gauze and Telfa pads is not advisable.

DISCHARGE INSTRUCTIONS

High-risk wounds such as animal and/or human bites, hand wounds, heavily contaminated wounds, and wounds that require prophylactic antibiotic coverage should be reevaluated within 24 hours.

Patients should be made aware, orally and in writing, that up to one in 10 persons develops a wound infection that can be treated with an oral antibiotic. Puncture wounds are considered high-risk injuries that can result in bone infections. Patients should immediately return to the Emergency Department or their primary physician if a wound becomes red or has a discharge, if redness or red streaks are emanating from the wound, or if they develop a fever.

Explain briefly the progression of healing. The new scar's appearance is usually worst at 3 to 5 weeks. Most scars remodel within 6 to 12 months. Any revision of the wound should be postponed for at least 6 to 12 months from the time of injury.

SUTURE REMOVAL

The length of time that the sutures remain in place depends upon the location of the wound, the amount of tension on the wound, and the healing time of the involved tissue. Some general guidelines are listed in **Table 92-4**. Appropriate and timely removal of sutures minimizes scarring. Full-thickness sutures can be left in place for 2 or more weeks without risk of suture-track formation in areas where sebaceous glands and other adnexal structures are not present, such as the plantar and palmar surfaces. Leaving sutures in place too long results in epithelialization of the suture tracts, larger scars, and possibly infections. Suture removal kits are commercially available. They typically contain a metal or plastic forceps, a scissors, and a few gauze squares. These kits are inexpensive, disposable, and intended for single-patient use.

TABLE 92-4 Suture Removal Recommendations

Location	Days
Face	3–4 (child), 3–5 (adult)
Neck	2–3 (child), 3–4 (adult)
Upper extremity	7–10
Hand	10–14
Chest	7–10
Back	10–14
Buttocks	10–14
Legs	8–10
Foot	10–14
Delayed closure	8–12
Retention sutures	14–30
Overlying joints	10–14

Sutures should be removed using aseptic and sterile techniques. Clean the wound with saline. Apply hydrogen peroxide to remove any dried blood and serum encrusted around the sutures. Grasp the suture at the knot with forceps (**Figure 92-11**). Lift the knot off the skin. Cut the suture as close to the skin as possible with a scissors and where the suture enters the skin (**Figure 92-11**). This will avoid drawing contaminated suture through the depth of the wound. Sutures that are close together, small, or tight may require a #11 scalpel blade to cut them rather than a scissors. Gently pull the suture strand out of the tissue with the forceps and across the wound. Pulling a suture out away from the wound may result in the wound edges opening (dehiscing). Remove one to three sutures and ensure that the wound edges do not dehisce. Remove the remaining sutures. Apply skin adhesive strips (e.g., Steri-strips) across the wound to provide support.

MANAGEMENT OF PUNCTURE WOUNDS

Puncture wounds are considered to be at higher risk for infection than simple lacerations. They should be allowed to heal by delayed intention, particularly if they penetrate into the subcutaneous tissues. Local cleansing is the initial step in management. High-pressure irrigation, coring, and probing are generally not recommended.

Infection is most frequently due to *Staphylococcus aureus, Staphylococcus epidermidis*, or streptococcal species. Treatment should be reserved for compromised hosts, dirty wounds, or actual infected wounds.[30] Puncture wounds of the foot are of special concern due to the risk of *Pseudomonas aeruginosa* infection, particularly with wounds through athletic shoes. A tender wound that is not infected usually indicates that there may be a retained foreign body. Persistent infection from a plantar wound suggests an

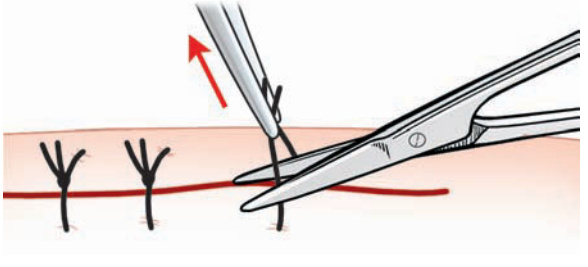


FIGURE 92-11. Suture removal.

underlying osteomyelitis that requires radiographs and treatment with a fluoroquinolone.[31]

PEDIATRIC ISSUES OF WOUND HEALING

Pediatric patients less than 15 years of age experience infection rates of less than 1% for clean surgical wounds.[7] This is less than that seen in adults. Young children, despite the ultimate in the way of gentle reassurance, will sometimes require sedation in order to make painful or difficult procedures possible. Safe and effective procedural sedation for patient comfort or cooperation to facilitate or expedite medical care is described in Chapter 129. Undermining is not useful in most pediatric wounds as they do not usually require advancement of skin over a significant tissue defect. Scalp lacerations account for 30% of pediatric lacerations. Scalp lacerations are well suited for single-layer repair with staples. Cosmetic results are comparable with those of sutured repairs, with no differences in complication and infection rates. Staples are six times faster, less expensive in cost of supplies and physician time than standard sutures, and can be implanted rapidly and accurately, even in a moving child.

ALTERNATIVE CLOSURES

Alternative methods of wound closure include skin closure tapes, tissue adhesives, and staples. These are mentioned briefly below. A more complete discussion can be found in Chapters 93 and 94.

SKIN CLOSURE TAPES

Skin closure tapes are adhesive strips that are used when skin tension and wound contamination are not concerning factors. Adhesive-backed long and narrow strips are used for approximating the edges of lacerations (with or without staples or sutures) and for closing the skin following many operative procedures. The most common type is the Steri-strip. Skin closure tapes are felt to develop and increase wound tensile strength faster than sutured wounds because uniformly orienting collagen fibers apply equal stress across the wound. Skin closure tapes are porous, which allows for good air inflow and the escape of water vapor from the wound during the healing process. Strips are placed perpendicular to the wound in conjunction with an adhesive such as tincture of benzoin, taking care not to get benzoin in the wound.

TISSUE ADHESIVES

Tissue adhesives such as the older and weaker butyl cyanoacrylates focused on small linear lacerations. Newer and stronger medical-grade octyl cyanoacrylate formulations have been approved by the US Food and Drug Administration. It has been clinically proven that there is no difference 1 year after treatment in the cosmetic outcome of wounds repaired with suture versus those closed with octyl cyanoacrylate tissue adhesive.[32]

STAPLES

Staple closure is time-efficient compared to the suture repair of lacerations.[33] It is primarily used for large wounds that are not on the face, neck, hands, or feet. Stapling is especially useful for closure of incisions in hair-bearing skin (i.e., scalp) areas as well as the trunk and extremities. The wound edges require manual eversion with forceps prior to placing the staples.

SUMMARY

Expert wound management consists of attention to the details surrounding the wound, gleaning important information concerning the host's history, as well as meticulous wound preparation. Aggressive attention to the presence of foreign bodies, underlying injury to anatomic structures of significance, and the possibility of subsequent wound infection should be kept in mind at all times. An effort should be made to educate the patient about the possible outcomes of wounds and lacerations and to encourage expedited follow-up.

93 Basic Wound Closure Techniques

Eric F. Reichman and Candace Powell

INTRODUCTION

Wound management is crucial to the practice of Emergency Medicine. Emergency Physicians routinely care for wounds ranging from simple lacerations to complex injuries in the trauma patient.[1–6] Wound repair is always secondary to the evaluation and stabilization of any life-threatening and limb-threatening emergencies. However, patients are often legitimately concerned about the outcome of wounds and lacerations. There are several basic suture principles that will help to provide optimal wound healing and ensure a more than acceptable cosmetic result. The previous chapter outlines the essential principles of wound management. This chapter describes the basic methods used to close wounds.

SUTURES

The choice of suture materials is important in wound closure. Sutures are made of a wide variety of materials, both natural and synthetic. Natural substances include gut (sheep and beef), cotton, and silk. **Natural substance sutures cause more tissue reactions and scarring, which limits their use.** Cotton sutures are not discussed, as they are no longer used in clinical practice. Synthetic sutures can be made of nylon, polyethylene (Dacron), polyglactin (Vicryl), polypropylene (Surgilene, Prolene), polyglycolic acid (Dexon), poliglecaprone (Monocryl), polydiaxanone (PDS), polyglyconate (Maxon), and metal.[6] Metal sutures are used in the Operating Room and not in the Emergency Department as they are difficult to handle, prone to breakage, and indicated in only a few situations. Synthetic sutures tend to have a problem with "memory." That is, they tend to retain the shape of their packaging. This can make it difficult to manipulate the suture during wound closure.

Sutures are constructed as monofilaments or polyfilaments. Polyfilament fibers consist of multiple filaments braided together to form one suture. They are easier to handle than monofilament sutures, as they tend to be more pliable. Polyfilament sutures have better knot security and therefore reduce the incidence of knot slippage. However, they can be associated with a higher incidence of infection than monofilament sutures. They allow bacteria to migrate (or wick) between the strands of the suture located at the skin surface and into the wound.

Select the smallest diameter suture that can adequately hold the tissue edges together in order to reduce tissue damage and scarring. The largest suture material available is size #5. The suture sizes decrease to zero (#4, #3, #2, #1, #0) and then are followed by #00 (2-0), #000 (3-0), and #0000 (4-0), in decreasing size. The smallest suture commonly used in the Emergency Department is 6-0 for facial lacerations, nail bed lacerations, as well as lacerations in cosmetically sensitive areas. The tensile strength of sutures is related

TABLE 93-1 Absorbable Suture Materials

Suture type	Source	Tensile strength	Tissue reaction	Knot security	Absorption
Plain surgical gut	Beef or sheep collagen	Poor	Moderate	Poor	1–2 weeks
Chromic surgical gut	Beef or sheep collagen	Poor	Moderate	Fair	2–3 weeks
Monocryl	Poliglecaprone 25	20% remains by 3 weeks	Minimal	Good	3 months
Coated Vicryl	Polyglycolic 910, polyglactin 370, and calcium stearate	65% remains at 2 weeks; 40% at 3 weeks	Minimal	Fair	3–6 months
Dexon	Polyglycolic acid	50% remains at 4 weeks	Minimal	Good	3–4 months
Vicryl Rapide	Polyglactin 910	50% remains in 5–6 days	Minimal	Good	42 days
PDS polydioxanone	Polyester polymer	70% remains at 2 weeks; 50% at 4 weeks	Slight	Poor	6 months
Maxon	Polyglyconate	50% remains at 7 weeks	Slight	Fair	6 months

to their size. The tensile strength of suture increases as the size increases. For example, 4-0 is stronger than 5-0.

The other main category of suture classification is absorbable versus nonabsorbable. In the past, absorbable sutures were primarily used to close the subcutaneous layers of a wound. More recently, absorbable sutures have also been used for skin closure. Nonabsorbable sutures are primarily used for skin closure.

ABSORBABLE SUTURE MATERIALS

Absorbable sutures are degraded by the body and do not require removal. They usually do not maintain their tensile strength for longer than 60 days. Body enzymes dissolve the absorbable sutures with the aid of an inflammatory reaction. The rate of absorption of the sutures varies based upon the tissue where it is placed, the composition of the suture, and the size of the suture. Absorbable sutures placed in mucous membranes absorb faster than those placed in muscle tissue or fascia. Smaller sizes of suture dissolve faster than larger sizes.

There are several types of absorbable sutures, both natural and synthetic (**Table 93-1**). The most commonly used absorbable sutures in the Emergency Department are plain gut, chromic gut, polyglycolic acid (Dexon), polyglactin (Vicryl), and Vicryl Rapide. Plain gut and chromic gut are both natural forms of absorbable sutures. They are made from the intestines of sheep and cattle. Gut is a tissue irritant and can cause a substantial tissue reaction while it is being absorbed and degraded by the body. Chromic gut is plain gut that has been soaked in chromic acid salts. This process helps to extend the half-life of the suture and allows it to maintain its tensile strength longer than plain gut. Chromic gut may retain its tensile strength for 2 to 3 weeks, while plain gut retains its tensile strength for 1 to 2 weeks. Both types of gut are packaged wet in order to keep them from drying out and becoming too stiff.

Synthetic absorbable sutures, such as Dexon and Vicryl, are typically used more often than natural absorbable sutures in the Emergency Department. They are degraded by the body more slowly than natural fibers and can therefore help maintain the strength of the wound longer. Vicryl and Dexon maintain their tensile strength at 80 days and 120 days, respectively. They cause less reaction in the tissues as they break down when compared to natural absorbable sutures.

Recently, absorbable sutures have gained some popularity for use in skin closure.[7–10] Absorbable sutures have been shown to yield equal results in their rate of dehiscence, rate of infection, and cosmesis when compared to nonabsorbable sutures.[7] Absorbable sutures have the added benefit for the patient of not having to return to have their sutures removed. Vicryl Rapide is a newer form of Vicryl that is especially suited for this purpose. This type of suture is rapidly absorbed. They begin to fall off in 7 to 10 days as the wound heals. This can be especially useful for children in whom suture removal can be difficult, under casts, or if a patient will not be able to follow up due to travel.

NONABSORBABLE SUTURE MATERIALS

Nonabsorbable sutures are not degraded by the body and must be removed. They maintain their tensile strength for longer than 60 days. They are composed of monofilament or polyfilament strands of organic, synthetic, or metal fibers (**Table 93-2**). Nonabsorbable sutures generally have greater tensile strength and lower tissue reactivity than absorbable sutures. They are used in a variety of applications including skin closure. Nonabsorbable sutures can be used within a body cavity and subcutaneously, where they will eventually become encapsulated in connective tissue.

Nonabsorbable sutures can be classified as organic, synthetic, and wire. Organic sutures include those made of cotton or silk. Cotton

TABLE 93-2 Nonabsorbable Suture Materials

Suture type	Source	Tensile strength	Tissue reaction	Knot security	Absorption
Silk (braided)	Organic protein	Gradual loss by progressive degradation	High	Good	Gradual encapsulation by connective tissue
Ethilon	Polyamide (nylon)	Progressive hydrolysis may result in gradual loss of tensile strength	Minimal	Fair	Gradual encapsulation by connective tissue
Nurolon	Polyamide (nylon)	Progressive hydrolysis may result in gradual loss of tensile strength	Minimal	Fair	Gradual encapsulation by connective tissue
Prolene	Polyamide (nylon)	Not subject to degradation	Minimal	Poor	Nonabsorbable
Mersilene	Polyester	No significant change occurs	Minimal	Good	Gradual encapsulation by connective tissue
Ethibond	Coated polyester	No significant change occurs	Minimal	Good	Gradual encapsulation by connective tissue
Stainless steel	Stainless steel	Indefinite	Minimal	Good	Nonabsorbable

is the oldest of the nonabsorbable sutures. It is not discussed here as cotton sutures are no longer used in general medical practice. Silk is a polyfilament suture that has limited use in the practice of Emergency Medicine. There are several advantages to silk suture material. Its pliability makes it very easy to handle. It holds knots better than other types of suture. However, as with all natural and/or polyfilament sutures, it has a greater tendency to cause wound infections. The polyfilament braids can provide a place for bacteria to lodge. Silk suture may actually protect the bacteria from attack by the body's defenses if the wound becomes infected. The primary use of silk sutures is for the repair of lip, oral cavity, and tongue lacerations.

Synthetic nonabsorbable sutures are available in monofilament and polyfilament forms. Commonly used synthetic sutures include nylon, polypropylene, polybutester, and Dacron. Nylon, polypropylene, and polybutester are monofilament synthetic sutures. Dacron is a polyfilament synthetic suture. The synthetic nonabsorbable sutures have several advantages over the natural nonabsorbable sutures. They are less reactive in tissues, generally stronger than the natural sutures, and retain their tensile strength over many years.

Nylon (Ethilon, Dermalon) is the most common nonabsorbable suture used in the Emergency Department. It is a monofilament suture, it is inert, and it does not tend to harbor bacteria. It is primarily used for skin closure. Nylon has good tensile strength and minimal tissue reactivity. However, nylon is difficult to handle and difficult to tie. It requires more knots to achieve good knot security than other types of suture. This is primarily due to the tendency of the suture to return to its packaged shape. This tendency is also known as "memory." Because the knot can unravel or slip, it is important to place at least four or five knots when using nylon suture.

Polypropylene and polybutester are less commonly used synthetic nonabsorbable sutures. Polypropylene (Prolene) is stronger but more difficult to work with than nylon because it has greater memory. Polybutester (Novafil) is a newer suture in this category. It is stronger than the other monofilaments and does not have significant memory. Therefore, it is easier to work with than the other monofilament synthetic sutures.

EQUIPMENT

- Needle drivers, 4.5 and 6.0 in.
- Skin hooks
- Scalpel blades (#10, #11, and #15)
- Scalpel handles
- Iris scissors, straight 4 in. and curved 4 in.
- Suture scissors, 6 in.
- Forceps, toothed Adson
- Metzenbaum scissors, curved 6 in.
- Hemostats, straight 6 in., and curved mosquitoes
- Suture material
- Skin closure tapes
- Benzoin solution, swabs, or spray
- Gum mastic (e.g., Mastisol)
- Tissue adhesive
- Tissue adhesive forceps
- Skin stapler
- Staple remover
- Gauze, 4 × 4 squares

Much of the above equipment can be purchased in single-use, sterile, and disposable suture kits from several commercial manufacturers (**Figure 93-1A**). These kits tend to be expensive and occasionally have a limited amount of equipment. Many hospitals package and sterilize their own wound repair kits (**Figure 93-1B**). This decreases the cost, as the equipment can be repeatedly sterilized and reused. It also allows the kits to contain a wide variety of instruments for multiple situations (e.g., minor laceration, large laceration, and plastics closure).





FIGURE 93-1. The equipment required for basic wound closure techniques. **A.** The contents of a disposable and commercially available wound closure kit. **B.** A hospital packaged kit with reusable instruments.

Needle drivers come in a variety of sizes. A 4.5 in. needle driver can be used comfortably with most types of needles. A 6 in. needle driver may be required if large needles are used to close a wound. Hold the needle driver with the fingertips to provide greater flexibility. The fingers can also be placed through the finger holes, but this is not as efficient when closing a wound. Grasp the needle one-third of the way from the swag (distal) end with the tip of the needle driver.

The skin must be grasped and manipulated during wound repair to allow for proper suture placement. Forceps are most commonly used to grasp and manipulate the skin. **Smooth (nontoothed) forceps should never be used to grasp skin.** They require the application of a large amount of force to grasp the tissue. This can crush tissue very easily. An Adson forceps is the forceps of choice. It has fine teeth that grasp tissue securely with minimal force.

TABLE 93-3 Typical Suture Choices for Each Body Site

Anatomic site	Deep-layer suture size	Deep-layer suture material	Skin-layer suture size	Skin-layer closure material
Scalp	2–0, 3–0, or 4–0	Absorbable	4–0 or 5–0	Nylon, polypropylene, or staples
Eyelid	5–0, 6–0, or 7–0	Absorbable	6–0 or 7–0	Nylon or polypropylene
Face	4–0 or 5–0	Absorbable	5–0 or 6–0	Nylon or polypropylene
Neck	4–0 or 5–0	Absorbable	4–0 or 5–0	Nylon or polypropylene
Trunk	3–0 or 4–0	Absorbable	3–0 or 4–0	Nylon, polypropylene, or staples
Extremities	3–0 or 4–0	Absorbable	3–0, 4–0, or 5–0	Nylon, polypropylene, or staples
Hands and feet	Not advisable	Not applicable	4–0 or 5–0	Nylon or polypropylene
Sole of foot	3–0 or 4–0	Absorbable	3–0 or 4–0	Nylon or polypropylene

A skin hook is a sharp, pointed instrument that is inserted into the wound edge and grasps the tissue from the undersurface. It produces a small puncture wound in the subcutaneous tissues and does not penetrate the skin surface. Skin hooks are preferable to forceps, as they do not crush tissues. A skin hook is awkward to use at first. With proper instruction and experience, the Emergency Physician will most certainly prefer a skin hook to forceps.

Several types of scissors are required for proper wound closure. Iris scissors have sharp, delicate tips for making precise cuts in tissue. They should not be used to cut suture material, as this rapidly dulls and nicks the blades. Suture scissors have one blunt tip and one pointed tip. Both blades of the suture scissors are sharp. Suture scissors are used to cut adhesive tape, gauze, rubber drains, and suture material. Metzenbaum scissors should be used to debride heavy tissue, bluntly dissect tissue, and undermine tissue.

Hemostats are used to clamp small vessels that are bleeding, to explore a wound, and to grasp fascia. Hemostats are available in a variety of sizes and styles. A straight 6 in. hemostat is used for most purposes during wound repair. A curved 5 in. mosquito hemostat can be used for small wounds or delicate tissues. **Do not use a hemostat to grasp or drive the suture needle.** The suture needle can bend, rotate, and break as it enters tissue if driven by a hemostat.

Three different scalpel blades should be available when a wound is being repaired. A #11 blade is used to make stab incisions. It is often used for the incision and drainage of abscesses, cricothyroidotomies, and the removal of small or tight sutures. A #10 blade is used to make straight cuts in the skin and debride wound edges. It is rarely used in laceration repair. A #15 blade is small and curved to allow precise incisions. It is used for excising foreign bodies and wound debridement.

SUTURE TECHNIQUES

Proper wound closure requires an understanding of certain basic principles. **The needle should enter and exit the skin at a 90° angle and perpendicular to the wound edges.** By doing so, when the suture loop is closed, the wound edges will be everted. **Sutures should be placed as close to the wound edge as possible (2 to 3 mm) in order to avoid excessive tension on the wound.** More force will be required to close the wound if the sutures are placed too far from the wound edge. Edema develops in a wound in the first 48 hours after closure. Sutures placed too far from the wound edge can result in large scars when the edema subsides.

The layers of the wound should be matched evenly and each layer should be closed separately. If a wound involves the deeper layers of skin, fascia should be matched to fascia, dermis should be matched to dermis, and epidermis should be matched to epidermis. **The proper matching of layers avoids an uneven closure, helps to prevent an unnecessarily large scar, and eliminates dead space.**

The epidermal edges of the wound must be everted to allow for proper healing. Scars contract with time. They will flatten and heal with a better cosmetic result if the wound edge is everted and slightly elevated. The wound edges will contract into a "pit" below the plane of the skin, will be more noticeable, and the final result will be less appealing cosmetically if the wound edges are not everted.

Handle the tissues gently and do not squeeze or twist them too tightly with the instruments. This helps to avoid strangulation, which can result in tissue necrosis. **The sutures should be placed carefully and with the proper amount of tension to help promote healing.** Sutures should be snug. Attempts should be made to avoid excessive tension on the wound edges in order to prevent wound dehiscence. The use of the smallest suture size necessary to approximate the wound edges will reduce tissue damage and minimize scarring. **Table 93-3** lists the appropriate suture types and sizes for each body region.

If there will be a temporary delay in the closure of a laceration because of other injuries that may be life-threatening or of greater importance, cover the wound with a saline-soaked gauze in order to keep the tissues from drying.

PRINCIPLE OF HALVING

Large wounds gape open and are difficult to approximate. Closure of the deeper layers will often bring the skin edges into apposition. If not, the principle of halving may be used to approximate the wound (**Figure 93-2**). Identify the midpoint of the laceration. Place the first suture at the midpoint (**Figure 93-2A**). This stitch is known as the central suture. The next sutures are placed in halves on each side of the central suture (**Figures 93-2B & C**). Continue the process by placing sutures halfway between previous sutures until the wound is approximated. This results in even closure of the wound edge. This principle can be used for closure of both the deep layers and the skin.

TWO-HANDED SQUARE KNOT

This is the easiest and most reliable method of tying most suture materials. It involves the classic "right-over-left and left-over-right"

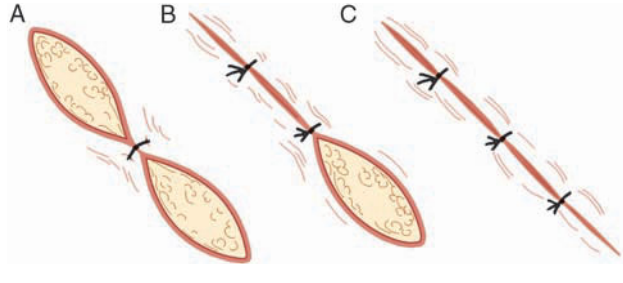


FIGURE 93-2. The principle of halving. **A.** The first suture is placed in the middle of the laceration. **B.** The second suture is placed halfway between the first suture and the upper end of the laceration. **C.** The third suture is placed halfway between the first suture and the lower end of the laceration.

tie (**Figure 93-3**). The incorrect "right-over-left and right-over-left" is a granny knot, which will slip if it is tied in this manner. This square knot is quick and simple to perform. However, it does take significant practice to master this technique.

Place a suture through the skin on both sides of the laceration (**Figure 93-3A**). Pull the suture through the wound until half is on each side of the laceration. Grasp the right half of the suture with the right thumb and index finger (**Figure 93-3A**). Grasp

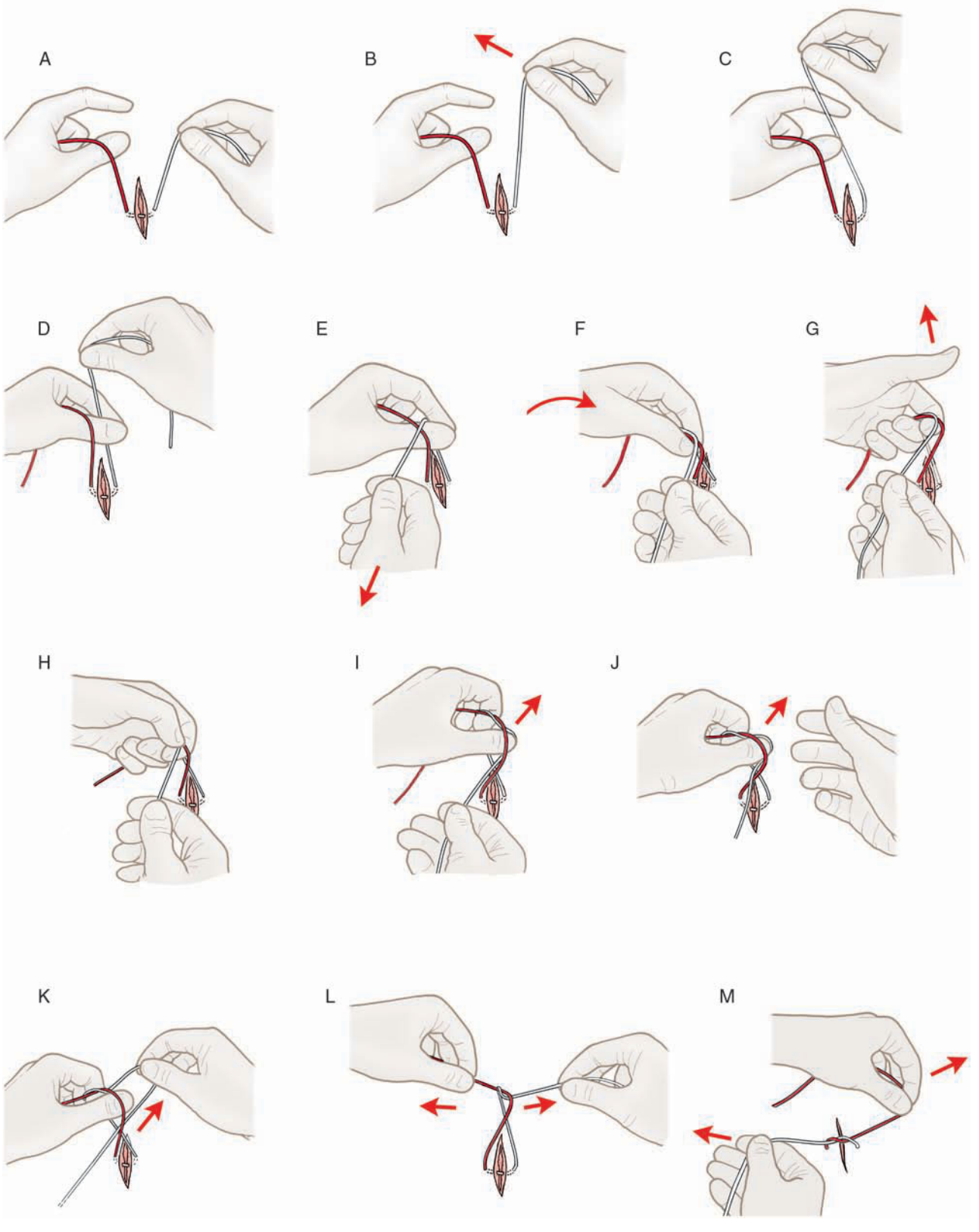


FIGURE 93-3. The two-handed square knot.

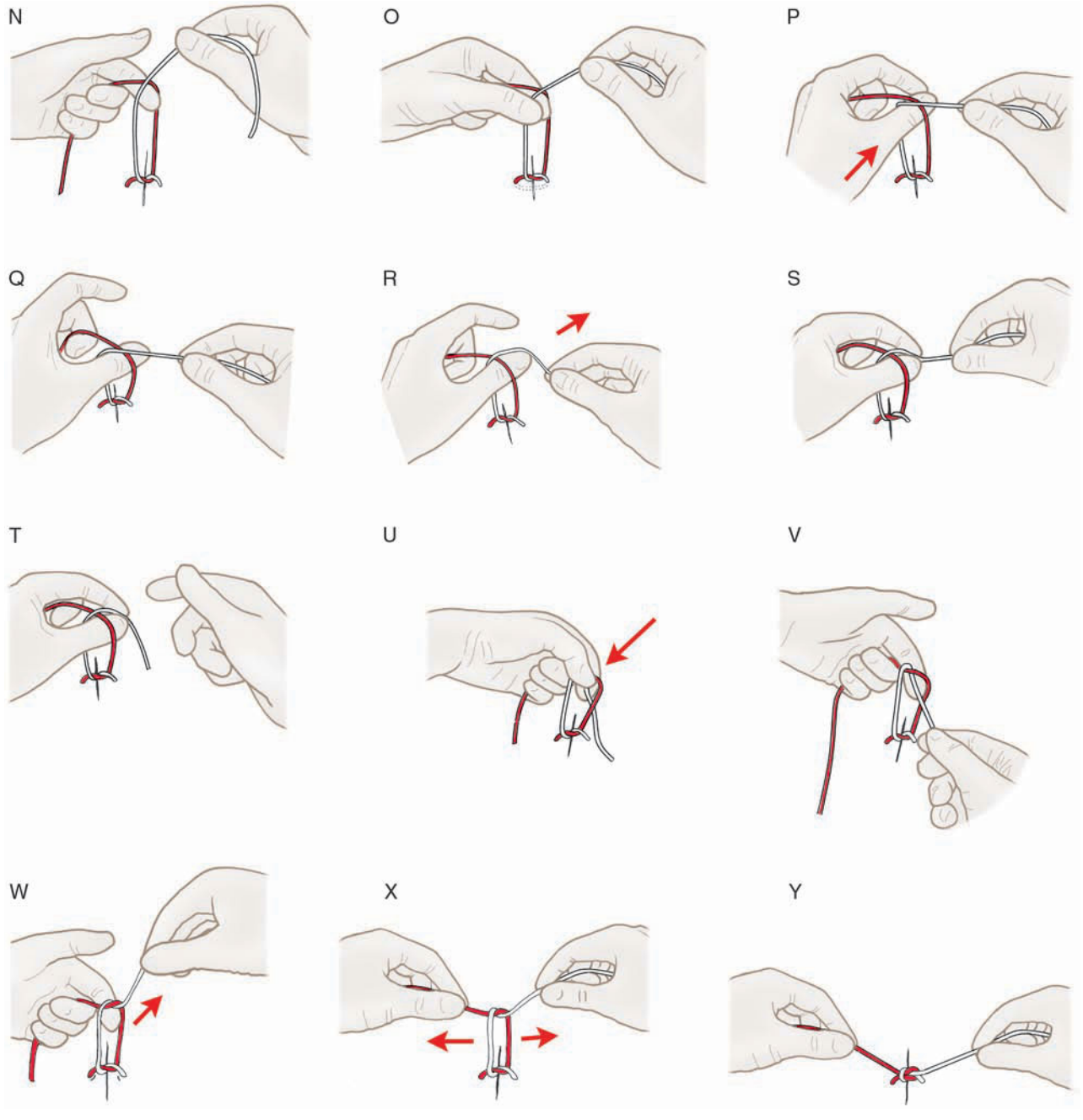


FIGURE 93-3. (*continued*)

the left half of the suture with the left third through fifth fingers and the suture draped over the thumb (**Figure 93-3A**). Cross the right hand toward the left hand (**Figure 93-3B**). Continue to move the right hand until the suture is between the left thumb and index finger (**Figure 93-3C**). Close the left thumb and index finger to entrap the right half of the suture in the pads of the fingers (**Figure 93-3D**). Pull the right hand down and to the left so that the two halves of the suture form an X over the left thumb (**Figure 93-3E**). Flex the left wrist to slide the X off the left thumb and onto the left index finger (**Figure 93-3F**). Lift the left thumb backward and upward so that the X overlies the tip of the left index finger (**Figure 93-3G**). Reapply the left thumb over the left index finger to entrap the X (**Figure 93-3H**). Extend the left wrist to push the left thumb and the X through the loop (**Figure 93-3I**). Release the suture held with the right hand (**Figure 93-3J**). Regrasp the suture with the right hand after it passes through the loop (**Figure 93-3K**). Pull the suture completely through the loop with the right hand. Simultaneously move the left hand toward the left and move the right hand toward the right (**Figure 93-3L**). Cross the hands so that the left hand goes toward the right side and the right hand goes toward the left side (**Figure 93-3M**). Continue to pull both sides of the suture until the knot lies flat and the skin edges are apposed (**Figure 93-3M**). The first half of the knot is now complete.

Make the second half of the knot to complete the square knot. Raise both hands upward and uncross them until an X is formed over the left index finger (**Figure 93-3N**). Close the left thumb and index finger to entrap the suture being held with the right hand (**Figure 93-3O**). Extend the left wrist to push the left thumb through the loop (**Figure 93-3P**). Lift the left index finger upward

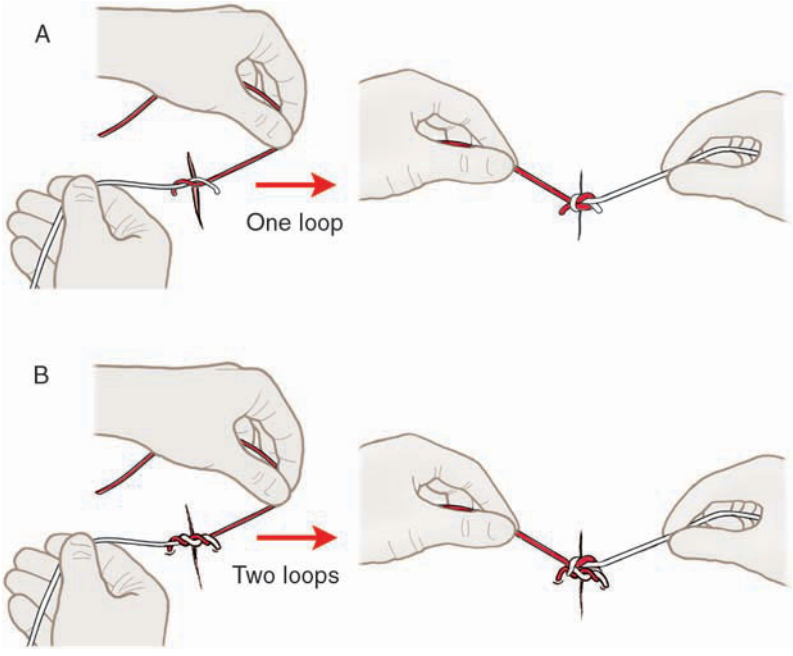


FIGURE 93-4. The square knot (**A**) versus the surgeon's knot (**B**). The first throw of the square knot has one loop (**A**), while that of the surgeon's knot has two loops (**B**). The second throw of both knots is a simple loop.

(**Figure 93-3Q**). Move the right hand away from you until the suture it holds drapes over the left thumb (**Figure 93-3R**). Reapply the left index finger onto the thumb to entrap the suture held with the right hand (**Figure 93-3S**). Release the suture held with the right hand (**Figure 93-3T**). Flex the left wrist to push the left index finger and suture through the loop (**Figure 93-3U**). Regrasp the free suture with the right hand after it passes through the loop (**Figure 93-3V**). Move the right hand upward and to the right to complete the second half of the knot overlying the left index finger (**Figure 93-3W**). Simultaneously move the left hand toward the left and move the right hand toward the right (**Figure 93-3X**). Continue to pull both halves of the suture until both halves of the knot come into contact (**Figure 93-3Y**). Pull both halves of the suture to secure the knot. The square knot is now complete. Continue the process to add additional knots onto the suture. Cut off excess suture on both sides of the knots.

SURGEON'S KNOT

The physician may choose to use a surgeon's knot instead of a square knot (**Figure 93-4**). The square knot has one loop in the first throw and one loop in the second throw (**Figure 93-4A**). The surgeon's knot has two loops in the first throw and one loop in the second throw (**Figure 93-4B**). The only difference between these two knots is the two loops in the first throw. The second throw and subsequent knots are exactly the same for both knots. The advantage of the surgeon's knot is that the two loops are more secure and stay in place while the second throw is being tied. The choice to use either knot is dependent on the experience and the training of the physician.

INSTRUMENT TIE

The instrument tie is the most efficient method to complete a simple interrupted suture (**Figure 93-5**). It is the tie that is most commonly used in the Emergency Department. An instrument tie is often quicker, requires less dexterity, and is easier to perform than the two-handed method. It may be used with the square knot or the surgeon's knot.

Place a suture through the skin on both sides of the laceration (**Figure 93-5A**). Carefully grasp the needle in its midportion and pull it through the laceration (**Figure 93-5B**). Continue to pull the needle until approximately 1 to 2 cm of suture on the tail end remains outside the laceration (**Figure 93-5C**). A large amount of suture will be wasted if the tail is left too long, as it will be later cut off and discarded. On first learning the instrument tie, it may be best to leave a tail of 3 to 4 cm until one is proficient with this technique.

Place the needle driver over the laceration but not touching it (**Figure 93-5C**). Loosely loop the needle end of the suture over (**Figure 93-5D**) and around (**Figure 93-5E**) the needle driver. Loosely loop the needle end of the suture over and around the needle driver a second time (**Figures 93-5F & G**). This will eventually result in the first half of a surgeon's knot. Looping the suture once around the needle driver will result in a simple square knot. Move the tip of the needle driver toward the tail of the suture without letting the loops fall off the needle driver (**Figure 93-5H**). Grasp the tail of the suture with the needle driver (**Figure 93-5I**). Pull the tail of the suture through the loop (**Figure 93-5J**). Pull the tail completely through the loops (**Figure 93-5K**). Simultaneously move the left hand toward the right and the right hand/needle driver toward the left (**Figure 93-5L**). Continue to pull both sides of the suture until the hands are opposite each other, the knot lies flat, and the skin edges are apposed (**Figure 93-5M**). The first half of the knot is now complete.

Make the second half of the knot. Continue to hold the needle and release the tail of the suture from the needle driver (**Figure 93-5N**). Place the needle driver over the laceration but not touching it (**Figure 93-5N**). Loosely loop the needle end of the suture over (**Figure 93-5O**) and around (**Figure 93-5P**) the needle driver. Move the tip of the needle driver toward the tail of the suture without letting the loop fall off the needle driver (**Figure 93-5Q**). Grasp the tail of the suture with the needle driver (**Figure 93-5R**). Pull the tail of the suture completely through the loop (**Figure 93-5S**). Simultaneously move the left hand toward the left and the right hand/needle driver toward the right (**Figure 93-5T**). Continue to pull both sides of the suture until both halves of the knot come into contact. Pull both sides of the suture to secure the knot. The knot is now complete. Continue

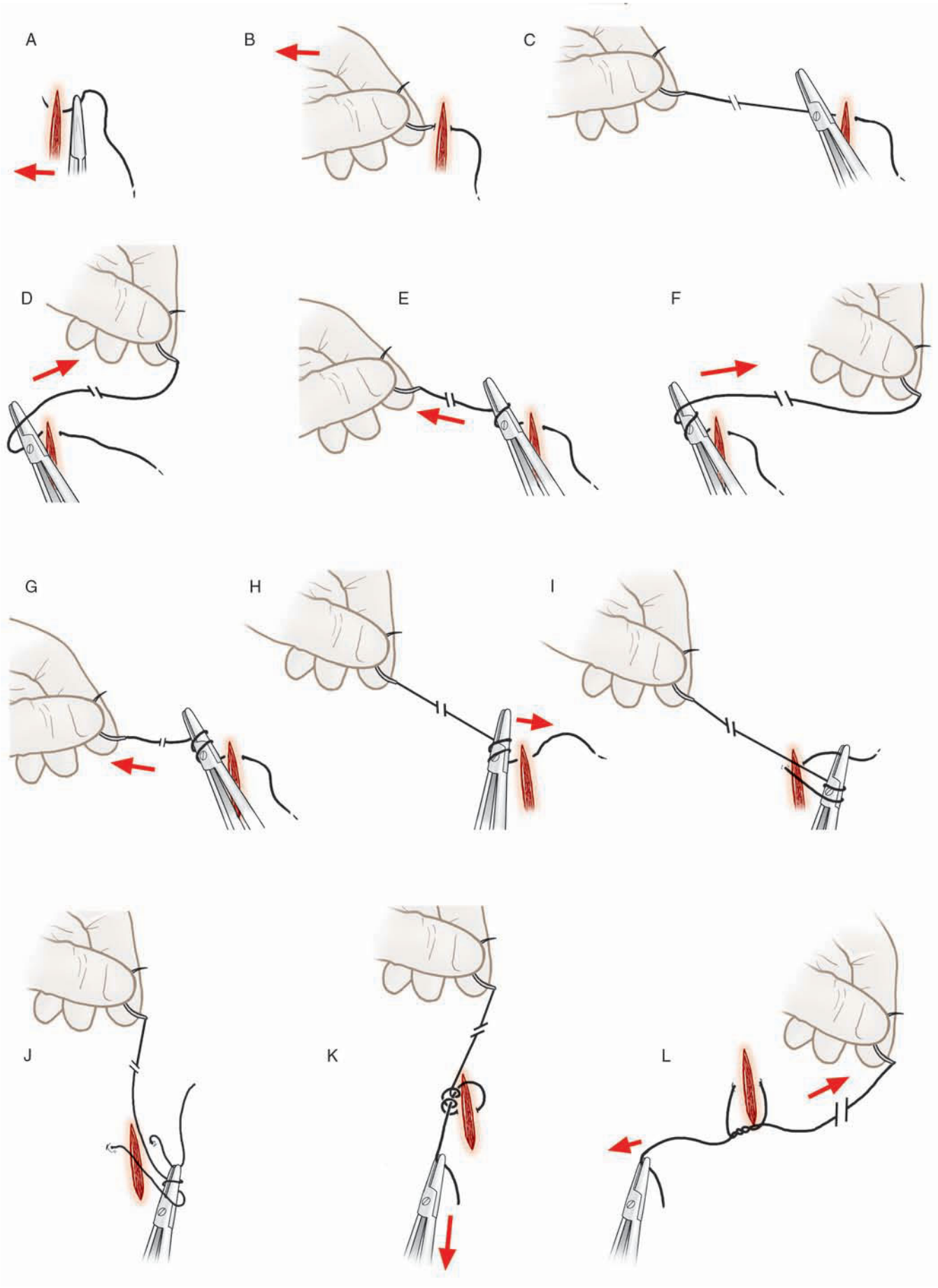


FIGURE 93-5. The instrument tie.

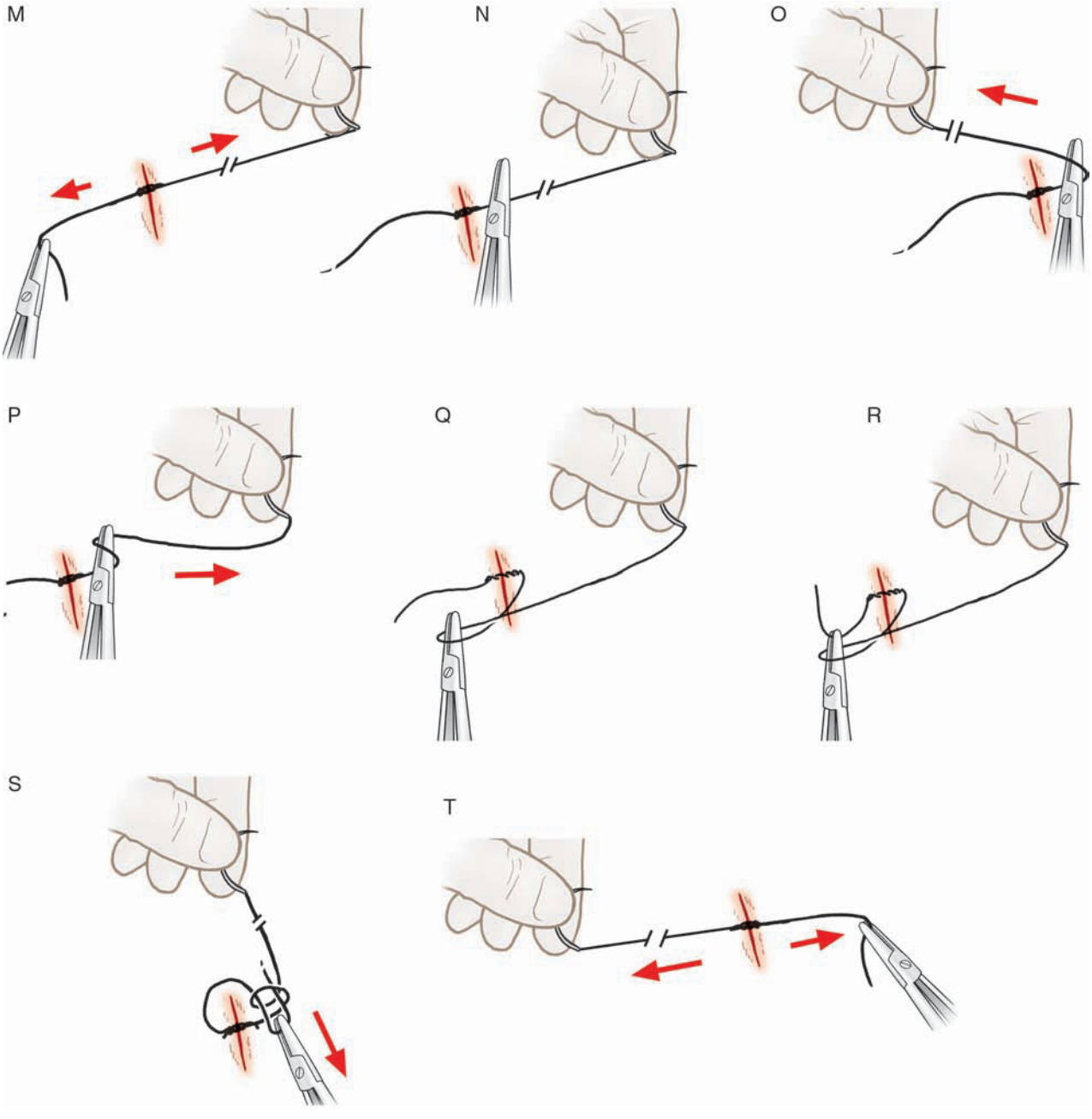


FIGURE 93-5. (*continued*)

this process three or four more times, each in alternative directions, to place additional knots. Cut off the excess suture on both sides of the knots.

SIMPLE INTERRUPTED STITCH

The simple interrupted stitch is the most commonly used suture technique and is useful in many situations (**Figure 93-6**). One major advantage is that each stitch is placed independent of the others. Therefore tension on each stitch can be adjusted separately. Additionally, the entire repair is not compromised if one suture should happen to come out. The other sutures will remain in place to help assure proper wound healing. **The needle must enter and exit the skin at a 90° angle to help evert the wound edges. Take equal volumes of skin from each side of the area being sutured. Drive the needle equidistantly into and out of the wound edges and incorporate the base of the wound.**

Insert the needle at a 90° angle to the skin (**Figure 93-6A**). Drive the needle through the tissue until the tip exits the skin (**Figure 93-6B**). Grasp the needle behind the tip and pull it through the wound (**Figure 93-6C**). **The suture should enter and exit the skin equidistant from the wound edges (Figure 93-6D). If it does not, pull the suture out and repeat the stitch so that it is equidistant from the wound edges.** Make a loop in the suture with the two-handed tie or the instrument tie. Pull the suture to appose the wound edges and cinch down the knot (**Figure 93-6E**). The tissue at the base of the wound will come into apposition before the tissue at the skin surface and thus evert the wound edge. Complete the knot to one side of the laceration (**Figure 93-6F**). Just prior to cinching the second throw onto the first, pull the ends so that the knot is not directly over the wound and the edges of the wound remain in apposition. Apply additional sutures equidistant from each other until the wound is closed (**Figure 93-6G**).

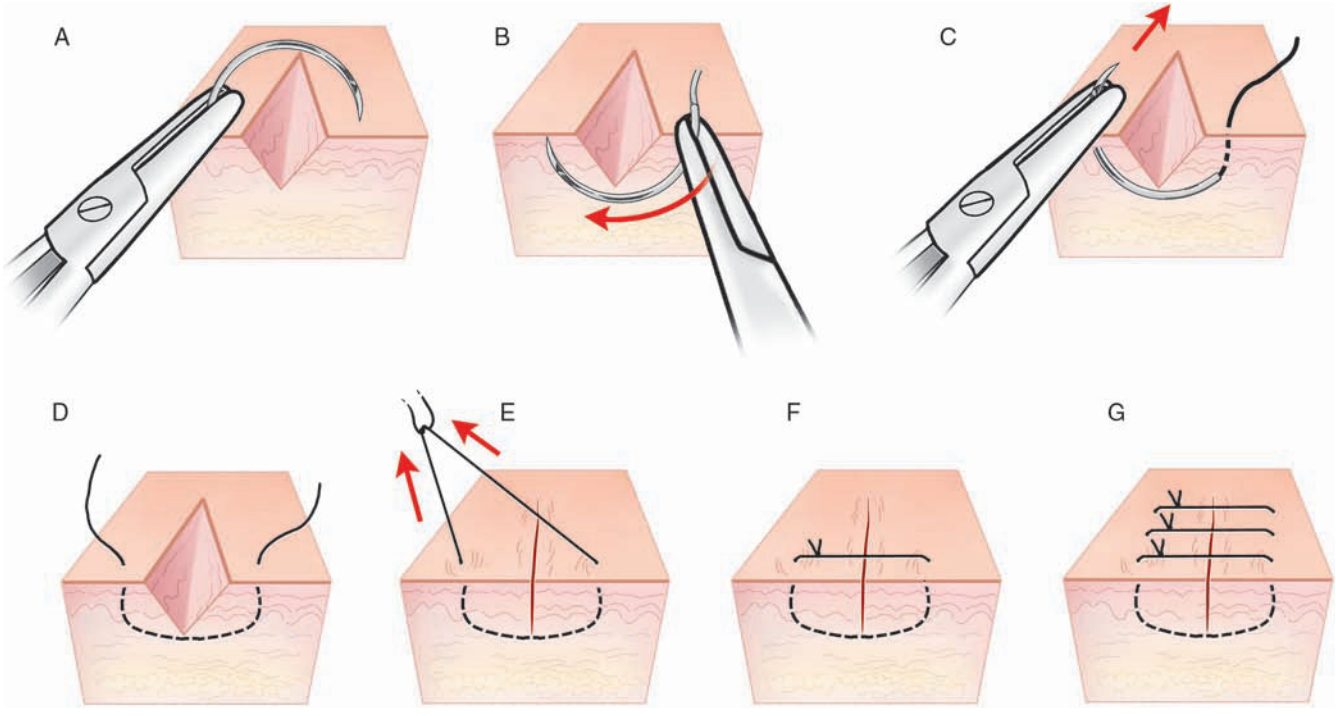


FIGURE 93-6. The simple interrupted stitch.

OPEN-LOOP SIMPLE INTERRUPTED STITCH

The open-loop simple interrupted stitch is a variation of the simple interrupted stitch (**Figure 93-7**). The same basic technique is used except that the knot is tied differently. The tie involves laying down the first knot with an instrument tie. However, the second knot placed on the suture is not pulled all the way down. Pull the second knot only until it is just above the first knot (**Figure 93-7A**). In other words, the second knot is loosely tied, leaving a loop between the first and second knots. Place a third knot as a single knot square to the second knot (**Figure 93-7B**). Cinch the third knot tightly to the second knot. This "locks" the third knot onto the second knot.

This knot is indicated when there is the possibility of edema forming at the suture site. If edema forms, the first knot will have room to open as it slides toward the second knot. This stitch avoids excessive tension on the wound and prevents the suture from cutting into the skin. This stitch facilitates suture removal when numerous small stitches are placed next to a wound edge. Cutting the open loop unravels the knot and allows for easy removal of the suture. This stitch should not be used in areas where the skin is thin or if there is little subcutaneous tissue (e.g., dorsal hand and foot). In these areas, the wound edges often become unopposed while the knot is being secured.

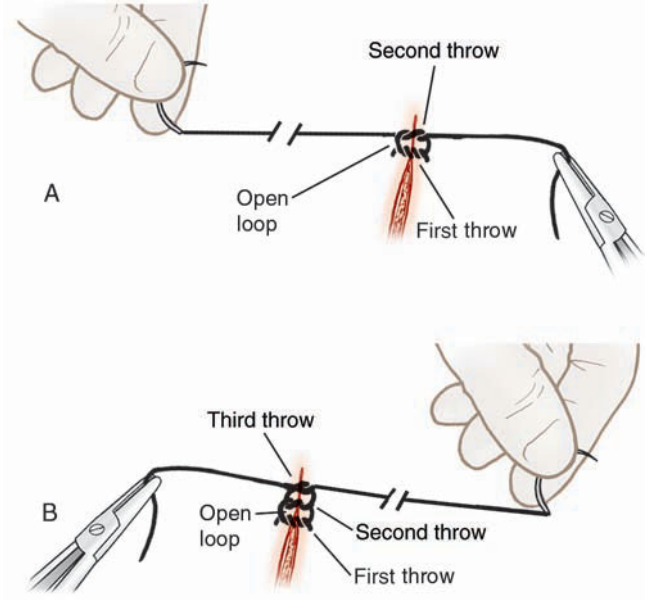


FIGURE 93-7. The open-loop simple interrupted stitch.

INTERLOCKING SLIP KNOT

This technique can be used in patients who will be traveling, camping, or otherwise away from their primary source of medical care (**Figure 93-8**). The patient can easily remove the sutures without having to find an unfamiliar or foreign healthcare provider for routine suture removal. The interlocking slip knot can be removed by hand without the use of a scissors or a scalpel. This can be useful for suture removal in pediatric patients, who may find it hard to sit still for suture removal.

Place a suture through the skin on both sides of the laceration (**Figure 93-8A**). Loop the tail end of the suture around the tip of the needle driver (**Figure 93-8A**). Grasp the needle end of the suture with the needle driver (**Figure 93-8B**). Pull the needle end of the suture through the loop while simultaneously pulling on the tail end of the suture with a second needle driver (**Figure 93-8C**). Continue to pull both suture halves in opposite directions until a knot is formed against the skin and the wound edges are apposed (**Figure 93-8D**). Release the needle driver holding the now formed loop. Insert the needle driver through the loop and grasp the tail end of the suture (**Figure 93-8E**). Grasp the needle end of the suture with the second needle driver (**Figure 93-8E**). Pull the

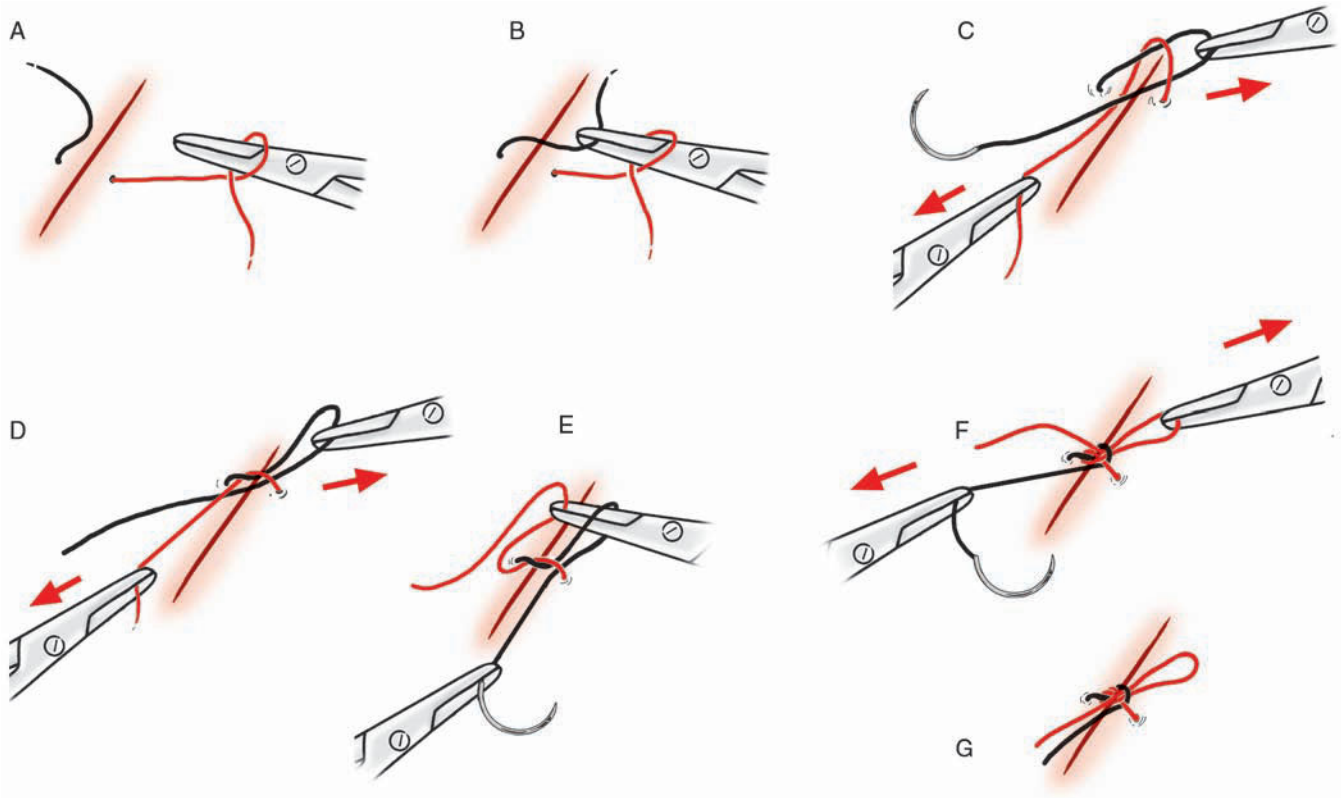


FIGURE 93-8. The interlocking slip knot.

needle drivers in opposite directions to lock and secure the knot (**Figure 93-8F**). The knot is now complete (**Figure 93-8G**). To remove the stitch, pull the free end of the suture to unlock the knot. Continue to pull the suture until it is free from the skin. This stitch can easily become loose or open before the wound is healed. Thus, it is recommended to cover the wound and sutures with skin closure tape (e.g., Steri-Strips).

CONTINUOUS OVER-AND-OVER STITCH (SIMPLE RUNNING STITCH)

Continuous (simple running) sutures minimize the time required for laceration repair. Stitches can be placed very quickly, since each individual stitch does not have to be tied. This stitch provides strength and applies equal tension on all sutures in the repair. This stitch can be used to achieve hemostasis. The wound must be long and straight. Simple running stitches can effectively be used in partial-thickness lacerations and wounds under minimal tension.

However, there are several disadvantages to this stitch. It can be associated with significant epithelialization of the suture track. This is especially true if the suture is not removed early and remains for a prolonged period of time. Inclusion cysts may form within a few weeks after removal of the sutures. **Simple running stitches should not be used on any wound under tension.** If one suture breaks, the entire wound may open. **This stitch should not be used when closing a wound where there is a risk of subsequent hematoma formation.** Hematoma formation would require the removal of all of the sutures in order to drain the hematoma. Although this suture is not commonly used in the Emergency Department, it can be very helpful for closing bleeding scalp wounds, as the injury will be covered with hair and cosmesis is a secondary concern.

Place the initial stitch as a simple interrupted stitch (**Figure 93-9A**). Do not cut the suture after the knots are securely tied. Place a second stitch 3 to 5 mm from the first stitch as if placing another simple interrupted stitch (**Figures 93-9B & C**). Place a third stitch 3 to 5 mm from the second stitch (**Figures 93-9D & E**). Continue to place additional stitches until the end of the laceration is reached. **Use care to ensure that the sutures are all lined up with each other and equidistant from the laceration.** Do not pull the last throw taut against the skin (**Figure 93-9F**). The loop will act as the tail end of the suture for knot tying. Loop the needle end of the suture twice around the tip of the needle driver (**Figure 93-9G**). Grasp the last throw with the tips of the needle driver (**Figure 93-9G**). Pull the last throw through the loops until the knot is against the skin (**Figure 93-9H**). Perform three to five more instrument ties to secure the knot. Cut off the excess suture (**Figure 93-9I**).

CONTINUOUS SINGLE-LOCKED STITCH (RUNNING-LOCKED CLOSURE)

This stitch may promote less epithelialization of the suture track than the continuous over-and-over stitch. It maintains the advantages of a continuous suture. This variation of the simple running closure locks each stitch after it is placed (**Figure 93-10**). It provides a secure apposition of the wound edges while each subsequent stitch is placed. The main disadvantage of this stitch is the time it takes compared to a continuous over-and-over stitch.

Place the initial stitch as a simple interrupted stitch (**Figure 93-10A**). Do not cut the suture after the knots are securely tied. Loop the tail end of the suture over the nondominant fifth finger (**Figure 93-10B**). Apply slight tension on the tail end of the suture while placing the second stitch (**Figures 93-10C & D**).

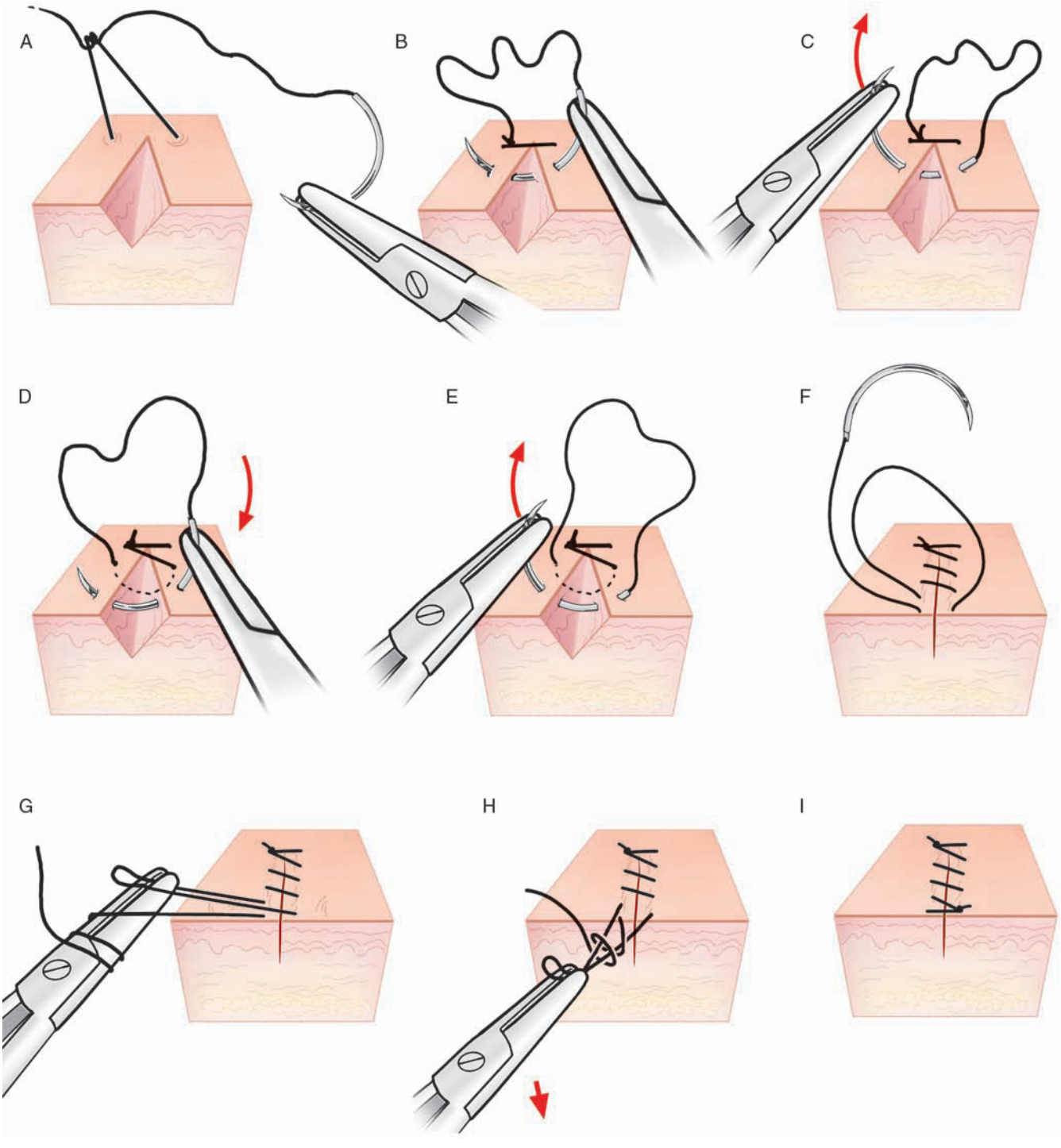


FIGURE 93-9. The continuous over-and-over or simple running stitch.

As the needle exits the skin, move the nondominant hand to bring the suture loop down and over the needle (**Figure 93-10E**). Grasp the front of the needle with the needle driver. Simultaneously pull the needle and suture through the laceration while releasing the loop from the fifth finger (**Figure 93-10F**). Repeat this procedure until the laceration is closed (**Figure 93-10G**). **Do not pull the last throw taut against the skin.** The loop will act as the tail end of the suture for knot tying. Loop the needle end of the suture twice around the tip of the needle driver (**Figure 93-10H**). Grasp the last throw with the tips of the needle driver. Pull the last throw through the loops until the knot is against the skin (**Figure 93-10I**). Perform three to five more instrument ties to secure the knot. Cut off the excess suture (**Figure 93-10J**).

VERTICAL MATTRESS STITCH

The vertical mattress stitch is a double stitch that provides for excellent wound eversion (**Figure 93-11**). It optimizes wound closure of lacerations under tension. This stitch is useful in areas where the skin is very lax, such as the elbow and the dorsum of the hand. This

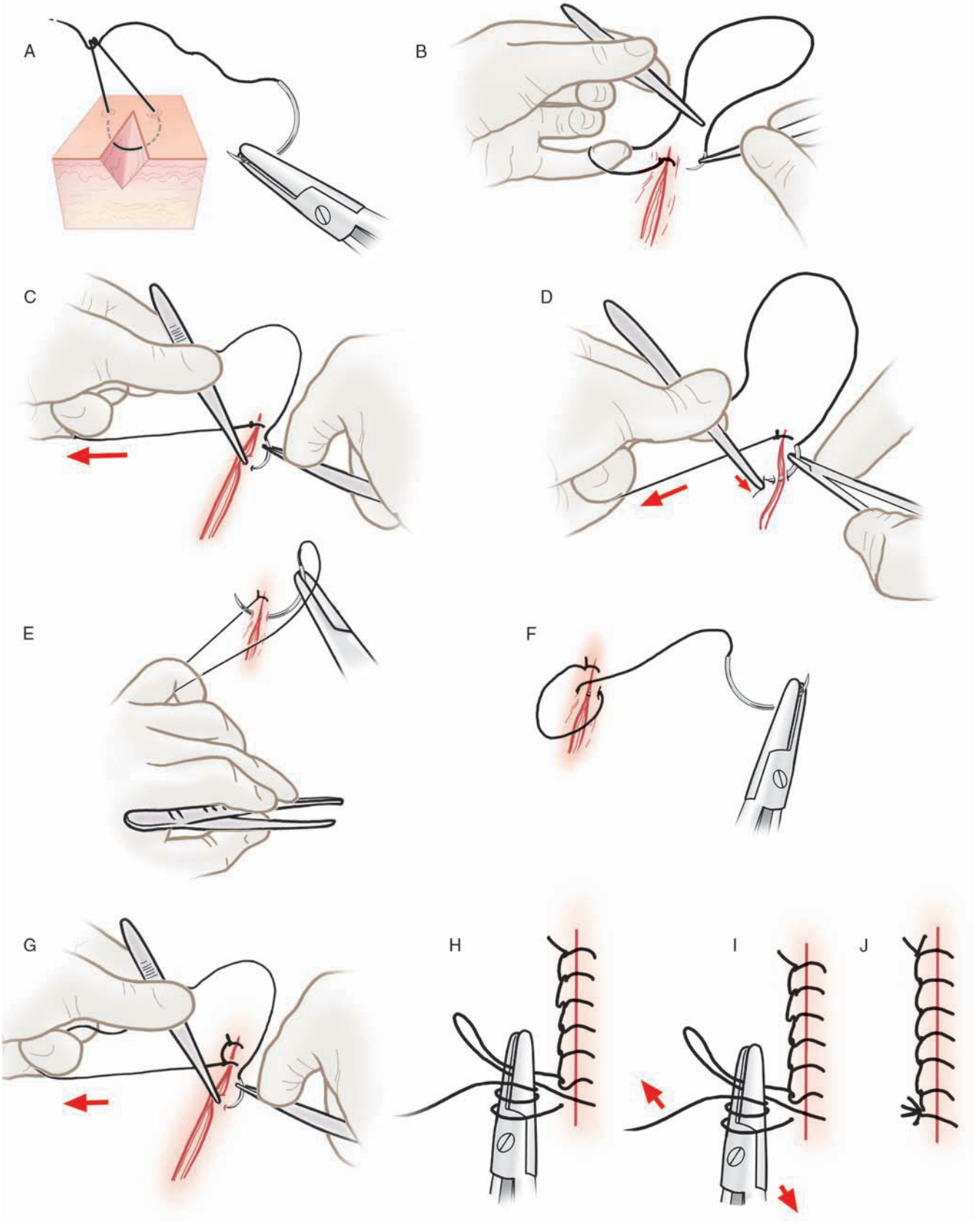


FIGURE 93-10. The continuous single-locked or running-locked stitch.

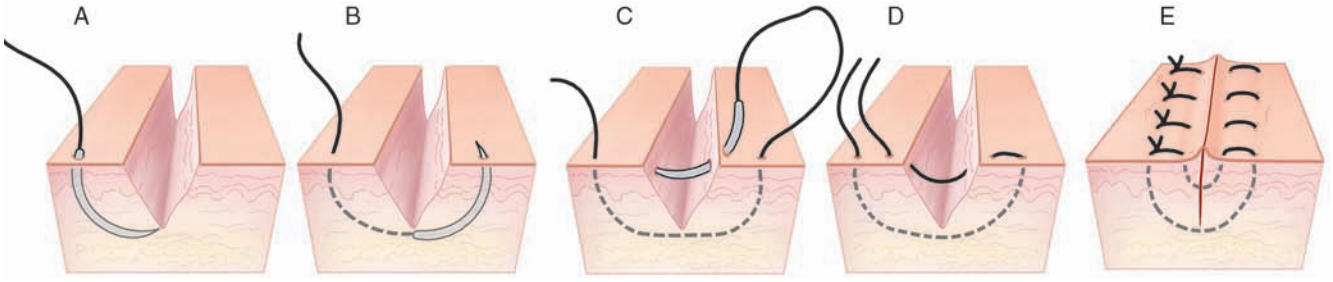


FIGURE 93-11. The vertical mattress stitch.

stitch provides for both superficial as well as deep closure of lacerations. **This stitch is contraindicated in lacerations involving the volar aspect of the hands and feet or the face, as it requires the blind placement of a deep suture.** The main disadvantage of the vertical mattress closure is the time it takes to place it.

Place the first throw much like a simple interrupted stitch with a few noted differences. The needle should enter and exit the skin 1.0 to 1.5 cm from the wound edge. The needle should traverse the base of the wound and grasp a large amount of tissue (**Figures 93-11A & B**). Reverse the needle. The second throw should enter and exit the skin approximately 2 to 3 mm from the wound edge (**Figures 93-11C & D**). **The first and second throws must be directly over each other and parallel.** Tie the suture to approximate the wound edges (**Figure 93-11E**). The first throw will close the wound base and relieve the tension at the skin surface. The second throw approximates and everts the skin edges.

The newer version of the classic vertical mattress is referred to as the "shorthand" vertical mattress stitch (**Figure 93-12**). It provides wound eversion in half the time as the traditional method. Place the first throw close to the lacerated wound edge to approximate the skin edges (**Figures 93-12A & B**). Grasp and pull the suture to elevate the wound edges (**Figure 93-12C**). This allows the needle to more easily take a large bite of tissue on the second throw. Place the second throw 1.0 to 1.5 cm from the wound edge (**Figures 93-12C & D**). Release the suture. Tie the suture to approximate the wound edges and evert the skin surface (**Figure 93-12E**). The final product looks exactly the same as the traditional vertical mattress suture (**Figure 93-12F**).

LOCKED VERTICAL MATTRESS STITCH

The locked vertical mattress stitch is useful in areas that are widely separated and where deep sutures must be avoided (**Figure 93-13**). This stitch helps to reduce the amount of tension needed to close a wound. It helps to avoid the pain and scarring that can result if too much tension is applied to a laceration. It does not put an

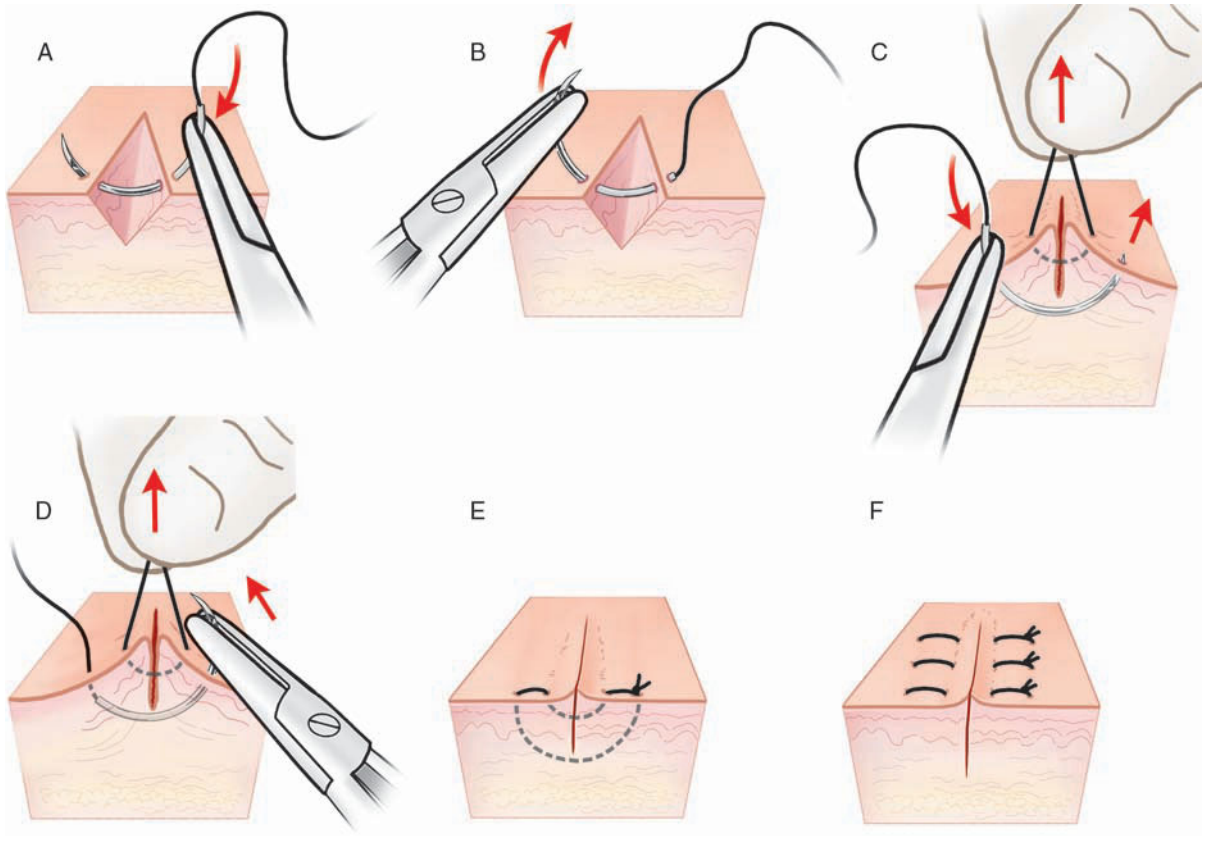


FIGURE 93-12. The "shortcut" vertical mattress stitch. An alternative method to place the vertical mattress stitch.

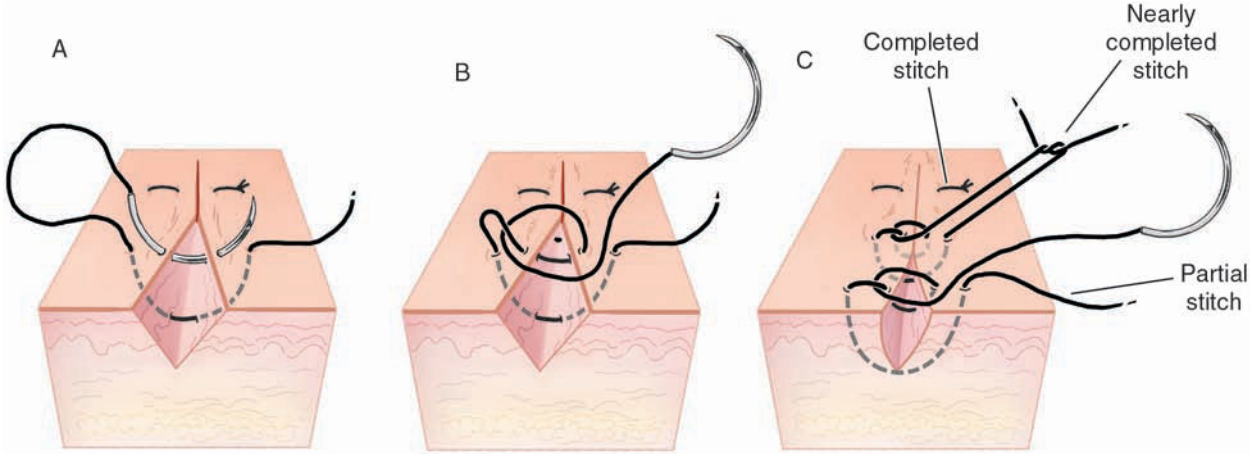


FIGURE 93-13. The locked vertical mattress stitch.

excessive amount of tension on the deep throw, as does the vertical mattress stitch.

This is a modification of the vertical mattress stitch (**Figures 93-11 & 93-12**). Place the first two throws as if placing a vertical mattress stitch (**Figure 93-13A**). Leave the suture lax with a loop above the wound surface. Pass the needle end of the suture through the open loop (**Figure 93-13B**). This step will form the locked portion of the stitch. Pull the needle end of the suture taut to appose the wound edges (**Figure 93-13C**). Tie and secure the suture in the standard manner.

HORIZONTAL MATTRESS STITCH

The horizontal mattress stitch is placed along the axis of the wound and helps to eliminate tension on the wound (**Figure 93-14**). It is a good closure technique for wounds with relatively poor circulation to the wound edges because, theoretically, no suture is placed through the wound edges. This helps to avoid tension on the wound edges from the suture and subsequent local necrosis. This stitch is placed more rapidly than the vertical mattress stitch. It requires fewer stitches to close a wound with horizontal rather than vertical mattress stitches. The throws are side by side rather than on top of each other, as with the vertical mattress, and each stitch closes more tissue. This closure may be used on the volar surfaces of the hands and fingers, as these delicate skin areas may swell and be cut by simple interrupted sutures. The main disadvantage of the horizontal mattress stitch is that it takes more experience to properly place this stitch to achieve wound eversion than with the vertical mattress stitch.

Place the first throw much like a simple interrupted stitch with a few noted differences. The needle should enter and exit the skin 0.5 to 1.0 cm from the wound edge. The needle should traverse the

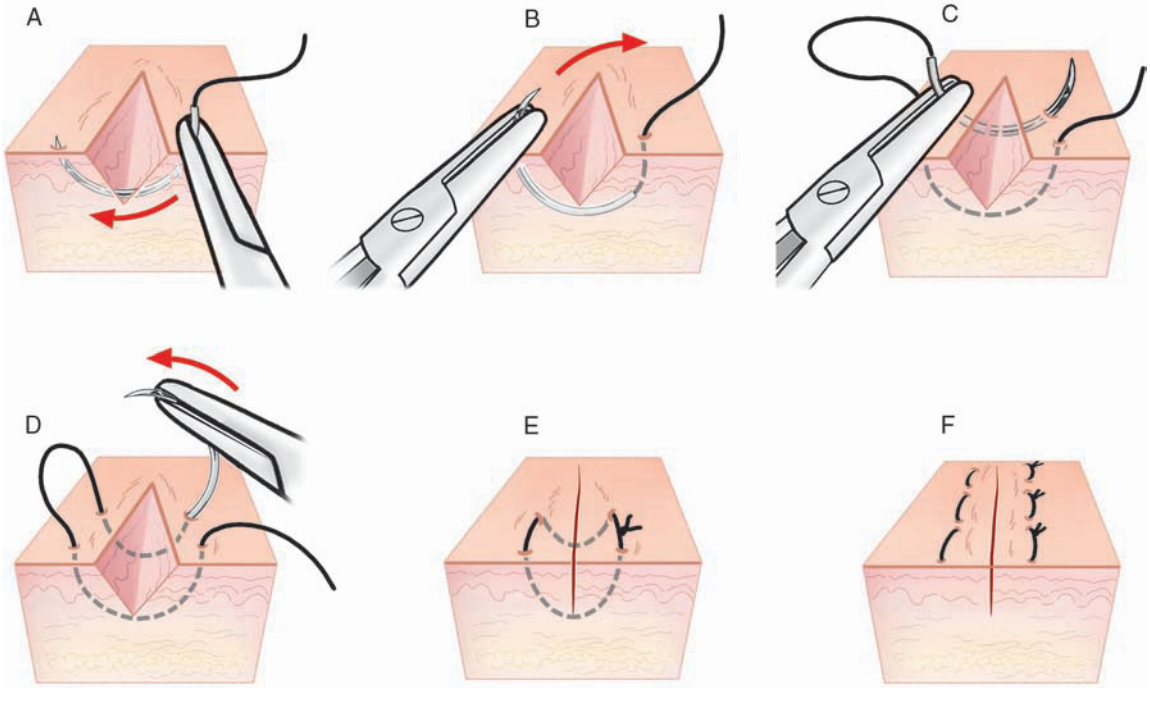


FIGURE 93-14. The horizontal mattress stitch.

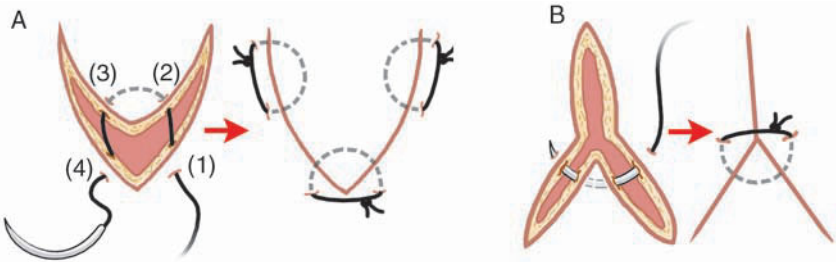


FIGURE 93-15. The half-buried horizontal mattress stitch is used to approximate a star-shaped (stellate) laceration (**A**) and a Y-shaped laceration (**B**).

base of the wound (**Figures 93-14A & B**). Reverse the needle and make a second throw 0.5 cm from the first (**Figure 93-14C**). **The needle must enter and exit the skin and the wound edges so that the first and second throws are parallel to each other** (**Figures 93-14C & D**). Pull the free ends of the suture taut to appose and evert the wound edges (**Figures 93-14E & F**). Tie and secure the suture in the standard manner.

HALF-BURIED HORIZONTAL MATTRESS STITCH

This is the stitch of choice to close complex wounds with multiple flaps in a single-layer closure. This stitch is ideal to close stellate, Y-shaped, V-shaped, and T-shaped lacerations. The half-buried horizontal mattress stitch allows a tissue flap to be reapproximated without tension on the edges of the flap. The vascular supply to a flap is derived from its base. The flaps sometimes have a limited or poor vascular supply. This stitch may be used to approximate a flap-like laceration in which the corner has limited vascularity and/or viability.

The key to this stitch is that the needle and suture pass through the dermis of the flap and not the epidermis (Figure 93-15). Begin by placing the first stitch percutaneously through the skin adjacent to the tip of the flap (**Figure 93-15A**). Advance the needle through the dermal layer of the flap, the dermal layer of the skin adjacent to the tip of the flap, and out the skin adjacent to the tip of the flap opposite to where the stitch began (**Figure 93-15A**). **The needle must traverse the dermis of the flap and adjacent tissue at the same level of the dermis to properly approximate the wound edges.** Gently pull on the free ends of the suture to approximate the flap against the adjacent skin edges. Tie and secure the suture in the usual manner. Secure the edges of the flap with half-buried horizontal mattress stitches (**Figure 93-15A**), simple interrupted stitches, vertical mattress stitches, or horizontal mattress stitches.

Stellate lacerations are often seen in the Emergency Department. They occur due to bursting of the skin from crush injuries. These lacerations are often encountered on the extremities, forehead, and scalp. Begin by inserting the needle through the skin of the largest flap. Advance the needle so that its tip exits the dermis. Continue to advance the needle through the dermis of each flap. The half-buried horizontal mattress stitch should encompass the tips of all the flaps (**Figure 93-15B**). The remainder of the procedure is as described above.

CONTINUOUS (RUNNING) HORIZONTAL MATTRESS STITCH

The running horizontal mattress stitch is indicated in areas of the body where there is loose skin that tends to overlap or invert, such as the skin of the upper eyelids or the dorsum of the hand. This stitch can also be used as the surface closure in a multiple-layer closure if there is a tendency for wound inversion. Like the traditional horizontal mattress stitch, it provides good apposition and can be placed rapidly. The running horizontal mattress stitch is contraindicated in wounds under tension if the goal of wound closure is optimal cosmesis.

This stitch begins with a simple interrupted stitch at one end of a laceration (**Figure 93-16**). The needle is then run along the length of the wound while placing horizontal mattress stitches. The difference between this and the standard horizontal mattress stitch is that the suture is not tied and cut after each individual stitch. Rather, the stitch is continued (running) the length of the laceration. At the end of the laceration, the stitch is tied and secured in the same way as the simple running stitch (**Figure 93-9**).

CONTINUOUS SUBCUTICULAR STITCH

This closure is ideal for lacerations of the face and neck. It provides excellent cosmesis, leaves no suture marks on the skin, and causes minimal scarring. It requires more time and skill to place than other types of stitches. It may be performed for the temporary pull-out (**Figure 93-17**) or permanent placement (**Figure 93-18**) of subcutaneous sutures. Polypropylene or nylon sutures must be used for this stitch. Polypropylene is preferred as it is stiffer, stronger, and easier to remove than nylon.

The use of this stitch is limited to lacerations that are clean, straight, have sharp edges, and are less than 6 cm in length. It may be extremely difficult to remove the suture material for the pull-out technique if the laceration is greater than 6 cm in length. The laceration can be longer if the permanent placement of absorbable sutures is being used. The dermis and subcutaneous tissue must be apposed before proceeding with this stitch. If necessary, apply buried absorbable sutures to appose the dermis before applying this stitch. **The superficial wound surface must be tension-free, as this stitch is for cosmesis and not strength.** The wound may require undermining to release the tension from the wound edges. Refer to Chapter 92 for details regarding wound undermining.

The pull-out technique allows the subcuticular stitch to be removed after the laceration heals (**Figure 93-17**). The subcuticular suture should enter the intact skin 3 to 4 mm from one end of

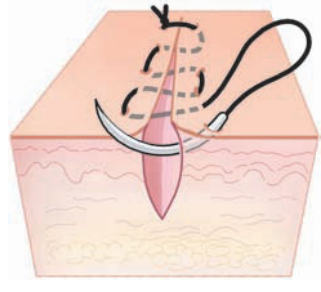


FIGURE 93-16. The continuous or running horizontal mattress stitch.

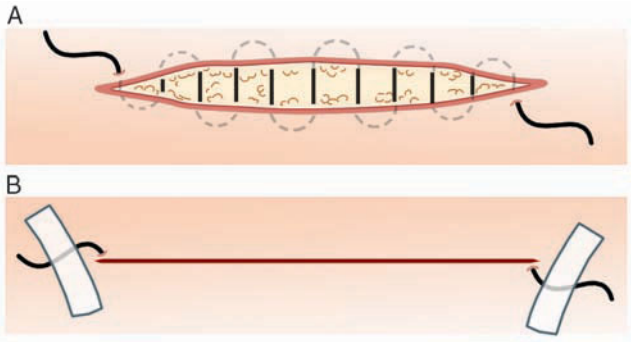


FIGURE 93-17. The continuous subcuticular pull-out stitch.

the laceration and burrow through the dermal-epidermal junction to emerge through the skin at the other end of the laceration (**Figure 93-17A**). The suture will continuously pass through the subcuticular layer on alternate sides of the laceration. **The point of entry of each stitch should be directly across from or slightly behind the exit point of the previous stitch. It is very important to keep the needle at the same level of depth throughout the wound. The tension on the suture should be adjusted to ensure that there is no puckering of the skin.** Tape the free suture at both ends of the laceration to the skin (**Figure 93-17B**). Place wound tape (e.g., Steri-strips) across the laceration to help maintain the apposition of the epidermis. This stitch is easily removed. Remove the wound tape and slowly pull one end of the suture with a needle driver.

As an alternative, the continuous stitch may be placed using absorbable suture material to provide longer-lasting strength to the wound (**Figure 93-18**). Suture material of choice includes Dexon, PDS, or Vicryl. The same indications, preparation, and stitch are used as with the pull-out technique. The only difference is in the starting and ending stitch. Place the first stitch into the dermis, just inside the laceration edge, as a buried knot (**Figures 93-18A to C**). Place the continuous suture until the opposite end of the laceration is reached (**Figure 93-18D**). The final throw should be left lax with a trailing loop of suture (**Figure 93-18E**). The loop should be used as the "tail end" to perform an instrument tie (**Figure 93-18F**). Tie three or four knots in the suture. Lift the free ends of the suture and cut them just above the knot. Apply wound tape across the laceration to help maintain the apposition of the wound.

BURIED (SUBCUTANEOUS) KNOT STITCH

This stitch helps to decrease potential dead space underneath a laceration and gives tensile support for up to 4 to 6 weeks, while the wound is still weak. The loop is constructed so that the knot lies at the bottom of the wound base (**Figure 93-19**). This helps to keep the skin surface smooth and flat. The buried knot stitch is most useful in closing subcutaneous tissue just under the skin surface.

This stitch requires practice to master. Insert the needle into one side of the base of the wound (**Figure 93-19A**). Drive the needle from deep to superficial and exiting at the dermal-epidermal junction (**Figure 93-19A**). Insert the needle through the dermal-epidermal junction on the opposite side of the wound and drive it through the base of the wound (**Figure 93-19B**). **The suture**

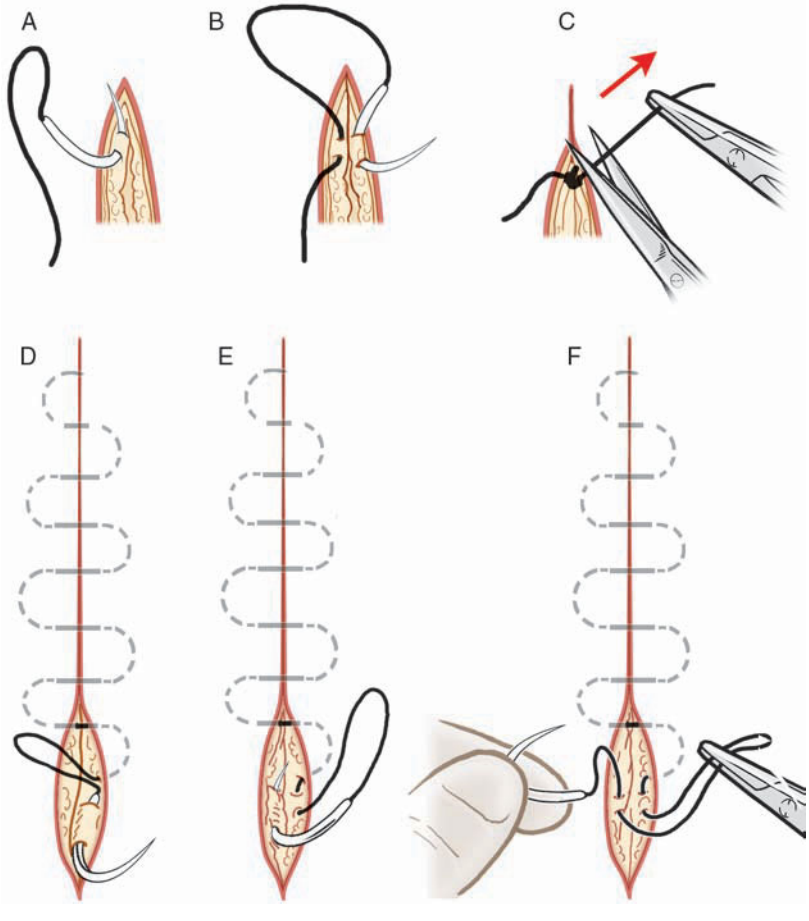


FIGURE 93-18. The continuous subcuticular permanent stitch.

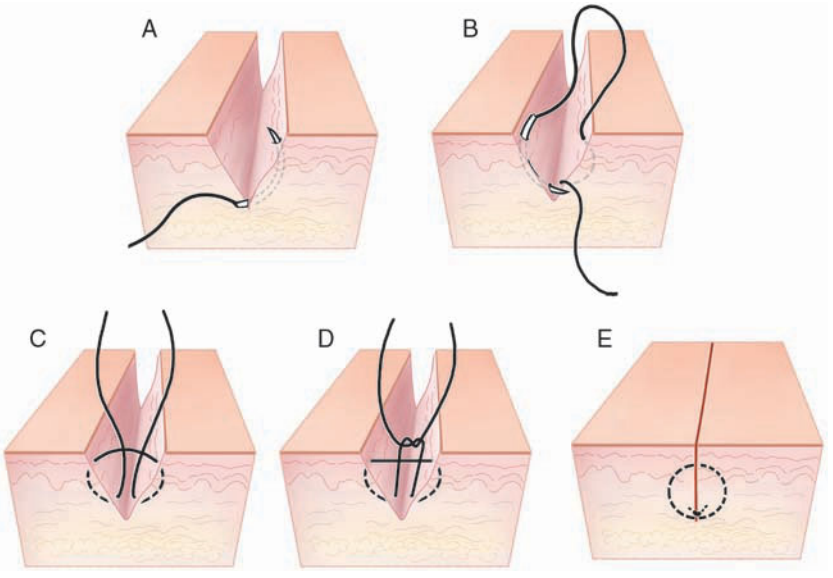


FIGURE 93-19. The buried (subcutaneous) knot stitch.

should exit the base of the wound across from and level with the entrance site of the first throw. Pull both free ends of the suture up and out through the laceration (**Figure 93-19C**). Tie a knot in the suture (**Figure 93-19D**). Pull both free ends of the suture to lower the knot to the base of the wound and appose the tissue (**Figure 93-19E**). Tie two additional knots to secure the suture. Cut off any excess suture.

REINFORCING (RETENTION) SUTURES FOR WOUNDS UNDER TENSION

Reinforcing or retention sutures are particularly useful for wounds in which the edges are widely separated or where the skin is too atrophic to approximate without the suture cutting through the skin. The reinforcing sutures help to decrease the tension on the wound by providing more support for the wound edges. Reinforcing sutures can be placed using sterile buttons or rubber tubing (**Figure 93-20**). Heavy sizes of nonabsorbable suture materials are used for reinforcing sutures. This is not for strength but to avoid the finer suture from cutting through the tissue.

Ideally, a double-swaged (needle) suture should be used to place suture from the inside of the wound toward the outside skin to avoid pulling potentially contaminated epithelial cells through the wound. The stitch is placed like the horizontal mattress stitch and sterile buttons or rubber tubing is used to achieve approximation to a point where the wound edges can be closed without significant tension (**Figures 93-20A & B**). **Do not attempt to appose the wound edges when using retention sutures.** Appose the remaining skin edges with simple interrupted, vertical mattress, or horizontal mattress stitches. The reinforcing sutures should remain in place after the skin sutures are removed. The reinforcing sutures should be removed after the wound has healed and gained significant tensile strength.

SUTURE REMOVAL TECHNIQUES

Remove sutures as soon as possible to avoid the possibility of infection and prevent the formation of suture marks. However, if they are removed too early, wound dehiscence may occur. Simple interrupted sutures should be cut at the end away from the knot and then pulled out (**Figure 93-21A**). This helps to prevent the outer contaminated portion of the suture from passing back through the wound. In order to remove a running simple or running-locked stitch, grasp the knot at the end of the closure and cut each loop

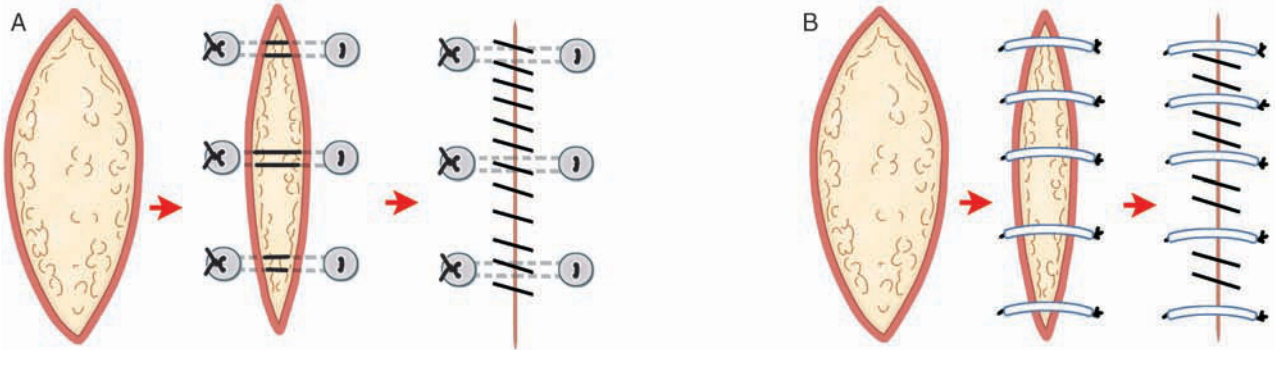


FIGURE 93-20. Reinforcing sutures for wounds under tension. Sterile buttons (**A**) or pieces of sterile rubber tubing (**B**) can be used to secure the suture and prevent injury to the soft tissues.

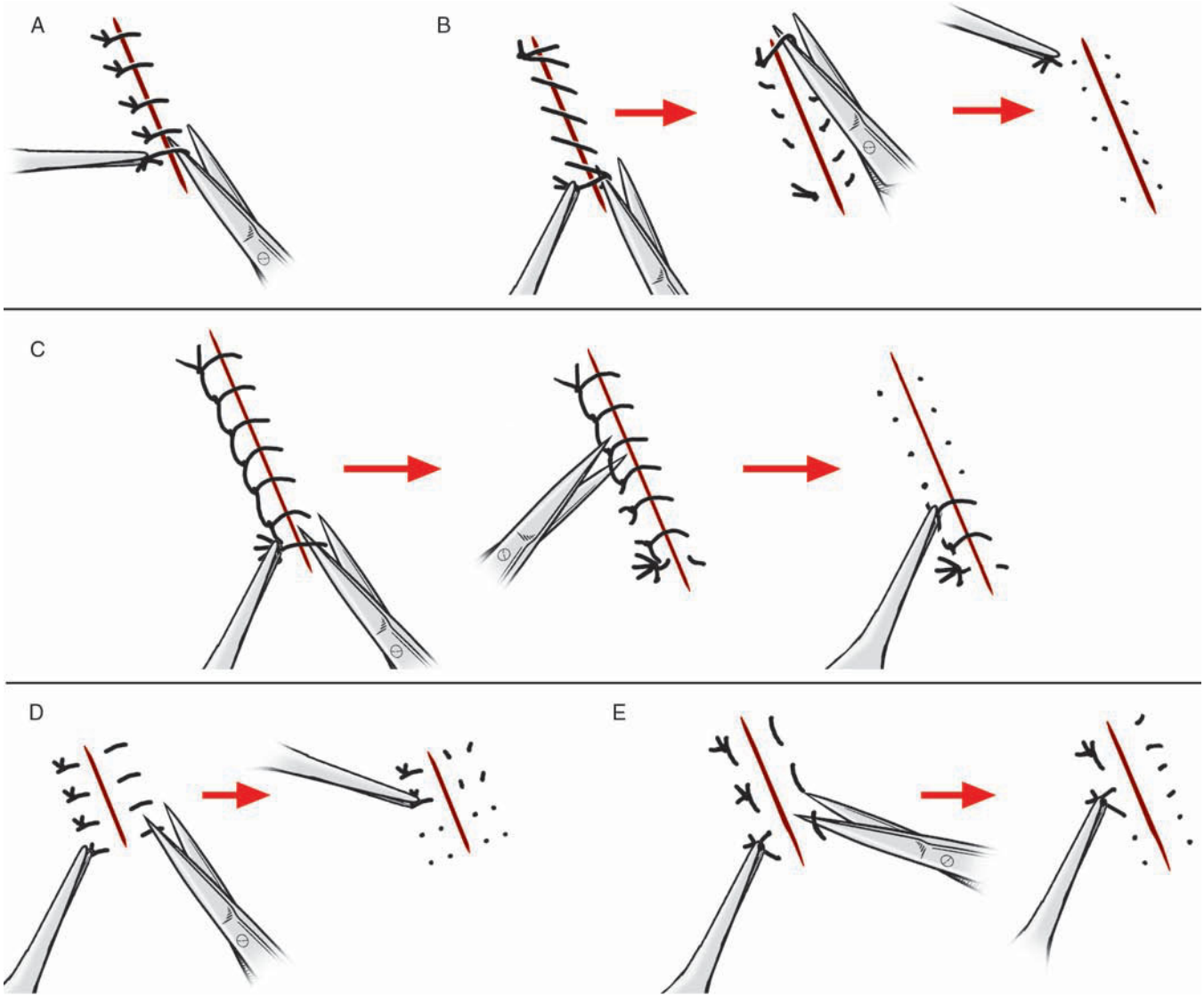


FIGURE 93-21. Suture removal techniques. **A.** Simple interrupted stitch. **B.** Simple running stitch. **C.** Running-locked stitch. **D.** Vertical mattress stitch. **E.** Horizontal mattress stitch.

(**Figures 93-21B & C**). Pull out each individual suture piece. Vertical and horizontal mattress sutures can be removed in much the same way as the simple interrupted stitch (**Figures 93-21D & E**).

TISSUE ADHESIVE CLOSURE (CYANOACRYLATES)

Tissue adhesives (skin glues) are best used to close low-tension, small, straight-edged, and superficial wounds (**Figure 93-22**). They should not be used for lacerations that are bleeding, lacerations over joints, or lacerations under tension. There must be adequate hemostasis and the tissue must be as dry as possible. The major advantage to the use of tissue adhesives is speed. Wounds can be repaired quickly and without anesthesia. Other contraindications to this type of closure are angled or beveled wounds. Petroleum-based ointments or similar products will dissolve the tissue adhesive and should be avoided on this type of closure. Refer to Chapter 94 for a more complete discussion of tissue adhesives.

Tissue adhesives come in a variety of forms and applicator tips (**Figure 93-22A**). Approximate the wound edges with forceps. Commercially available, disposable, single-patient-use tissue forceps can be used (Bionix Development Corp., Toledo, OH). These are specifically designed to approximate the wound edges prior to using cyanoacrylates (**Figure 93-22B**). Apply the adhesive in two or three layers along the wound edge (**Figure 93-22C**). The adhesive may also be applied in spots over the laceration (**Figure 93-22D**) or across the laceration, like wound tape (**Figure 93-22E**). Droplets or lines should be placed 0.5 cm from each other. Support the wound for 30 to 60 seconds while the adhesive dries.

SKIN CLOSURE TAPES

Skin closure tapes (e.g., Steri-Strips) are used to close very low tension wounds that are tidy and small. They can be used as the primary closure technique for superficial wounds (**Figure 93-23**) or they can provide reinforcement after sutures have been placed

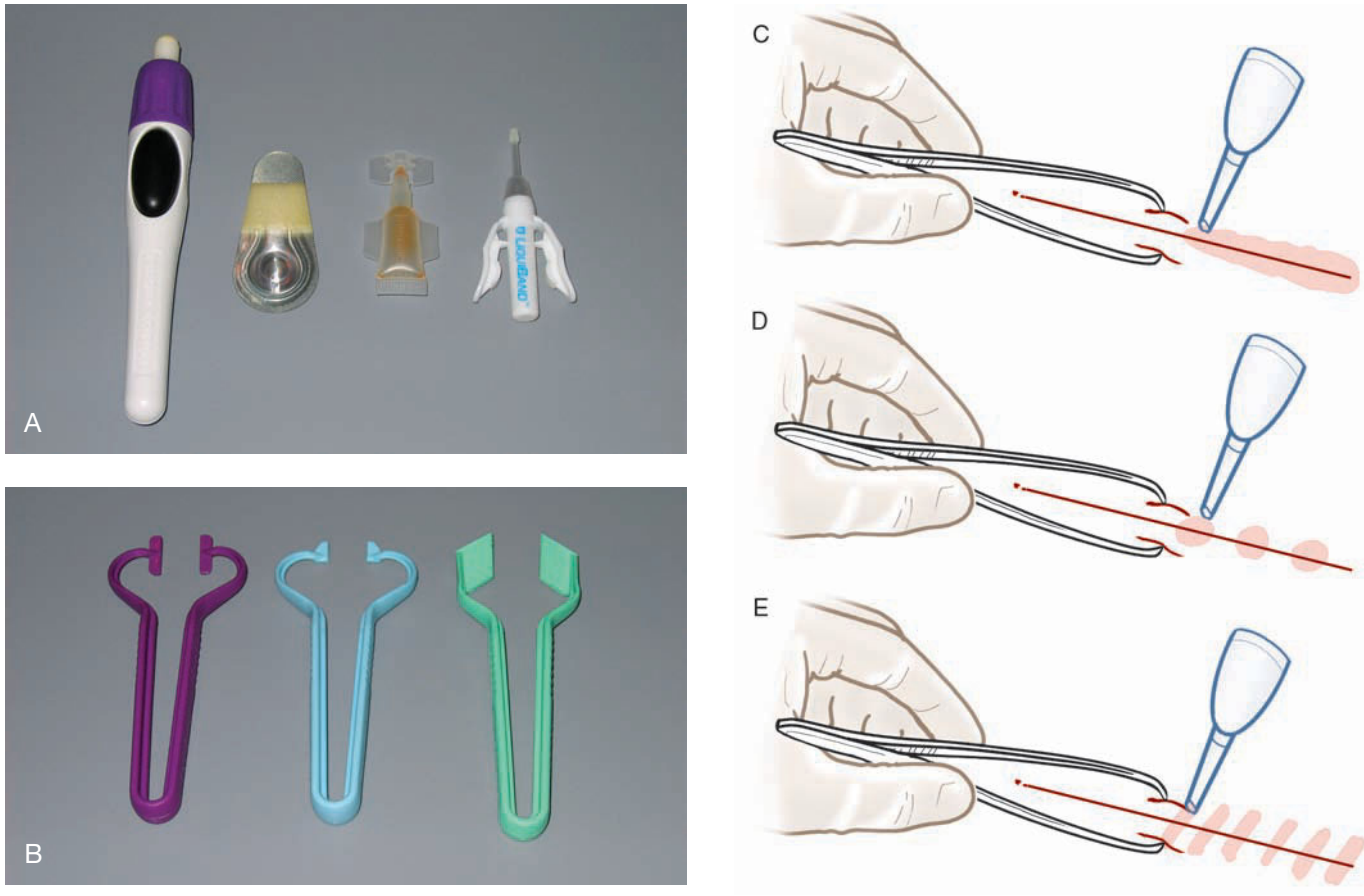


FIGURE 93-22. Laceration repair with cyanoacrylate tissue adhesive. **A.** Several examples of tissue adhesive. From left to right: Dermabond ProPen, SurgiSeal, Indermil Loctite, Liquiband Flow Control. **B.** Commercially available wound forceps (Bionix Development Corp., Toledo, OH). **C.** Tissue adhesive applied continuously over the laceration. **D.** Tissue adhesive applied in spots over the laceration. **E.** Tissue adhesive applied across the laceration.

(**Figure 93-24**). Skin tapes are easy to use and can be placed relatively quickly. They do not leave suture marks and have no skin reactivity.

Skin closure tapes should not be used in wounds where the edges are widely separated or on parts of the body where there is movement or moisture. This technique does not work well on irregularly shaped wounds or wounds where there will be a propensity for swelling of the wound edges. Care should be taken in using these tapes in a child. If they are not secured properly, the child may remove them prematurely.

After the initial cleansing of the skin, clean the skin surface with acetone or alcohol to remove any surface oils. Allow the skin to dry. Apply benzoin solution, or gum mastic (e.g., Mastisol), to the skin on both sides of the wound (**Figure 93-23A**). Allow 60 to 90 seconds for the liquid benzoin to dry and become tacky. Cut the skin closure tapes to the proper length (**Figure 93-23B**). Gently tear the end-tab off the back of the card to prevent the strips from deforming (**Figure 93-23C**). Remove a strip from the card (**Figure 93-23D**). Firmly secure the tape to one side of the wound (**Figure 93-23E**). Use the nondominant hand to appose the wound edges as the tape is brought over and secured to the skin on the opposite wound edge (**Figure 93-23F**). Place additional tapes at 2 to 3 mm intervals until the wound edges are apposed (**Figures 93-23G & H**). Place pieces of tape across the tape edges to prevent premature removal and skin blistering from the tape ends (**Figure 93-23I**).

Skin closure tapes may be placed over a sutured laceration (**Figure 93-24**). The tapes will provide additional support to the wound edge and help to prevent dehiscence. This technique is especially useful in areas of cosmetic concern, such as the face.

The skin closure tapes should remain in place for at least as long as the sutures. They must be kept dry to prevent them from coming off prematurely and the wound from dehiscing. The wound should be observed daily for signs of infection.

Skin closure tapes may be placed across a wound when sutures or staples are removed. The tapes will maintain the apposition of the epidermis as the wound matures. Apply benzoin solution to the skin before removing the sutures or staples. Remove several sutures or staples and apply the skin closure tapes. Continue this process until all the sutures or staples have been removed and the wound is covered with skin closure tapes. Alternatively, remove all of the sutures or staples and then apply the skin closure tapes.

Suturing lacerations in a thin-skinned individual is often difficult. The skin frequently tears as the wound is approximated and the suture is tied. The use of skin closure tapes can facilitate wound closure, strengthening the skin edges, and allow for a more secure wound closure. Clean, prep, and anesthetize the skin. Apply benzoin solution to the skin adjacent to and on both sides of the laceration. Allow the benzoin to sit and become tacky. Apply skin closure tapes over the benzoin on both sides of the laceration. Suture the laceration, ensuring that the needle enters the skin on one side of the laceration and exits the skin on the other side of the laceration through

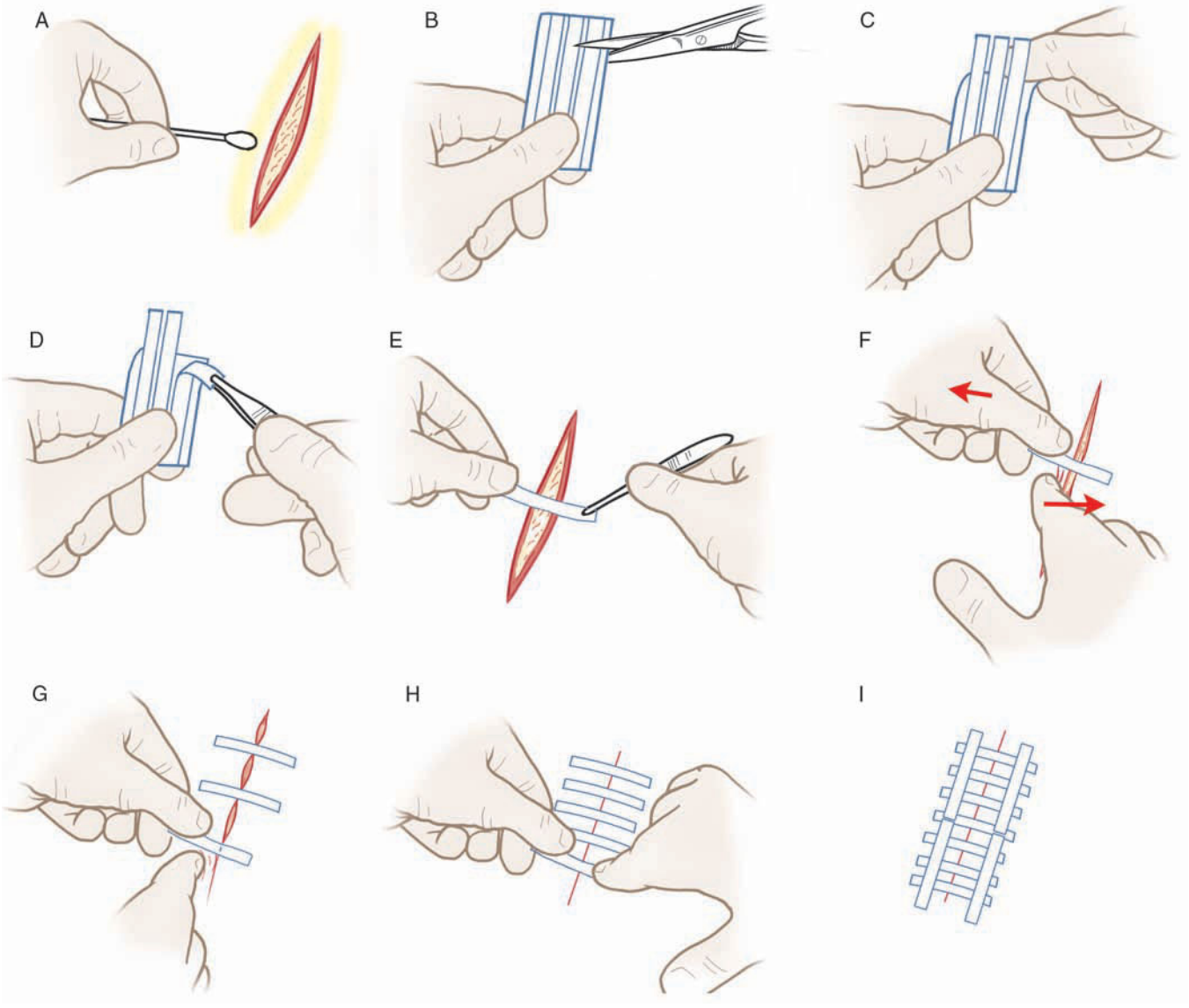


FIGURE 93-23. Skin closure tapes to primarily close a laceration.

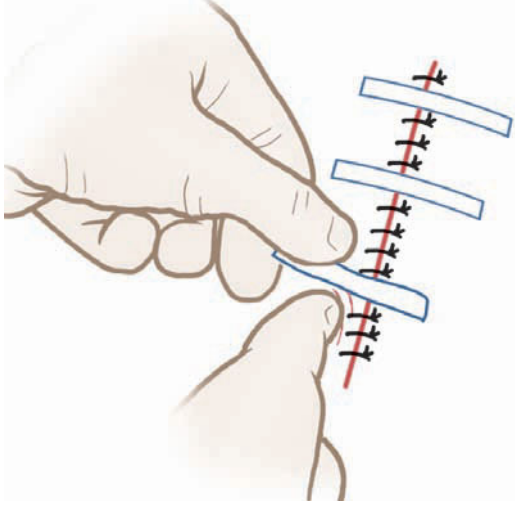


FIGURE 93-24. Skin closure tapes can provide reinforcement for sutures.

the skin closure tapes on each side. Remove the skin closure tapes at the time of suture removal.

Two advanced skin closure tape-based systems are the ClozeX (Clozex Medical LLC, Wellesly, MA) and the 3M Steri-Strip S Surgical Skin Closure (3M Healthcare, St. Paul, MN). These are nonlatex, disposable, single patient use, transparent, adhesive-based wound closure devices for the primary closure of lacerations and wounds not under tension. They align the wound edges and provide good cosmetic results. They come in a variety of sizes, ranging from 10 to 100 mm.

STAPLE CLOSURE

Stapling is a rapid closure technique that is useful for superficial scalp lacerations and linear lacerations of the trunk and extremities. Staples should not be used on the face, neck, hands, or feet. These areas have little subcutaneous tissue and the staples can damage underlying structures. Staples should also be avoided in any area of the body that will be exposed to computed tomography (CT) or magnetic resonance imaging (MRI). The staples are

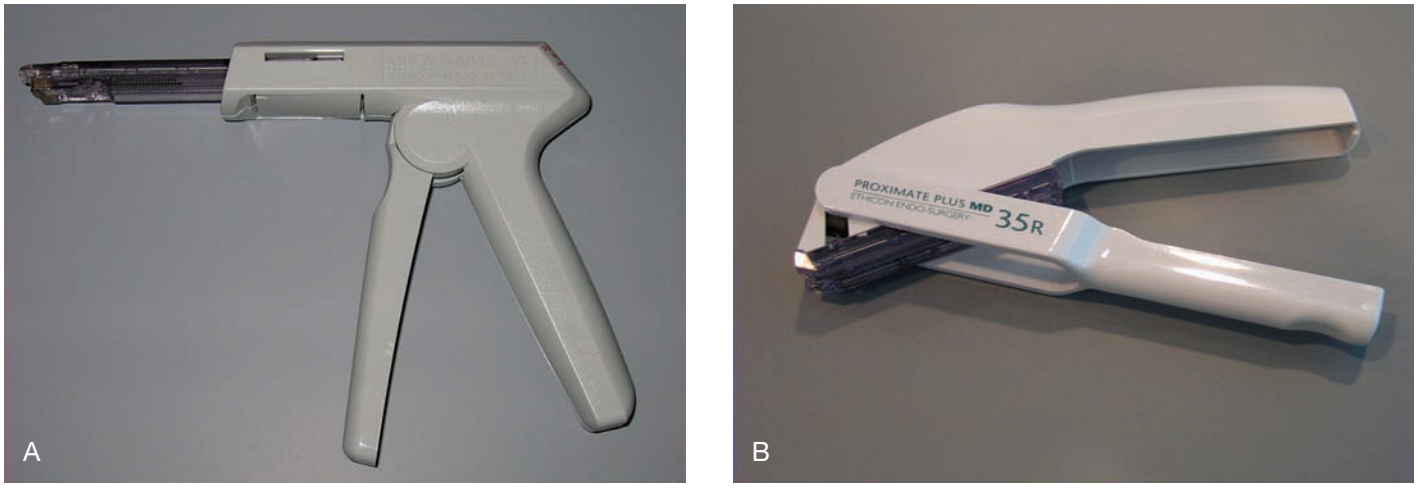


FIGURE 93-25. Examples of two styles of skin staplers.

made of an inert material, which helps to decrease tissue reactivity. Staples should not be used for wounds that are crush wounds, infected, irregular, macerated, over bony prominences, or under tension.

The skin stapler is a simple device (**Figure 93-25**). It is a single patient use, sterile, disposable unit that is preloaded with staples. It is grasped and held with one hand. When the handle is squeezed, a staple is inserted into the tissue. The stapler automatically loads the next staple after one staple is discharged. Skin staplers typically have 10 or 35 preloaded staples.

Prepare the wound for stapling. Place deep sutures to close the subcutaneous tissue and, if the wound is gaping, bring the wound edges into apposition. Approximate the skin edges with the dominant hand (**Figure 93-26A**). Evert the wound edges with a forceps

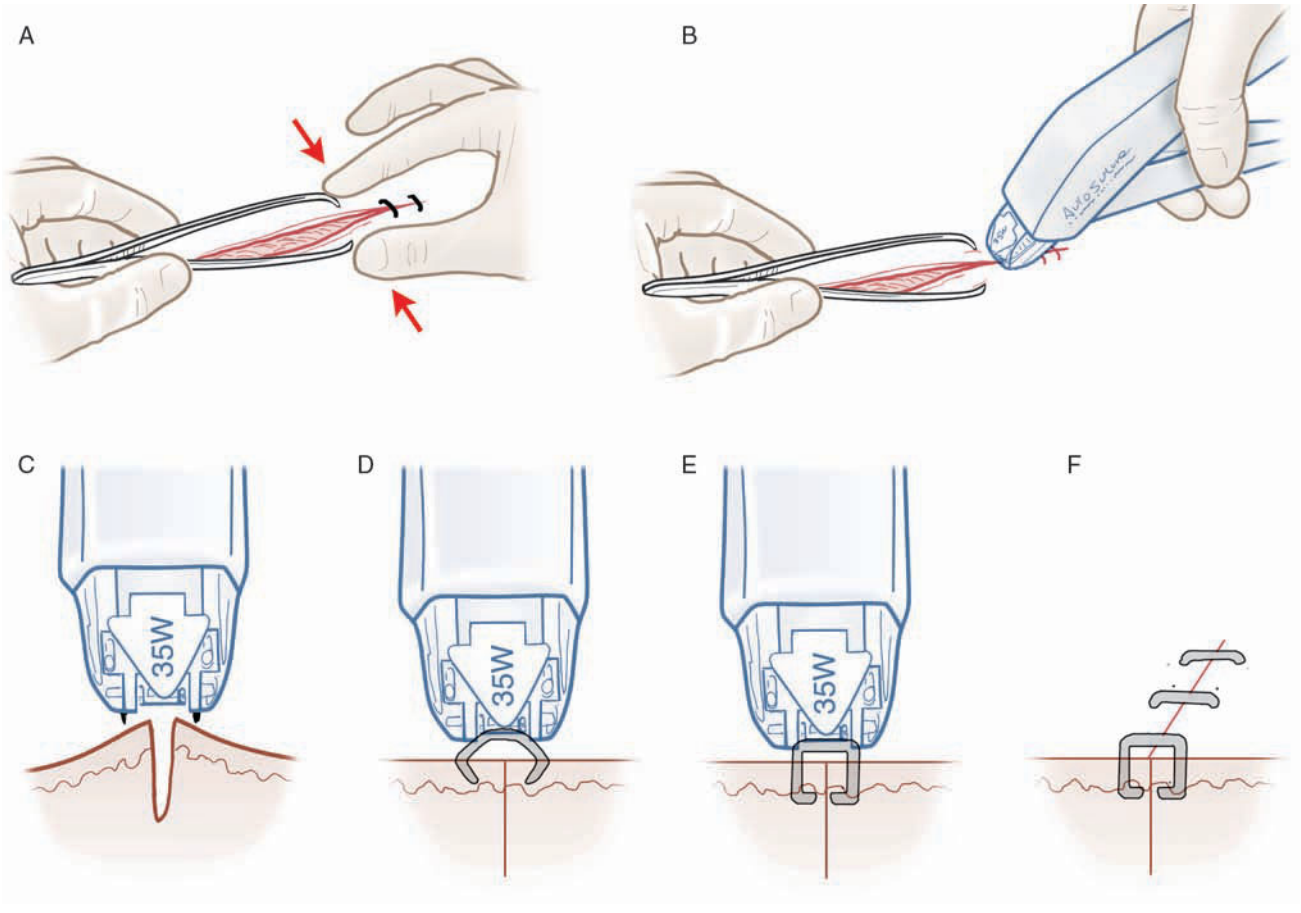


FIGURE 93-26. Laceration repair with staple closure. **A.** The wound edges are apposed and everted. **B.** The stapler is applied over the laceration. **C.** The stapler is applied over the everted wound edges. **D.** The plunger advances the staple into the wound margins. **E.** The anvil bends the staple into shape. **F.** The final product.

held in the nondominant hand (**Figure 93-26A**). Grasp the stapler with the dominant hand. Gently place the skin stapler over the laceration (**Figure 93-26B**). Start at one end of the laceration and work toward the opposite end. **Do not indent the skin with the stapler, as this will cause the staples to be placed too deep.** Align the arrow on the front of the stapler over the laceration (**Figure 93-26C**). Squeeze the handle of the stapler. A plunger will advance a staple into the wound margins (**Figure 93-26D**). An anvil will bend the staple into a square or rectangular shape to secure the staple (**Figure 93-26E**). Continue to evert the wound edges and apply staples every 3 to 5 mm until the wound is approximated and without any gaps (**Figure 93-26F**). A small space will be visible between the skin surface and the staple if it is properly positioned. If the staple is against the skin, it has been placed too deep. Remove the staple and replace it.

There are a few complications associated with staple use. Their removal can be uncomfortable or difficult. Minor bleeding can occur from the holes after the staples are removed. Staples placed on the face, feet, hands, and neck can damage superficial subcutaneous structures (e.g., blood vessels, muscles, nerves, and tendons). Improper wound eversion can result in wound dehiscence upon staple removal, larger scars, and poor wound healing. Staples can cause larger and more prominent skin marks and subsequent scarring when compared to sutures.





FIGURE 93-27. The staple remover. **A.** Overview. **B.** The tip with the jaws open.

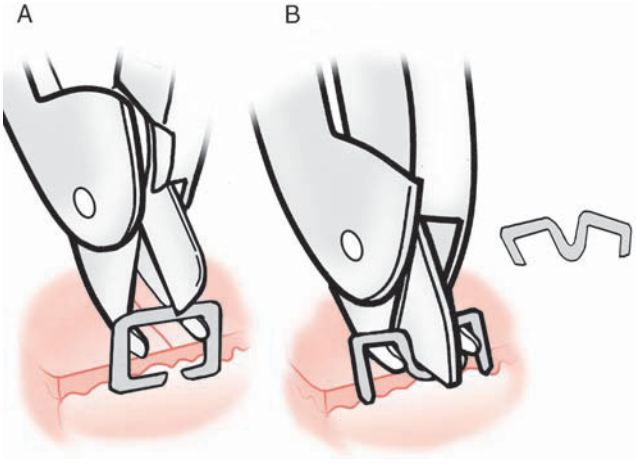


FIGURE 93-28. Staple removal. **A.** The lower jaw of the staple remover is placed under the staple. **B.** The upper jaw compresses the center of the staple and allows the staple arms to exit the skin.

STAPLE REMOVAL

Staples should remain in place for approximately 5 to 10 days, the same amount of time as sutures. They can remain longer if placed over a joint or in cases of slow wound healing. The staple remover is a disposable, sterile, single-patient-use device (**Figure 93-27A**). It is made of metal or plastic with metal tips. The lower jaw of the stapler has two upwardly angled metal prongs (**Figures 93-27B & 93-28**). The upper jaw of the stapler is a flat piece of metal. Insert the prongs of the lower jaw of the staple remover between the staple and the skin (**Figure 93-28A**). Close the handles of the staple remover. This will cause the upper jaw to compress the center of the staple and the arms of the staple to withdraw from the skin (**Figure 93-28B**). Lift the staple remover and staple off of the skin. Discard the staple and continue the process until all the staples have been removed. A patient who plans to follow-up in a clinic or office should be given a staple remover to take with them, as many clinics and offices do not routinely stock these devices.

HAIR APPOSITION

Scalp wounds can be closed using hair-tying, also known as the hair apposition technique (HAT).[11–15] This technique is relatively painless, does not usually require anesthesia, results in a shorter procedure time, eliminates the need for staple or suture removal, is cost-effective, and the wound outcome is similar or superior to sutures.[11,12,15] This technique should not be used on wounds under tension, wounds with ongoing hemorrhage, wounds that are grossly contaminated, or if the hair is <3 cm in length.

Clean, prep, anesthetize, and dry the laceration and surrounding skin. Start at one end of the laceration and grasp 5 to 15 hairs on each side of the laceration. Twist the hair strands on each side of the laceration to form a single "rope." Tie the two "ropes" of hair together to close the wound and appose the edges. Use a hemostat and an instrument tie to make the process simpler and easier. Continue this process until the entire laceration is closed with hair ties. As the laceration heals, the hair know will grow away from the wound edges. The hair knot can be cut off by a family member, friend, or primary care provider in 2 to 4 weeks.

An alternative HAT uses tissue adhesive instead of making a hair knot (**Figure 94-5**).[15] Clean, prep, anesthetize, and dry the laceration and surrounding skin. Start at one end of the laceration and grasp 5 to 15 hairs on each side of the laceration. Twist the hair strands on each side of the laceration to form a single "rope." Twist the two "ropes" of hair together to close the wound and appose the edges. Apply tissue adhesive to the twisted hair and apposed skin segment of the laceration. Allow 30 seconds for the tissue adhesive to dry. Apply a second layer of tissue adhesive and allow it to dry. Continue this process until the entire laceration is closed. This method does not require the later cutting away of the hair knot. Unfortunately, this technique may not produce as much hemostasis or wound eversion as tying a hair knot.[15]

MISCELLANEOUS WOUND CLOSURE DEVICES

V-LOC ABSORBABLE WOUND CLOSURE DEVICE

The V-Loc (Covidien, Norwalk, CT) is an absorbable, disposable, single use, unidirectional barbed wound closure device. The proximal end is the suture needle attached to an absorbable barbed suture. The distal end is a fixed loop of the suture material. This self-anchoring loop and barb combination eliminates knot tying when closing wounds. It is placed similar to a running subcuticular stitch. The barbs are circumferentially distributed on the suture strand and spread tension evenly across the wound. This device is mostly used for postoperative skin wounds but may become more popular in the Emergency Department.

INSORB SUBCUTICULAR SKIN STAPLER

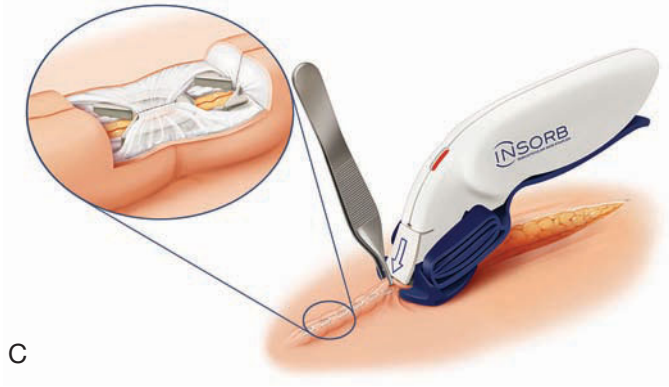
The Insorb subcuticular skin stapler (Incisive Surgical, Plymouth, MN) combines absorbable sutures and a device similar to a skin stapler (**Figure 93-29**). This is a sterile, single patient use device that deploys up to 20 absorbable subcutaneous staples (**Figure 93-29A**). The subcutaneous staples are horse shoe-shaped (**Figure 93-29B**). The device allows wound eversion with no external sutures or metal staples that require later removal (**Figures 93-29C & D**). The final cosmetic results are similar to sutures or skin staples. The company also sells a reusable three-arm proprietary forceps to make wound approximation easier for one person.



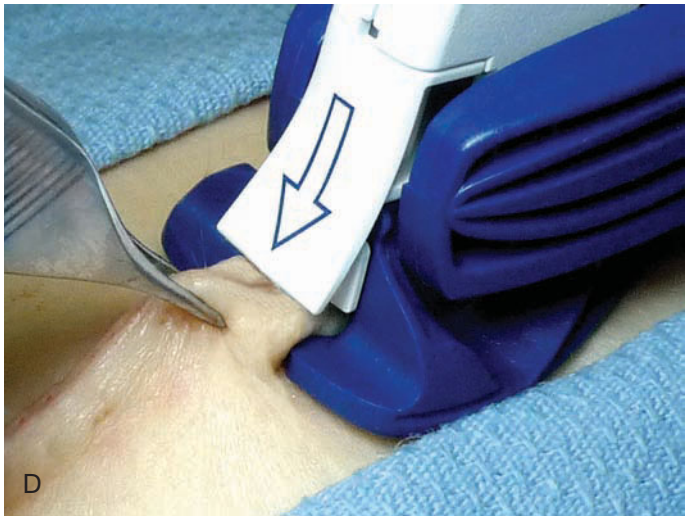
A



B



C



D

FIGURE 93-29. The Insorb subcuticular skin stapler. **A.** The staple unit. **B.** The absorbable staple resting on a fingertip. **C.** Artist illustration of the unit in action. The inset shows the relationship of the staple to the subcutaneous tissues. **D.** The unit closing a laceration. (Photos courtesy of John L. Shannon Jr., Incisive Surgical Inc.)

SUMMARY

There are multiple techniques available for closing wounds. The principles and techniques discussed will help to provide the most appropriate closure for the various types of wounds that are seen in the Emergency Department. Care should be taken to provide the best closure possible to provide good cosmesis and avoid complications.

94 Tissue Adhesives for Wound Repair

Hagop M. Afarian

INTRODUCTION

The year 1942 marked the discovery of cyanoacrylate, the chemical found in adhesives such as Superglue™.[1] The use of cyanoacrylates for wound closure has been described since the 1960s when it was first assessed for military use. It was not until 1998 that *N*-2-octylcyanoacrylate (Dermabond) was approved by the FDA for use in the United States. Tissue adhesives have since redefined the overall approach to laceration repair, especially in the Emergency Department. Their ease of use, relative painlessness, and simplicity of aftercare make it an ideal tool for small straight wounds and use in children.[2]

ANATOMY AND PATHOPHYSIOLOGY

Cyanoacrylates are a monomer liquid. When activated by water, they polymerize via an exothermic reaction to form a strong bond. Heat is released by this polymerization reaction and may cause some discomfort. Cyanoacrylates are classified as either butyl or octyl based on the length of their side chain.[20,23] Butyl cyanoacrylates have short and straight side chains. This allows them to form bonds that are strong, tight, and poorly flexible. Unfortunately, these bonds can become brittle and fracture. Butyl cyanoacrylates are best suited for short lacerations under no tension. Examples of butyl cyanoacrylates include Histoacryl (B. Braun, Bethlehem, PA) and Indermil (Syneture, Norwalk, CT). Octyl cyanoacrylates have longer side chains. This allows them to form bonds that are strong, flexible, and less likely to fracture. Octyl cyanoacrylates can be used on lacerations of any length. Examples of octyl cyanoacrylates include Dermabond (Ethicon Corp., Norwood, MA) and SurgiSeal (Adhezion Biomedical, Wyomissing, PA). Newer agents are a combination of the strong and fast-setting butyl cyanoacrylates with the flexibility of the octyl cyanoacrylates. An example is LiquiBand (MedLogic Global Ltd., Plymouth, UK).

The nonmedical and medical adhesives contain similar ingredients. The differences between these two types are sterile production, sterile packaging, and the attached alcohol chain in medical grade tissue adhesives. Converting a methyl to an octyl group reduces the heat produced by polymerization and decreases the amount of direct tissue inflammation caused by the breakdown products of the adhesive.[1,3]

The major advantage to the use of tissue adhesives is speed. Wounds can be repaired quickly and without anesthesia. Tissue adhesives have been shown to offer similar wound closure and cosmetic results as sutures and adhesive strips (e.g., Steri-strips).[4,18,19,24] The initial tensile strength of wounds repaired with tissue adhesives are not equivalent to wounds closed with sutures.[5,6] Within 7 days, however, any differences in tensile strength are no longer present.[5,6] The cost to the patient is less for lacerations repaired with tissue adhesives compared to suturing.[7,18] This takes into account physician time, procedure time, materials, and repeat visits for suture removal.[7,24] There is less need for the painful injection of local anesthetic solution. The risk of a needlestick injury is decreased when not suturing. An additional benefit of tissue adhesives is that they provide an occlusive covering for wounds, keeping them moist, water tight, and providing protection from invading microbials.[8] Wounds closed with tissue adhesive do not require routine follow-up like those sutured closed do for suture removal.

INDICATIONS

Tissue adhesives are best used to close low-tension, small, straight-edged, and superficial wounds. Although not an absolute contraindication, specific precautions should be taken when using tissue adhesives near the eye. The liquid adhesive has a tendency to run. If the eyelid margins are not protected, the tissue adhesive can cause iatrogenic sealing of the eyelids.[9] Tissue adhesive may be used for wounds that are deep or under tension as a superficial closure layer only after the subcutaneous layer has been repaired to bring the wound edges together and relieve tension. Most wounds on the head, neck, torso, and proximal extremities can be closed with tissue adhesive. Flap type lacerations and lacerations of thin skin can be closed where the use of sutures can compromise the skin. Long lacerations can be divided into segments and each segment closed as if it were a small laceration.[19]

CONTRAINDICATIONS

Tissue adhesives should not be used on wounds which are actively infected, heavily contaminated, greater than 6 to 12 hours old, a result of a crush injury, punctures, on the eyelids or surrounding skin, or due to bites. Tissue adhesives can only be used on the skin surface and not used within wounds, on mucous membranes, or on mucocutaneous junctions (e.g., the mouth and lips). Do not use tissue adhesives on patients with a known hypersensitivity to cyanoacetate and formaldehyde, as cyanoacrylates degrade into these byproducts. It is recommended that tissue adhesives not be used in areas of the body that are exposed to heavy moisture (e.g., the perineum and axilla) and parts of the body prone to frequent movement (e.g., hands, feet, and over joints).[10] Wounds must be dry. Do not use tissue adhesives on wounds that are actively bleeding or oozing. Tissue adhesive use in these areas may lead to wound dehiscence as the adhesive cracks and/or peels.[10] Stop the bleeding with direct pressure or the injection of local anesthetic solution with epinephrine prior to the application of tissue adhesive. They may be difficult to use in areas covered densely with hair (i.e., the scalp and axilla) since the tissue adhesive will not bond adequately to the skin. They are not recommended for stellate wounds because of the difficulty of adequately approximating the many wound edges. Other contraindications to this type of closure are angled or beveled wounds, unless deep sutures are first placed to approximate the wound edges and relieve any tension.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Gloves
- Wound adhesive (**Figure 94-1**)
- Wound cleaning and irrigation supplies (Chapter 92)
- Forceps



FIGURE 94-1. Several examples of tissue adhesive. From left to right: Dermabond ProPen, SurgiSeal, Indermil Loctite, and Liquiband Flow Control.



FIGURE 94-2. Commercially available wound forceps (Bionix Development Corp., Toledo, OH).

- Petroleum jelly
- Acetone or nail polish removal pads
- Gauze squares
- Occlusive dressing (e.g., Tegaderm)

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed consent for the procedure. Anesthetize the wound. Cleanse the wound and surrounding skin of any dirt and debris. Irrigate the wound with normal saline or tap water. If the wound is dirty, consider the use of a wound irrigation device as described in Chapter 92. Injuries which require substantial cleaning may not be good candidates for tissue adhesive closure. Inspect the wound for any retained foreign bodies or injuries to deep structures. All bleeding must be controlled prior to the application of the wound adhesive. Repair lacerations with continued or heavy bleeding with sutures to achieve adequate hemostasis. Dry the skin surrounding the laceration with gauze squares.

TECHNIQUES

GENERAL TISSUE ADHESIVE TECHNIQUE

The general technique will be described. There are some differences in the type of applicator. Prepare the tissue adhesive. Some only require the removal of a twist-off plastic cap. Others are supplied in ampules that must be crushed and allowed to soak the foam tip of the applicator. Use the tissue adhesive immediately after opening the container as it dries within minutes and may not continue to flow freely for very long.

Approximate the wound edges with forceps. Commercially available, disposable, single-patient-use tissue forceps can be used (Bionix Development Corp., Toledo, OH). These are specifically designed to approximate the wound edges prior to using tissue adhesives (**Figure 94-2**). Alternatives to these devices are Adson forceps or using gloved fingers. Place a thin layer of tissue adhesive over the wound and extending 5 to 10 mm beyond the wound margins (**Figure 94-3A**). The tissue adhesive may also be applied in spots over the laceration (**Figure 94-3B**) or across the laceration like wound tape (**Figure 95-3C**). Apply the droplets or lines of tissue adhesive approximately 0.5 cm from each other. **Hold the wound edges together for 30 to 60 seconds following the application of the first layer of tissue adhesive to allow for optimum polymerization.**

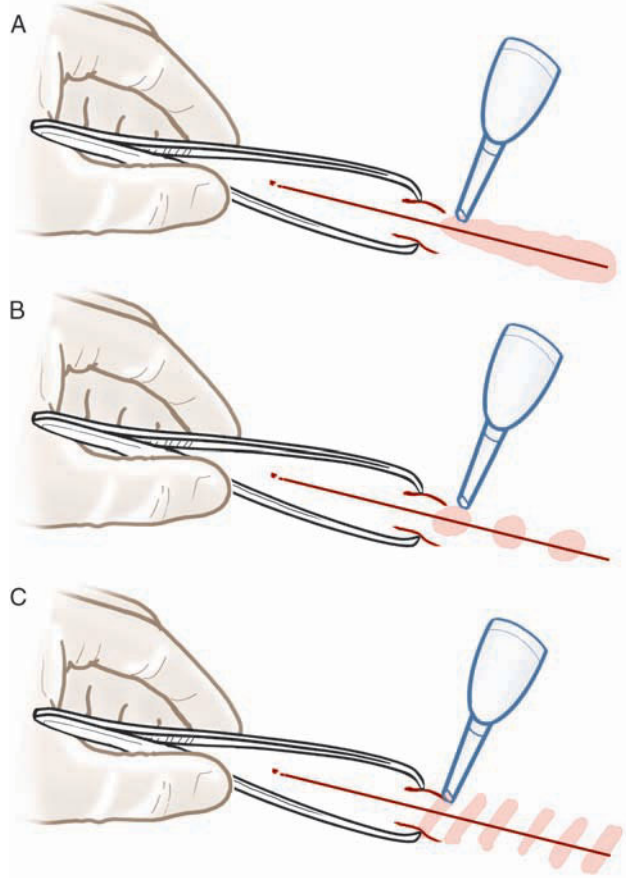


FIGURE 94-3. Laceration repair with tissue adhesive. **A.** Tissue adhesive applied continuously over the laceration. **B.** Tissue adhesive applied in spots over the laceration. **C.** Tissue adhesive applied across the laceration.

Apply a total of three to four thin layers of tissue adhesive. Allow each layer to dry for approximately 30 to 60 seconds before applying the next layer. Each successive layer will take longer to dry as the water available for the polymerization reaction has been covered by the previous layer. **Be careful to use only thin layers and not large drops of adhesive to assist drying time and prevent discomfort from any heat released by the exothermic polymerization reaction. Tissue adhesive should not be allowed to flow into the wound.** It can remain in the wound long after it has healed leading to delayed healing, prolonged inflammation, and tattooing.[20,21]

Do not touch the layers of wound glue as they are drying to prevent cracking and inadvertent adhesion of foreign bodies to the wound. If gloved fingers or other foreign bodies have become attached to the wound, gently peel them away from the most recent layer before it dries. Tissue adhesive applied to an area where it does not belong should be wiped away within 10 seconds.

PREVENTING THE TISSUE ADHESIVE FROM RUNNING

Techniques have been described for use when working around areas that must not come in contact with the tissue adhesive, such as the eye. The first and easiest precautionary technique is patient positioning. Position the patient so that the tissue adhesive will not run away from the wound. Ideally, the wound surface should be parallel to the floor. Unfortunately, this is not always possible to accomplish. Alternatively, position the patient in a manner such that the wound rests below the sensitive area. Gravity allows any of the liquid tissue adhesive to run away from the area of concern. Avoid squeezing the tissue adhesive container too much to control the amount expressed. This can help to minimize any runoff. Consider placing a piece of gauze or occlusive dressing over the area of concern to protect it from any runoff.

A barrier can be created between the wound and the sensitive area. Place a thin film of petroleum jelly between the wound and the sensitive area. This will ensure that if the tissue adhesive were to run, it will not spread beyond the barrier. Alternatively, apply the petroleum jelly in a wide circle surrounding the wound, creating a valley for the tissue adhesive to fill if it runs. It may become difficult, however, to hold the wound edges together in a small space covered with petroleum jelly. The oil-based petroleum jelly, if it gets on the skin immediately adjacent to the wound, may prevent adequate binding of the tissue adhesive.

A final technique to keep the wound adhesive from running is through the use of an occlusive dressing such as a Tegaderm (**Figure 94-4**).[11] Obtain an occlusive dressing large enough to cover the area in question (**Figure 94-4A**). Fold the dressing in half (**Figure 94-4B**). Cut a hemi-ellipse out of the dressing (**Figure 94-4C**). Unfold the dressing and center the cut-out ellipse over the wound (**Figure 94-4D**). Make sure that the newly created hole in the center is large enough to include the entire laceration and some surrounding skin. If not, cut additional material from the dressing. Remove the protective tape from the back of the dressing and apply it to the skin. Approximate the wound edges and apply tissue adhesive (**Figure 94-4E**). Cover the entire precut hole and some of the surrounding dressing with the tissue adhesive. Allow the layers of tissue adhesive to completely dry. Carefully remove the dressing. The result is a well-demarcated, circular film of tissue adhesive overlying the closed laceration (**Figure 94-4F**).

HAIR APPOSITION TECHNIQUE

Scalp wounds can be closed using hair-tying, also known as the hair apposition technique (HAT).[11–16] This technique is relatively painless, does not usually require anesthesia, results in a shorter procedure time, eliminates the need for staple or suture removal, is cost-effective, and the wound outcome is similar or superior to sutures.[12,13,16] This technique should not be used on wounds under tension, wounds with ongoing hemorrhage, wounds that are grossly contaminated, or if the hair is <3 cm in length.

Clean, prep, anesthetize, and dry the laceration and surrounding skin. Start at one end of the laceration and grasp 5 to 15 hairs on each side of the laceration (**Figure 94-5A**). Twist the hair strands on each side of the laceration to form a single "rope." Tie the two "ropes" of hair together to close the wound and appose the edges. Use a hemostat and an instrument tie to make the process simpler and easier. Tissue adhesive can be applied to the hair knot for added security. Continue this process until the entire laceration is closed with hair ties. As the laceration heals, the hair know will grow away from the wound edges. The hair knot can be cut off by a family member, friend, or primary care provider in 2 to 4 weeks.

An alternative HAT uses tissue adhesive instead of making a hair knot.[16,22] Clean, prep, anesthetize, and dry the laceration and surrounding skin. Start at one end of the laceration and grasp 5 to 15 hairs on each side of the laceration with your gloved fingers or a hemostat (**Figure 94-5A**). Twist the hair strands on each side of the laceration to form a single "rope." Twist the two "ropes" of hair together to close the wound and appose the edges (**Figures 94-5B & C**). Apply tissue adhesive to the twisted hair and apposed skin segment of the laceration (**Figure 94-5D**). **Do not allow the tissue adhesive to run into the wound.** Allow 60 to 90 seconds for the tissue adhesive to dry. Apply a second layer of tissue adhesive and allow it to dry. Continue this process until the entire laceration is closed. This method does not require the later cutting away of the hair knot. Unfortunately, this technique may not produce as much hemostasis or wound eversion as tying a hair knot.[16]

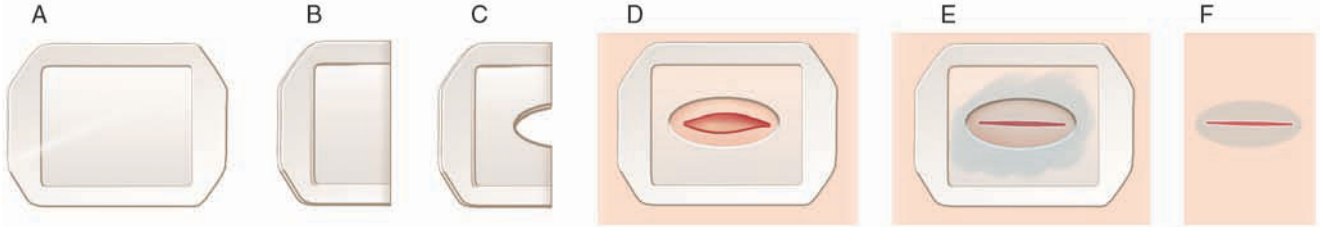


FIGURE 94-4. The use of an occlusive dressing for protection of nearby sensitive structures when using tissue adhesives. **A.** The occlusive dressing. **B.** The dressing is folded in half. **C.** A hemi-ellipse is cut out of the dressing. **D.** The dressing is opened with the cut-out ellipse centered over the wound. The protective tape is removed and the dressing adhered to the skin. **E.** The wound is approximated and tissue adhesive is applied. **F.** The result after the dressing has been removed reveals a well-circumscribed area of tissue adhesive.

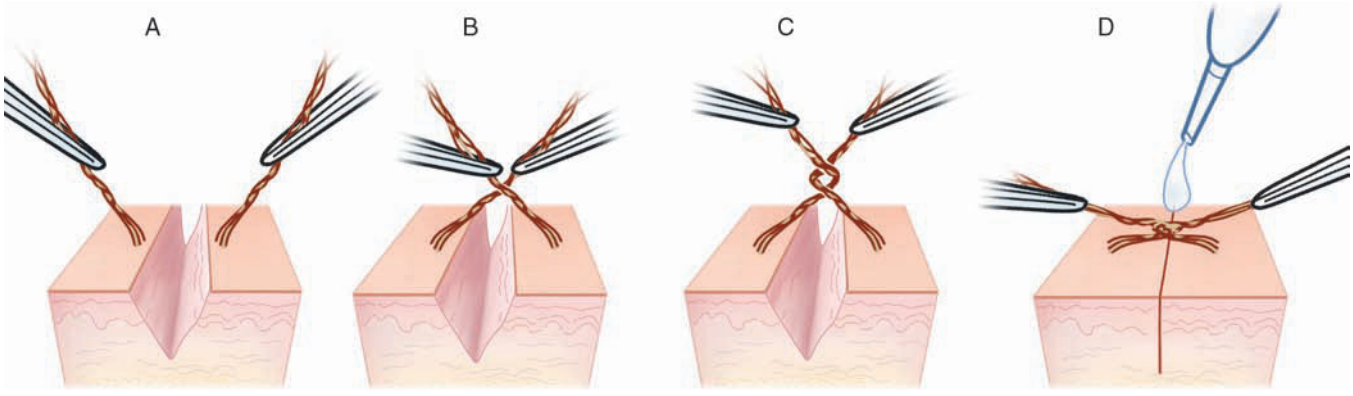


FIGURE 94-5. The hair apposition technique (HAT) to close a scalp laceration. **A.** Grasp 5 to 15 hairs on each side of the laceration. Twist the hair strands on each side of the laceration to form a single "rope." **B.** Cross the hair ropes to opposite sides of the laceration. **C.** Twist the two "ropes" of hair together to close the wound and appose the wound edges. **D.** Apply tissue adhesive to the twisted hair and apposed skin segment of the laceration.

PEDIATRIC CONSIDERATIONS

Pediatric patient movement is the factor that causes the greatest difficulties when working with wound adhesives. Although tissue adhesives are most useful in the pediatric population, this specific population has the greatest risk of movement as well. Movement will permit running of the adhesive and leakage onto uninvolved areas. Extra caution must be incorporated when working around sensitive areas. A high viscosity tissue adhesive may be used to limit leakage when working around sensitive areas or on children who have trouble remaining still.

ASSESSMENT

Assess the closed wound to ensure that the edges are approximated. Tissue adhesive that has adhered and dried on uninvolved areas may be removed using petroleum jelly or topical antibiotic ointment. Apply the oil-based jelly or ointment to the dried tissue adhesive and let it stand for 30 minutes. Gently peel away the tissue adhesive. Use acetone or nail polish remover pads to remove the tissue adhesive more quickly instead of waiting the time for the oil-based products to work.[17] **Be careful to not let acetone drip into the eye or on mucous membranes.**

Tissue adhesive occasionally does enter the eye or the eyelids become glued shut. Tissue adhesives are not toxic to the globe and will not cause damage to the conjunctiva or cornea. **Do not attempt to pry open the eyelids or cut between the eyelid margins to separate the eyelids.** Immediately wipe away any excessive adhesive and flush the eye with saline or tap water. If the eyelids are sealed shut, apply an ophthalmic antibiotic ointment to the eyelids. Allow the ointment to sit for 30 minutes. Instruct the patient to open their eyelids. If they can open their eyelids, gently wipe the ointment and adhesive from the eyelids. If they cannot open their eyelids, instruct them to apply the ointment five to six times a day and gently attempt to open their eyelids. Within 2 to 3 days at most, their eyelids will separate.

AFTERCARE

Instruct the patient that oil-based substances should not be used on any wound repaired with tissue adhesives.[1] Tissue adhesive does not need to be removed. It will peel away within 5 to 10 days as new epithelial layers are formed below it. Wounds repaired with tissue adhesive may briefly come in contact with water (e.g., showering), but should not be scrubbed clean. Do not soak the wound, whether in a bathtub, spa, or pool. Instruct the patient to return immediately to the Emergency Department or to their primary care provider for any signs of a wound infection.

COMPLICATIONS

Many of the complications associated with the use of tissue adhesives are preventable. The Emergency Physician must choose the proper patient, the proper wound, and the appropriate wound location. These few things in association with the appropriate tissue adhesive application technique will avoid most complications. The details of these have been described previously in the indications, contraindications, and techniques sections.

A certain percentage of repaired wounds will become infected. Minimize any infections by properly preparing the wound (Chapter 92). This includes the use of anesthesia if appropriate, wound irrigation, wound debriding, wound undermining, wound exploration for foreign bodies, and the use of deep sutures to release tension.

SUMMARY

Tissue adhesives have changed the face of laceration repair. Wounds are repaired more quickly with tissue adhesives and often at a lower cost compared to suturing. Patient satisfaction is increased. There are very few limitations to the use of tissue adhesives. Proper patient selection, proper wound selection, and proper wound preparation will minimize any complications.

95 Advanced Wound Closure Techniques

Eric F. Reichman

INTRODUCTION

Traumatic wounds or skin lacerations are among the most common injuries, occurring in people of all ages, that require evaluation and treatment in the Emergency Department. The result of many if not all wound closures is scar formation. Although most wounds heal with a surprisingly pleasing cosmetic transformation from their initial presentations, it is not uncommon for some wounds to present

complications during the healing period as well as to produce an undesirable scar. A systematic approach to wound management serves to help in deciding how to close complicated wounds, reduce the risk for infection, and minimize less favorable outcomes.

Wound management in the Emergency Department includes an assessment of the mechanism and conditions that were present at the time of injury. Initially, one must address the concerns of the patient, family members, or friends with a concise explanation of how the wound will be treated and what can be anticipated for aftercare. Many lawsuits and concerns of poor care evolve from poor cosmetic outcomes. **It is recommended that verbal wound care instructions be offered once wound closure is completed, in addition to giving the patient written discharge instructions.**[1]

Regardless of the severity of the wound or possible inherent complications associated with the injury, many patients are primarily concerned with the potential for scarring or disfigurement. Most patients expect cosmetic and functional perfection as an ultimate result after their wounds are treated and the healing process is completed. These expectations are often not clearly expressed during the evaluation and treatment in the Emergency Department. **The Emergency Physician must openly explain and discuss the fact that virtually no wound heals without a scar following wound closure.**[1,2] A clear understanding of this is not to be used as an explanation for a poor outcome but to counter any misconception that a wound will heal to look exactly like the previously intact skin. Treatment is rendered to offer the best possible functional and esthetic outcome while reducing the risk of potential soft tissue infection.

An overall plan of wound site preparation and closure will be needed to provide the greatest likelihood of a pleasing cosmetic result.[1] The mechanism of injury, severity of the wound, location of the wound, and the presence or risk of necrotic tissue can all influence the risk of infection. Additionally, the decision of how to approach wound closure will be affected by the patient's skin type, age, gender, occupation, and hobbies.

Wound healing ultimately takes place over at least 6 to 9 months. Any wound presenting with concerns for a poor outcome or an obvious likelihood of wound revision in the future should be evaluated and treated by a Plastic Surgeon when possible.[1,2] All other wounds requiring complex closures should be properly assessed and treated by the Emergency Physician.

ANATOMY AND PATHOPHYSIOLOGY

In order to have a better understanding of scar tissue formation and the antecedent techniques of wound closure, the Emergency Physician should have knowledge of specific physiologic conditions and anatomic areas that may increase the chances of unfavorable scarring following wound repair.[2,3] The age of the patient and appearance of the patient's intact skin should be taken into consideration. The younger patient tends to heal more rapidly, while the older patient tends to have a more favorable cosmetic outcome with wound closure. Older patients have less overall elastic and subcutaneous tissue and more wrinkling, thus decreasing the tension on the healing wound and making scarring less noticeable.[2,3] Wrinkling, or lines of minimal tension, makes wound repair more technically challenging.

Suturing of asymmetrical, deep, or large wounds requires particular attention to the preexisting lines of minimal tension or lines of facial expression. Without properly addressing such preexistent anomalies, the cosmesis of wound repair can be grossly affected.[2,3] Scars from wounds closed perpendicular to preexisting functionally anatomic lines undergo repetitive physical stress and may result in hypertrophic scar tissue. With markedly less skin elasticity and subcutaneous fat, older patients will often experience more favorable cosmetic results from less complex wound closures. However, younger patients will benefit from more advanced wound closure techniques to properly close large or complicated wounds. Rotational and advancement flaps are frequently performed to make scarring less obvious when suturing across lines of tension.[3]

The type of skin, regardless of age, will affect scar formation.[3,4] Oily or hyperpigmented skin more frequently has poor scar tissue formation, resulting in scars that are hypertrophic, deep, and asymmetrical. Consideration of wound outcome should be given to areas of the skin that are rich in sebaceous glands or simply hyperpigmented (from environmental exposure or ethnicity). Patients with underlying connective disease disorders or conditions with a high likelihood of concomitant vitamin deficiencies should also be scrutinized, as wound closure and healing may be compromised in such cases, resulting in highly variable and less predictable outcomes.

The mechanism of injury, including environmental exposure to underlying tissue, should not be overlooked, so that adequate debridement and preparation may be done prior to a complex wound closure. This allows the Emergency Physician to better visualize the anatomic layers of the skin. It can be difficult to determine a clear delineation between the anatomic layers of the skin when the wound was a result of a crush injury, shredding mechanism, or any circumstance resulting in uneven or macerated wound edges. Delineate the pigmented epidermis from the thicker underlying dermis, especially when multilayer wound closures are required, as suturing may then become unnecessarily complicated and affect the overall integrity of the wound closure.

It should be noted that the literature supports a significant underutilization of multilayer closures, though these are often necessary. Single-layer closures and excessively large suture materials are the greatest causes of residual scar tissue.[1] It is recommended to prepare the wound edges by creating a bevel or undercutting of the wound margin to allow subtle epidermal eversion, thus augmenting the natural process of scar formation.[1,2] This allows the natural flattening and depression of the forming scar to occur without excessive depression from the wound margins.[2] This will also help to reduce the thickness of the scar tissue and decrease the refraction of light from the scar, making it less noticeable.

Depending on the presentation of the tissue defect, more than one wound closure technique may be used to adequately close a wound. Utilizing more than one technique will help remove underlying tension and allow better approximation of the epidermis. With the help of specific camouflage techniques used in closing the epidermis, irregularly shaped wounds can heal with less obtrusive scarring. Familiarity with a few of these techniques and their application will allow the Emergency Physician to comfortably close the more challenging wounds encountered, with expectantly more favorable cosmetic prognoses.

INDICATIONS

Advanced wound closure techniques are indicated for closing wounds with irregularly shaped defects or defects too large for primary closure. They can be used to close circular, square, elliptical, or asymmetrical skin defects. Advanced wound closure techniques are beneficial when there is a need to reduce skin tension and contracture, which are likely to result in hypertrophic scar formation.[3,4] Rotational and advancement flap techniques are useful in areas where tissue loss must be avoided and the undermining of wound edges must be minimized. This is often encountered with facial wounds in proximity to the eyelids, eyebrows, canthi, nasolabial folds, or lip borders. These techniques allow the initial shape of the wound to be altered such that there is reduced tension on the wound edges, which may then be closed simply.

CONTRAINDICATIONS

Specific wound closure techniques should take into account the potential for scar formation to occur in an undesirable location. This can happen when a wound must be elongated to create parallel lines and to decrease the tension on the wound edges. Elongation of a wound may bring it into proximity of other anatomic positions or landmarks, thus further complicating the healing process. If not planned well, excessively large defects may result, making it more likely that the scar will require later revision. More obvious conditions may exist that compromise complex wound closures. Particular attention must be given to crush injuries with devitalized or contaminated tissues. Severely contaminated wounds, including those with prolonged exposure, generally are at greater risk of infection with multilayer closures. Do not perform these techniques if the patient is at risk for poor wound healing (i.e., diabetes, poor vascular supply to the area, or prior radiation therapy to the area), keloid formation, or coagulopathic. Careful wound assessment may result in a decision to use simple approximation of the wound edges with close follow-up for ongoing wound care. Contraindications to complex wound closures will at times be reliant on temporal factors, such as the need to close a wound prior to the patient receiving surgical intervention for more life-threatening injuries. There must be a commonsense approach in deciding how to close more challenging wounds in the Emergency Department.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Needle drivers, 4.5 and 6.0 in.
- Skin hooks
- Scalpel blades (#10, #11, and #15)
- Scalpel handles
- Iris scissors, straight 4 in. and curved 4 in.
- Suture scissors, 6 in.
- Forceps, toothed Adson
- Metzenbaum scissors, curved 6 in.
- Hemostats, straight 6 in., and curved mosquitoes
- Suture material
- Skin closure tapes
- Benzoin solution, swabs or spray
- Tissue adhesive
- Tissue adhesive forceps
- Gauze, 4 × 4 squares
- Overhead light source or headlight

The above equipment can be purchased in single-use, sterile, and disposable plastic surgery wound kits from several commercial manufacturers. These kits tend to be expensive and occasionally have a limited amount of equipment. Many hospitals package and sterilize their own wound repair kits. This decreases the cost, as the equipment can be repeatedly sterilized and reused. It also allows the kits to contain a wide variety of instruments for multiple situations (e.g., minor laceration, large laceration, and plastics closure).

Needle drivers come in a variety of sizes. A 4.5 in. needle driver can be used comfortably with most types of needles. A 6 in. needle driver may be required if large needles are used to close a wound. Hold the needle driver with the fingertips to provide greater flexibility. The fingers can also be placed through the finger holes, but this is not as efficient when closing a wound. Grasp the needle one-third of the way from the swag (distal) end with the tip of the needle driver.

The skin must be grasped and manipulated during wound repair to allow for proper suture placement. Forceps are most commonly used to grasp and manipulate the skin. **Smooth (nontoothed) forceps should never be used to grasp skin.** They require the application of a large amount of force to grasp the tissue. This can crush tissue very easily. An Adson forceps is the forceps of choice. It has fine teeth that grasp tissue securely with minimal force.

A skin hook is a sharp, pointed instrument that is inserted into the wound edge and grasps the tissue from the undersurface. It produces a small puncture wound in the subcutaneous tissues and does not penetrate the skin surface. Skin hooks are preferable to forceps, as they do not crush tissues. A skin hook is awkward to use at first. With proper instruction and experience, the Emergency Physician will most certainly prefer a skin hook to forceps.

Several types of scissors are required for proper wound closure. Iris scissors have sharp, delicate tips for making precise cuts in tissue. They should not be used to cut suture material, as this rapidly dulls and nicks the blades. Suture scissors have one blunt tip and one pointed tip. Both blades of the suture scissors are sharp. Suture scissors are used to cut adhesive tape, gauze, rubber drains, and suture material. Metzenbaum scissors should be used to debride heavy tissue, bluntly dissect tissue, and undermine tissue.

Hemostats are used to clamp small vessels that are bleeding, to explore a wound, and to grasp fascia. Hemostats are available in a variety of sizes and styles. A straight 6 in. hemostat is used for most purposes during wound repair. A curved 5 in. mosquito hemostat can be used for small wounds or delicate tissues.

Three different scalpel blades should be available when a wound is being repaired. A #11 blade is used to make stab incisions. It is often used for the incision and drainage of abscesses, cricothyroidotomies, and the removal of small or tight sutures. A #10 blade is used to make straight cuts in the skin and debride wound edges. It is rarely used in laceration repair. A #15 blade is small and curved to allow precise incisions. It is used for excising foreign bodies and wound debridement.

PATIENT PREPARATION

Explain the risks, benefits, and complications of the wound closure to the patient and/or their representative. The risks include poor healing, wound dehiscence, bleeding, pain, a worse scar, infection, loss of the tissue, and further surgery. The benefits include improved cosmesis and wound healing. Alternatives to advanced wound closure include wet-to-dry dressings and allowing the wound to granulate or follow-up with a Plastic Surgeon for closure or a skin graft. Discuss the presence of a visible scar after the repair, which may require subsequent revision. Explain the aftercare and follow-up. Obtain a signed informed consent for the procedure.

Place the patient in a position of comfort that is equally comfortable for the Emergency Physician. This should allow for appropriate stretcher or seat height, lighting, and maneuverability so that physical obstacles are not a complicating variable during the wound repair. Clean the wound and surrounding skin of any dirt and debris. Flush the wound with normal saline. Apply povidone iodine or chlorhexidine solution to the surrounding skin, not the wound, and allow it to dry. Anesthetize the area using local or regional anesthesia (refer to Chapters 123 through 127).

Examine the wound for obvious foreign bodies or contaminants. Remove these with pressure irrigation using sterile saline. Apply sterile drapes to demarcate a sterile field. Apply the drapes so that the wound may be approached easily from different angles and without the risk of contaminating the site or any of the materials being used. There can be a great degree of variability in sterile techniques;

therefore, it is important to note that the best way to avoid wound infections is to employ and maintain consistency with sterile procedures throughout the wound repair.

TECHNIQUES

Z-PLASTY

It can be challenging to change the axis of orientation of a wound. **The reason for changing the orientation of a wound is to create a more functionally and cosmetically pleasing scar.** The Z-plasty has been described as a basic technique for scar revision, though its application also proves useful to lengthen and reorient wounds.[5] Wound lengthening reduces the formation of contractures, which often occur when the wound crosses areas of flexion. The Z-plasty should not be used for wounds from burn injuries where normal skin is not present. It also breaks up a linear scar into an accordion-like scar that has some degree of elasticity.

The Z-plasty is generally described to redirect a wound occurring across a flexion crease, over a joint, or on the face. It requires two incisions that create two triangular flaps with approximately 60° of separation between the flaps, though the angle may vary between 30° and 90° (**Figure 95-1**).[5] The greater the angle, the greater the gain in wound length. Sharper angles increase the risk of necrosis in the tip of the flap. Broader angles result in difficulty in rotating the flaps. Angles of 60° increase the wound length by 75%. Angles of 45° increase the wound length by 50%. Angles of 30° increase the wound length by 25%. **The length of both arms of the incision must be the same length as the wound.** The undermining and separation of the two triangular flaps lengthens the wound and allows it to be reoriented perpendicularly to the original location. Additionally, small Z-plasties may be used in sequence to offset the appearance of straight wounds crossing lines of flexion or where contractures are likely to occur, so that the wound site then becomes parallel to the lines of flexion, further reducing the occurrence of contracture formation.[3,4]

Clean, prep, and anesthetize the wound and surrounding skin. If the wound edges are irregular, sharply debride them using a #15 scalpel blade to form straight edges (**Figure 95-1A**). Measure and draw 60° angles from the ends of the laceration (**Figure 95-1B**). Draw the arms of the Z on the patient's skin with a skin-marking pen. **The arms must be the same length as the original laceration.** Incise the arms of the Z using a #15 scalpel blade (**Figure 95-1C**). Undermine the flaps of the Z and the surrounding skin. Elevate the flaps of the Z (**Figure 95-1D**). Transpose the flaps so that the wound is reoriented (**Figure 95-1E**). Place simple interrupted sutures to approximate the wound edges (**Figure 95-1F**).

APPROXIMATING THE EDGES OF A LACERATION WITH GROSSLY UNEQUAL LENGTHS

Creating an equilateral triangle from the midpoint of the longest wound edge allows wound edges of unequal length to be closed easily (**Figure 95-2**).[3–5] Determine the widest point between the two wound edges. Determine which of the two wound edges is longer. Mark the middle of the longest wound edge (**Figure 95-2A**). Draw an equilateral triangle centered at this mark (**Figure 95-2B**). **The sides and base of the triangle must all be of equal length and the same length as the widest part of the original wound.** Incise the arms of the equilateral triangle with a #15 scalpel blade and remove the tissue (**Figure 95-2B**). Undermine the wound edges. Close the wound and the perpendicular incision from the triangle with simple interrupted or running sutures (**Figure 95-2C**). Closure of the two wounds results in a clean linear wound with a short perpendicular linear wound offsetting the previously unequal edges (**Figure 95-2C**).

CLOSING A SQUARE-SHAPED DEFECT

Wounds are rarely square-shaped after an injury (**Figure 95-3A**). Debride the wound to make a square-shaped defect (**Figure 95-3B**).

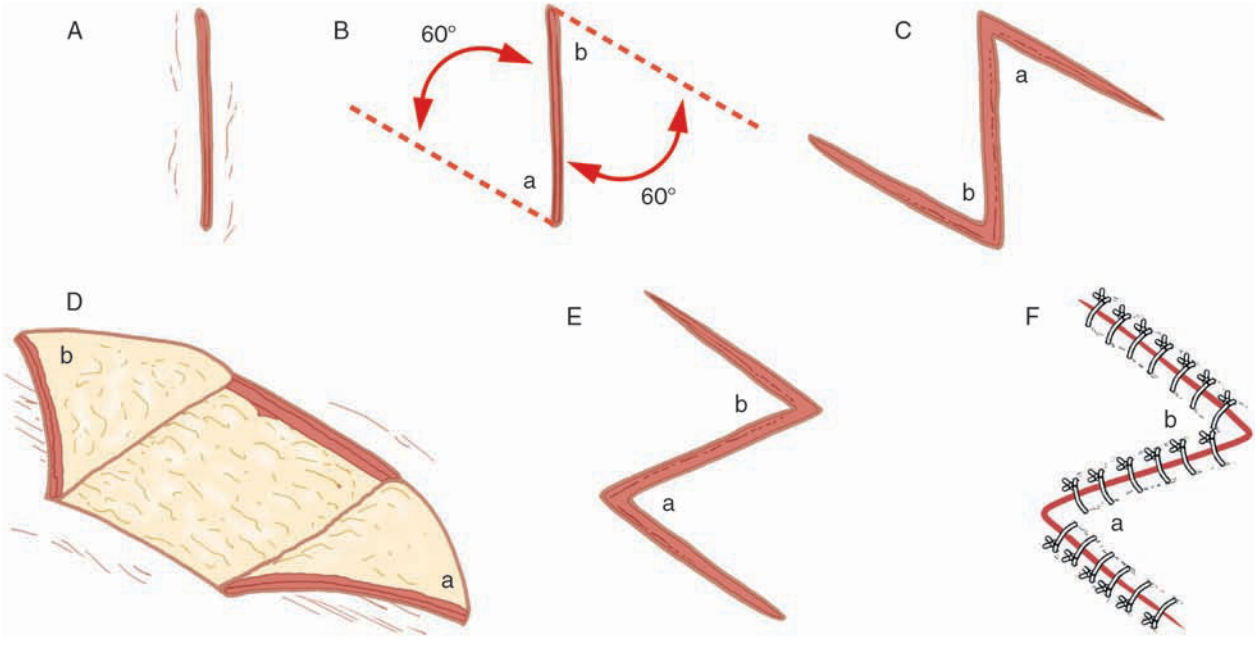


FIGURE 95-1. The Z-plasty. **A.** The original laceration. **B.** Draw the arms of the Z at a 60° angle from the ends of the lacerations. The arms must be the same length as the laceration. **C.** The skin has been incised to form the Z. **D.** Undermine and elevate the flaps. **E.** Transpose the flaps to reorient the wound. **F.** Approximate the wound edges with simple interrupted sutures.

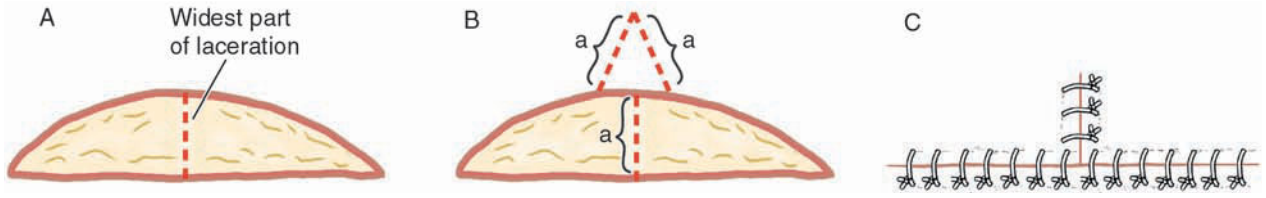


FIGURE 95-2. Approximating edges of grossly unequal lengths in repairing a laceration. **A.** The laceration. **B.** Draw an equilateral triangle along the longest side and centered about the widest part of the laceration. The sides of the triangle must be equal to the length of the widest part of the original laceration. **C.** Approximate the wound edges with simple interrupted sutures.

Square-shaped defects can be difficult to close and require a single pedicle advancement flap.[3] Elongating two sides of the square allows small- and moderate-sized defects to be closed primarily (**Figure 95-3C**). Draw lines to extend two parallel edges of the square by twice their length (**Figure 95-3C**). Draw Burow's triangles on the ends of the extended lines (**Figure 95-3C**). These triangles will be removed, allowing the flap to be transposed into the wound and creating a more symmetrical flap.[3–5] Draw the Burow's triangles as equilateral triangles whose sides are half the length of the square defect (**Figure 95-3C**).

Incise along the extended lines and Burow's triangles with a #15 scalpel blade. Remove the tissue of the Burow's triangles. Undermine the rectangular flap and the area surrounding the base of the flap. **Do not undermine the area lateral to the extended lines.** Advance the tissue flap to close the defect (**Figure 95-3D**). Place a simple interrupted suture in the center of the short edge of the flap to hold it in position. Place half-buried horizontal mattress sutures to secure the corners of the flap. Approximate the wound edges with simple interrupted sutures along the long arms. Approximate the corner of the Burow's triangles with half-buried horizontal mattress stitches and the rest of the triangle with simple interrupted sutures.[3–5]

CLOSURE OF A DIAMOND-SHAPED DEFECT

Diamond- or rhomboid-shaped defects require the rotation of a flap referred to as a Limberg flap. **The Limberg flap is a transposition flap suitable only for closing a diamond- or rhomboid-shaped defect. It requires the formation of two adjacent angles of the rhomboid that must be 60° and 120° for an optimal flap.**

Wounds are rarely diamond-shaped after an injury (**Figure 95-4A**). Debride the wound to make a diamond-shaped defect (**Figure 95-4A**). Draw a line to extend the distance of the short diagonal of the defect to double its total length (**Figure 95-4B**). Draw a line from the extended line and parallel (back cut) to the adjacent wound edge that is equal to the length of the extended line (**Figure 95-4B**). Incise along the extended lines with a #15 scalpel blade. Undermine the flap and adjacent skin. Rotate the flap into the diamond-shaped defect (**Figure 95-4C**). Approximate the wound edges with simple interrupted sutures along the linear edges and half-buried horizontal mattress sutures at the intersection or angles of the wound edges (**Figure 95-4D**).[3–5] Depending on the location of loose tissue and adjacent structures, one of four Limberg flaps can be created to close the defect (**Figure 95-4E**).

CLOSURE OF AN ELLIPTICAL DEFECT

Wounds are often irregular and elliptical (**Figure 95-5A**). Creating an ellipse from a wound allows more even closure of asymmetrical wounds. This is also referred to as an S-plasty. This technique may be used when there is concern of significant scarring and contracture formation from an associated thermal burn injury and Z-plasties are not recommended.[4] The less acute and more rounded edges of the ellipse tend to result in less tissue necrosis.[3,4]

Draw lines to debride the wound and form an S-shaped defect (**Figure 95-5A**). Incise the extended lines with a #15 scalpel blade

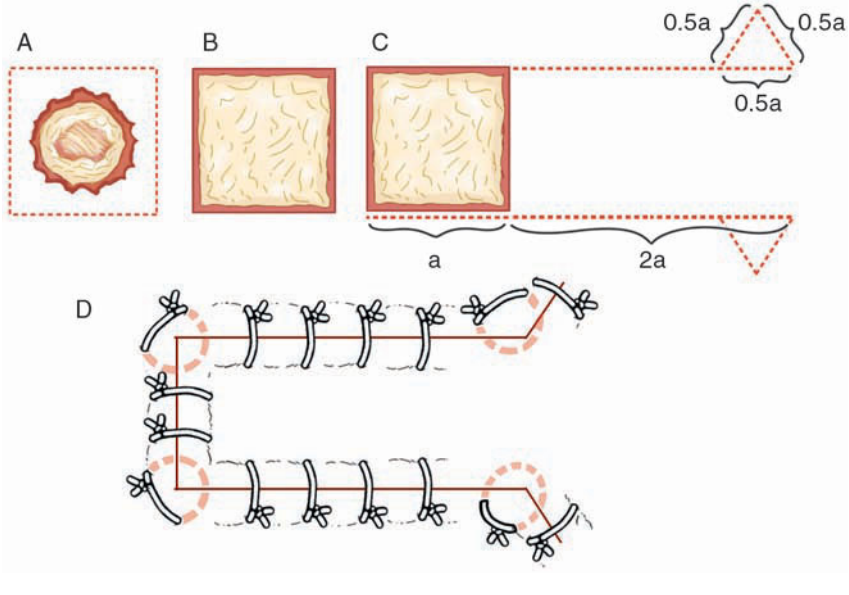


FIGURE 95-3. Closure of a square-shaped defect. **A.** The original tissue defect. Draw lines around the defect to form a square. **B.** The skin has been incised and the original defect removed to create a square-shaped defect. **C.** Draw lines to extend two sides of the square into a rectangle. Draw Burow's triangles at the ends of the rectangular lines. **D.** Advance the flap and approximate the wound edges.

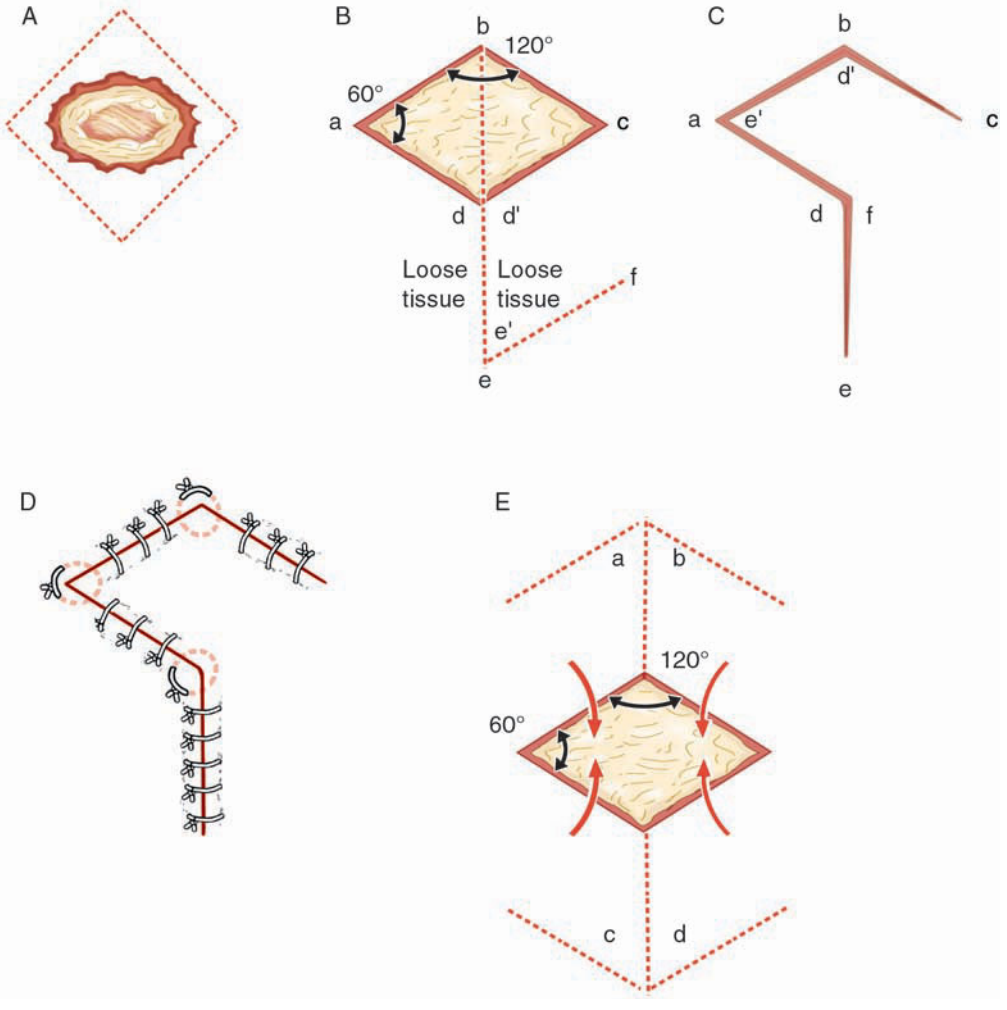


FIGURE 95-4. Closure of a diamond- or rhomboid-shaped defect. **A.** The original tissue defect. Draw lines around the defect to form a diamond or rhomboid. **B.** The skin has been incised to create a diamond-shaped defect. Draw lines to form the flap. Extend the short diagonal (BD) by one times its length to form line DE. Draw line EF parallel to line CD and the same length as line CD. **C.** Transpose the flap to close the defect. **D.** Approximate the wound edges. **E.** The four available Limberg flaps that can be created to fill the defect.

to form the S-shaped defect and excise the wound (**Figure 95-5B**). Undermine the wound edges. Place buried sutures to close the wound and prevent tension on the wound edges. Approximate the wound edges by placing simple interrupted sutures alternating at each end of the S-shaped defect and ending in the middle (**Figure 95-5C**). Suturing from the ends and moving inward reduces the tension on the wound edges.[3,4]

CLOSURE OF A V-Y ADVANCEMENT FLAP

The V-Y flap is not a rotational flap but rather a V-shaped flap created away from the wound site, which then allows the skin to be advanced into the defect (**Figure 95-6**).[3–6] These advancement flaps may be used to avoid defects from lacerations of the fingertips, lips, or face.

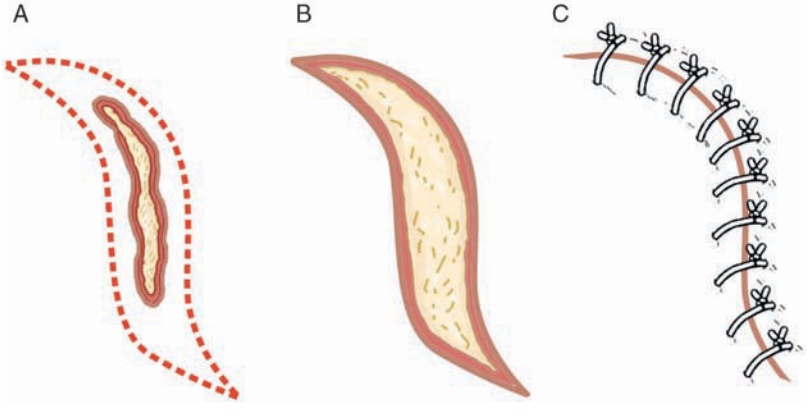


FIGURE 95-5. Closure of an elliptical defect. **A.** The original tissue defect. Draw lines around the defect to form an S-shaped defect. **B.** The skin has been incised and the original defect removed to create an S-shaped defect. **C.** Approximation of the wound edges with simple interrupted sutures.

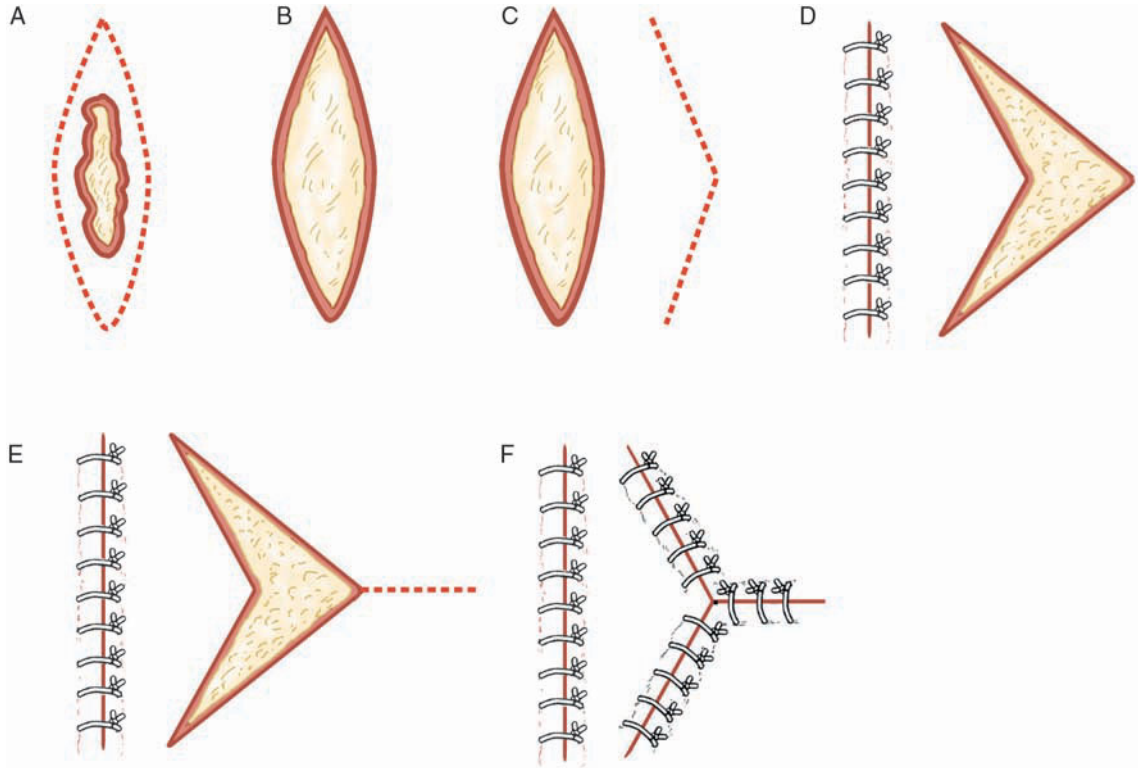


FIGURE 95-6. Closure of a V-Y advancement flap. **A.** The original tissue defect. Draw lines around the defect to form an oval. **B.** The skin has been incised and the original defect removed to form an oval-shaped defect. **C.** Draw a V-shaped line adjacent to the oval defect. It should be positioned the maximum width of the oval defect from the wound edge. **D.** Incise the V and undermine the skin edges. Approximate the oval-shaped defect with buried sutures and simple interrupted sutures. **E.** Draw and incise a line perpendicular to the apex of the V and equal to the maximum width of the V-shaped defect. This forms the V into a Y. **F.** Approximation of the Y-shaped defect.

Wounds may be oval and elliptical (**Figure 95-6A**). Creating an oval from a wound allows more even closure of asymmetrical wounds. Draw lines to debride the wound and form an oval-shaped defect (**Figure 95-6A**). Incise along the lines with a #15 scalpel blade to form the oval-shaped defect and excise the wound (**Figure 95-6B**). Draw a V-shaped line adjacent to the oval-shaped defect (**Figure 95-6C**). **The line should be the length of the oval-shaped defect and approximately the width of the original wound away from the defect along its entire length.** Although the two sites do not directly communicate with each other, the V-shaped incision allows the original wound to be closed primarily and without tension. Undermine the wound and the V-shaped incision. Approximate the oval-shaped defect with buried sutures, if necessary, and simple interrupted sutures (**Figure 95-6D**). This will result in an opening of the V-shaped defect (**Figure 95-6D**). Draw and incise a line perpendicular to the apex of the V-shaped defect with a #15 scalpel blade (**Figure 95-6E**). The line should be as long as the width of the V-shaped defect. Approximate the three arms of the defect with simple interrupted sutures to form a Y (**Figure 95-6F**).

An alternative V-Y advancement flap can be used to close the injury without making a second wound (**Figure 95-7**). Draw lines to debride the wound and form a V-shaped defect (**Figure 95-7A**). Incise along the lines with a #15 scalpel blade to form the V-shaped defect and excise the wound (**Figure 95-7B**). Draw and incise a line

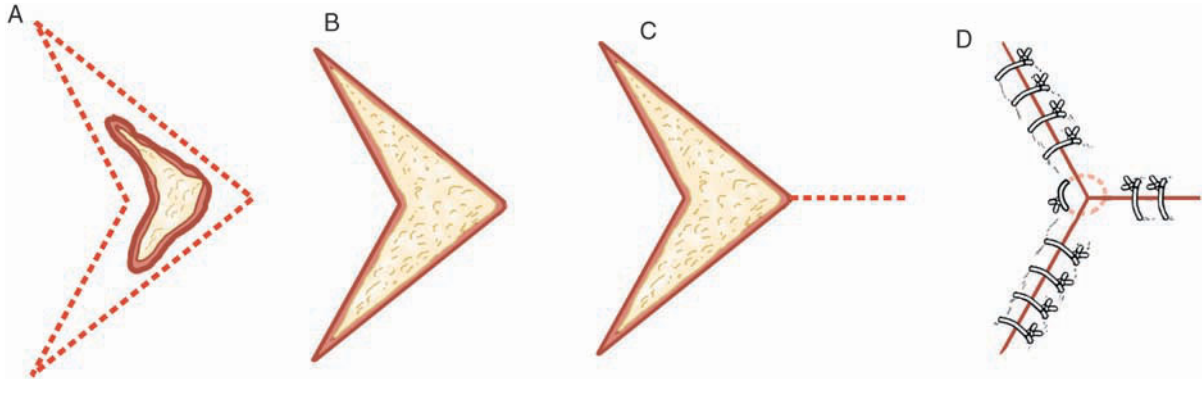


FIGURE 95-7. An alternative V-Y advancement flap closure. **A.** The original tissue defect. Draw lines around the defect to form a V. **B.** The skin has been incised and the original defect removed to form a V-shaped defect. **C.** Draw and incise a line perpendicular to the apex of the V and equal to the maximum width of the V-shaped incision. **D.** Approximate the center of the Y with a half-buried horizontal mattress suture. Approximate the arms of the Y with simple interrupted sutures.

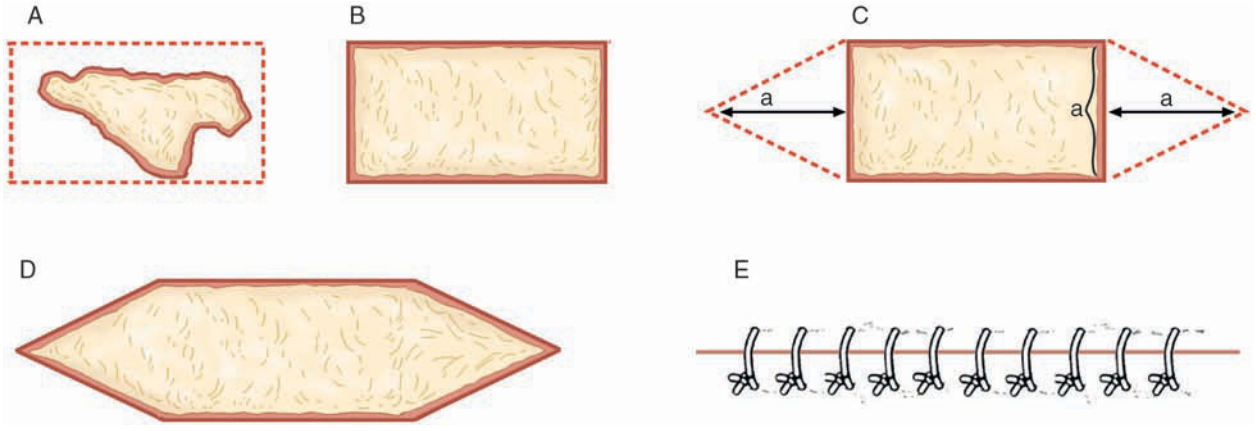


FIGURE 95-8. Closure of a rectangular defect. **A.** The original defect. Draw lines around the defect to form a rectangle. **B.** The skin has been incised and the original defect removed to form a rectangle. **C.** Draw triangles along the short sides of the rectangle. The length from the apex to the base of the triangle must be equal to the width of the rectangle. **D.** The resulting defect after incising and removing the triangles. **E.** Approximation of the wound edges to form a linear scar.

perpendicular to the apex of the V-shaped defect with a #15 scalpel blade (**Figure 95-7C**). The line should be as long as the width of the V-shaped defect. Undermine the V-shaped defect and the perpendicular line. Place a half-buried horizontal mattress suture to close the center of the Y (**Figure 95-7D**). Approximate the edges of the defect with simple interrupted stitches (**Figure 95-7D**).

CLOSURE OF A RECTANGULAR DEFECT

Wounds may be in the form of an ellipse or oblong (**Figure 95-8A**). These can be converted into a rectangular defect to allow primary closure.[3] Draw lines to debride the wound and form a rectangular defect (**Figure 95-8A**). Incise along the lines with a #15 scalpel blade to form the rectangular defect and excise the wound (**Figure 95-8B**). Draw lines to convert the short ends of the rectangle into triangles (**Figure 95-8C**). **The width of the rectangle should serve as the measurement to create an equal distance between the base and the apex of the triangle.** Excising triangles from the ends of the rectangular defect reconfigures the ends of the wound. Incise along the lines with a #15 scalpel blade and remove the triangles (**Figure 95-8D**). Undermine the skin surrounding the defect. Approximate the wound edges with simple interrupted sutures to form a straight line (**Figure 95-8E**).

CLOSURE OF A TRIANGULAR DEFECT (ROTATION FLAP)

Closing of a triangular defect can be accomplished with the use of a rotational flap (**Figure 95-9**). These flaps can be turned on a pivot point. **The flap must be planned carefully so that the direction of rotation coincides with the geometry of the defect.[3–5] Always plan and draw the arch of the flap carefully to visualize the pivot point and direction of rotation prior to making the incision. The creation of a rotation flap is a significant procedure. It can result in a vascular disaster and leave a deformity greater than the original defect it was supposed to correct. Do not create a rotation flap unless you have experience with this technique and know that the flap has an adequate vascular supply.**

Wounds are often irregular and elliptical (**Figure 95-9A**). Draw lines to debride the wound and form an isosceles triangular defect. Incise along the lines with a #15 scalpel blade to form the triangular defect and excise the wound (**Figure 95-9B**). **Draw the rotation flap very carefully.** The edge of the flap is an arch from the

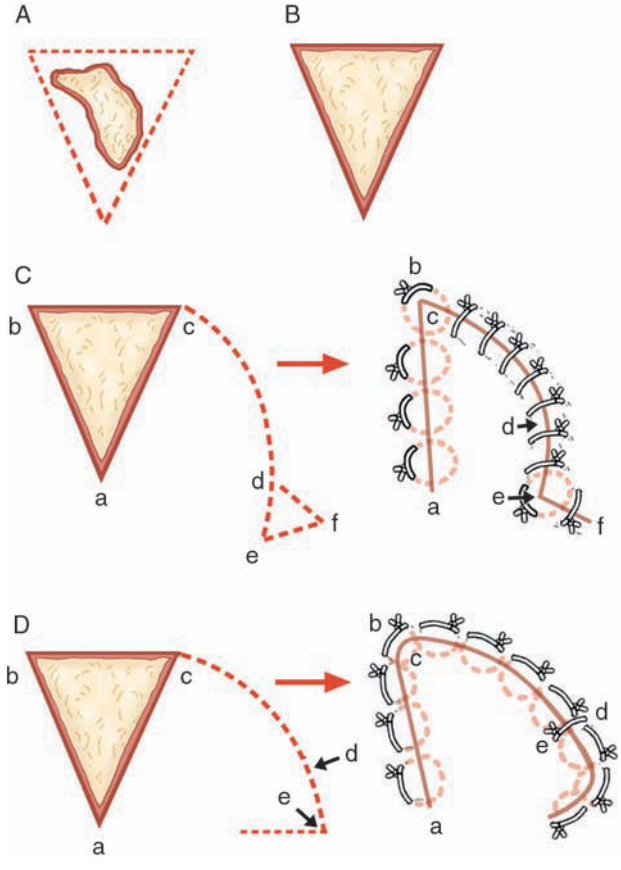


FIGURE 95-9. Closure of a triangular defect. **A.** The original defect. Draw lines around the defect to form a triangle. **B.** The skin has been incised and the original defect removed to form a triangle. **C.** Draw a line to extend the base of the triangle in a wide arc that is three to four times the length of the base of the triangle. Make sure that the arc is drawn beyond the line from point a to point d. Draw a Burow's triangle at the end of the arc. The base of the Burow's triangle should be half the length of the base of the triangular defect. Approximate the triangular defect and any corners with halfburied horizontal mattress sutures. **D.** An alternative technique. Draw a wide arc from the base of the triangle similar to that in (**C**) but which ends opposite the apex of the triangle (point a). Draw a line to make a back-cut that is three-fourths the length of the base of the triangular defect. Approximate the entire wound edge with half-buried horizontal mattress sutures.

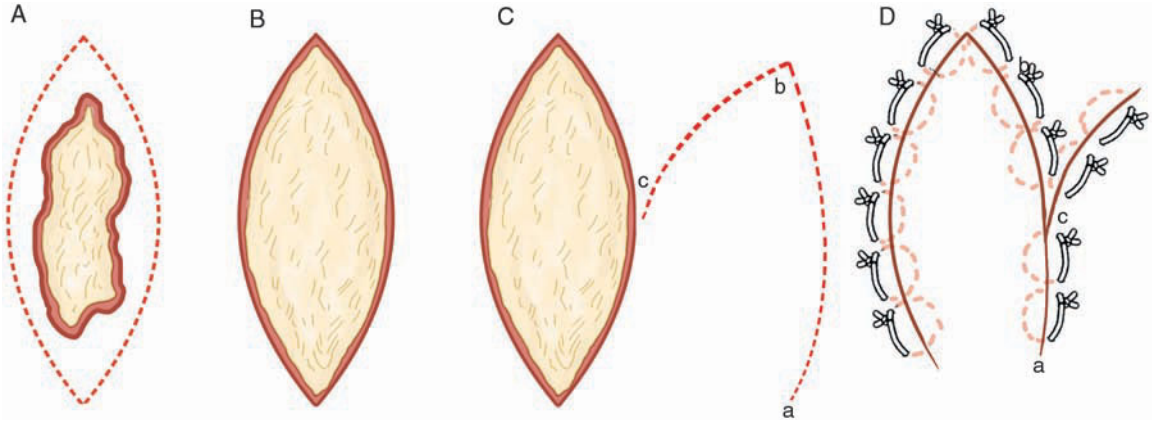


FIGURE 95-10. Closure of an oval-shaped defect. **A.** The original defect. Draw lines around the defect to form a rectangle. **B.** The skin has been incised and the original defect removed to form an oval. **C.** Draw a mirror image of the defect so that it is abutting the defect. **D.** The flap has been rotated and the wound margins approximated with half-buried horizontal mattress sutures.

base of the triangle and three to four times longer than the actual base of the triangle (**Figures 95-9C & D**).[3] Draw a second triangle as a Burow's triangle in the area next to the pivot point of the flap (**Figure 95-9C**).[3–5] **The base of the Burow's triangle should be half the length of the base of the triangular defect, with one corner of the base formed by the end of the arch.** Incise along the lines with a #15 scalpel blade. Remove the Burow's triangle. Undermine the rotation flap and the surrounding skin. Rotate the flap to close the defect and approximate the wound edges with interrupted sutures (**Figure 95-9C**). Place half-buried horizontal mattress sutures to approximate the triangular defect and any corners. Place simple interrupted sutures to approximate the remaining wound edges.

A triangular defect may be closed with a modification to the above technique when there is minimal room to form and excise the Burow's triangle or if lines of skin tension limit the location of the pivot point.[3] **This modified technique should be considered only when necessary, which may occur from poor planning of the initial flap or in areas where fascia can be separated from the subcutaneous layer (e.g., scalp wounds and areas involving the trunk).**[3–5] Form the triangle to debride the wound and draw the arch as described previously. **Do not draw the area beyond the point perpendicular to the apex of the triangle (Figure 95-9D).** Rather than drawing a Burow's triangle for excision, draw a line to make a back-cut from the pivot point (the end of the arc) and along the base of the flap (**Figure 95-9D**).[3,5] **This line should be three-fourths the length of the base of the triangular defect.** Incise along the lines with a #15 scalpel blade. Undermine the defect and the rotation flap. Rotate the flap to close the defect and approximate the entire wound edge with half-buried horizontal mattress sutures (**Figure 95-9D**). Suture the back-cut prior to closing the triangular defect or the arch.[3] **This alternative technique carries the risk of having a poor blood supply to the flap due to its small base.**

CLOSURE OF AN OVAL DEFECT

Oval defects can be closed by creating a rotational or interpolation flap from the intact adjacent tissue (**Figure 95-10**).[3] Wounds are often irregular and elliptical (**Figure 95-10A**). Choose a side of the oval defect to form the flap. The adjacent skin used to make the flap must be vascularly intact to avoid the risk of tissue necrosis once the flap is sutured into position. Draw lines to debride the wound and form an oval defect (**Figure 95-10A**). Incise along the lines with a #15 scalpel blade to form the oval defect and excise the wound (**Figure 95-10B**). **Draw the rotation flap very carefully. Draw a mirror image of the defect abutting the original wound (Figure 95-10C).** Incise only along the lines noted with a #15 scalpel blade. Undermine the rotation flap and surrounding skin. Rotate the flap to close the defect (**Figure 95-10D**). Approximate the edges of the flap with half-buried horizontal mattress sutures (**Figure 95-10D**). Approximate the wound from where the flap originated with simple interrupted sutures, if it is not excessively large or under tension, or with half-buried horizontal mattress sutures.

CLOSURE OF A CIRCULAR DEFECT

Some defects can be closed primarily. Examples include circular defects or triangular defects that are converted to ellipses (**Figure 95-11**). Excise the tissue defect to form a circle. Excise a surrounding ellipse of tissue centered about the circle (**Figure 95-11A**). **The ellipse must be 2½ to 3 times as long as its greatest width.** Undermine the edges of the ellipse. Close the resulting defect with deep sutures if required and cutaneous sutures (**Figure 95-11B**).

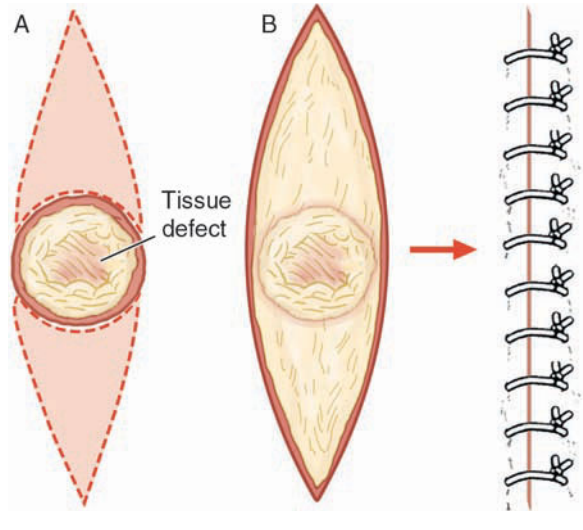


FIGURE 95-11. Closure of a circular tissue defect. **A.** Draw lines around the defect to form an ellipse. **B.** The skin has been incised and the original defect removed to form an ellipse. The wound edges are approximated with deep and cutaneous sutures.

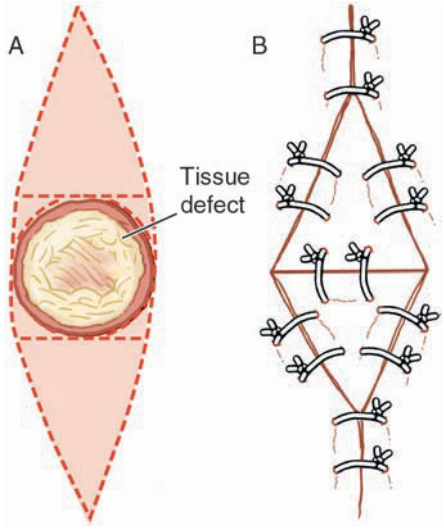


FIGURE 95-12. The double V-Y closure to repair a tissue defect. **A.** Create an ellipse centered about the tissue defect. Remove the tissue defect and form straight edges at the bases of the triangular flaps. **B.** Approximate the bases of the triangular flaps, followed by the arms and bases of the "Y's," using simple interrupted sutures.

Larger defects require the use of a double V-Y closure (**Figure 95-12**). Create two sliding pedicle flaps with a #15 scalpel blade. **Incise the skin and dermis but not the underlying subcutaneous tissue,** to form an ellipse centered about the tissue defect (**Figure 95-12A**). Remove the tissue defect and debride the tissues at the base of the flaps to form two straight edges (**Figure 95-12A**). Gently undermine the edges of the ellipse. **Do not undermine the triangular tissue flaps, so that their vascular supply is preserved.** Slide (advance) the flaps on their subcutaneous pedicles until the bases are touching. Approximate the base of one flap to the other using simple interrupted sutures (**Figure 95-12B**). Approximate the arms and bases of the Y's using simple interrupted sutures.

ASSESSMENT

Inspect the wound edges carefully for adequate approximation. Observe the wound for a period of time to make sure that it remains viable and is not compromised due to a poor blood supply or tight sutures. **A nonviable repair requires immediate removal of the sutures and consultation with a Plastic Surgeon.**

AFTERCARE

Pull the suture knots lying directly over the wound margin to one side so that all the knots lie on the same side. Wipe off any residual povidone iodine or chlorhexidine solution with sterile saline. Apply a topical antibiotic ointment to the wound, followed by a nonadherent dressing. Arrange follow-up in 24 hours with the patient's Primary Care Provider, a Plastic Surgeon, or the Emergency Department. Consider the use of prophylactic antibiotics even though there is no evidence to support or refute this practice.

Instruct the patient and/or their representative regarding wound care and dressing changes. Provide clear instructions of what to look for regarding possible signs of early infection, both localized around the wound site as well as systemic symptoms. Any patient who experiences excessive swelling, erythema, a purulent or foul smelling discharge, significant pain from the wound site, or fever should return to the Emergency Department immediately.

COMPLICATIONS

A brief discussion of the complications of wound closure is presented below. Refer to Chapter 92 for a more complete discussion. The complications of any wound can be greatly affected by the preparation of the wound prior to wound closure. The maintenance of sterile technique throughout wound closure and adequate irrigation of the wound will limit the risk of infection. It is unrealistic to expect any wound site to be bacteria-free.

Wounds may show poor scar formation or delayed healing due to several factors. Poor aftercare without adequate dressing changes or neglect (including premature exposure to environmental irritants such as dirty water, direct and excessive sun exposure, or chemicals) will likely result in a less favorable and unpredictable healing process. The wound site should be protected from excessive contact or use during the initial healing period. Mechanical trauma or overuse can increase the chance of edema or hematoma formation, leading to wound dehiscence or atypical scar formation.

Proper follow-up should be arranged and stressed within the initial 24 to 48 hours following the treatment and thereafter as may be warranted. Awareness that wound healing takes place in sequential physiologic steps is needed to properly direct patients, so that the risk of complications or the need for antibiotics will be minimal.

SUMMARY

Patients present to the Emergency Department with a wide variety of wound types. The use of local flap techniques allows the Emergency Physician to close difficult and complex wounds. If primary closure is not possible, these techniques decrease the tension on a wound and allow for appropriate cosmesis. They require close follow-up and appropriate patient selection if complications are to be prevented.

96 Management of Specific Soft Tissue Injuries

Christopher J. Russo and Ajay Desai

INTRODUCTION

Blunt and penetrating trauma can lead to a myriad of soft tissue injuries. The management of the majority of these injuries is discussed elsewhere in this text. Some specific soft tissue injuries require detailed explanations for their repair. These injuries are discussed below.

MULTIPLE FOREHEAD LACERATIONS

Forehead lacerations are common in all age groups, occurring most frequently during early childhood. While most forehead lacerations are not associated with any other significant injuries, their location demands a complete head and neck evaluation.[1] Furthermore, their visibility requires meticulous attention to detail. Knowledge of the principles regarding their repair allows for good cosmesis. The repair of forehead lacerations differs from that of other soft tissue injuries due to the role of skin tension lines, the lack of extra tissue, and scarring promoted by too many deep dermal sutures.[2–4] Forehead injury repair is governed by three principles: (1) skin tension lines run parallel to the skin creases and play a major role in the outcome of any forehead laceration; (2) lacerations running perpendicular to skin tension lines are more likely to result in a

noticeable scar[2,3]; and (3) there is little excess tissue on the forehead to allow later wound revisions. **Resist the temptation to excise ragged wounds.**[4] This leaves enough tissue for the Surgeon to work with if further revision is required. **Place as few deep sutures as possible,** as they tend to promote more tissue reaction and more noticeable scar formation.

Many forehead lacerations require repair in order to promote cosmesis and provide hemostasis. Perform primary repair at any time up to 24 hours after the initial insult. This allows referral to a consultant if there is any question about one's ability to achieve satisfactory cosmesis or if the wounds are so extensive as to take the Emergency Physician away from their departmental responsibilities for an unacceptably long time regardless of the level of complexity.

Laceration repair is dependent on the type of laceration. Small and uncomplicated lacerations can be closed with simple interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene).[1] Flaps smaller than 5 mm can be closed using simple interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene). Larger flaps can be closed using the half-buried horizontal mattress stitch. Partial-thickness abrasions and gouges less than 1 cm wide and 2 mm deep should be allowed to heal by secondary intention.[2,5,6] Bunched-up, small flap lacerations can be excised together and the resulting defect repaired primarily.[6] This technique is described under "Multiple Small Skin Flaps" in this chapter.

Deeper transverse lacerations that involve the deep fascia, the frontalis muscle, and the periosteum should be repaired in layers using 5-0 absorbable suture (e.g., nylon or Prolene).[1] The epidermal layer can be closed with either simple interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene), skin closure strips over adhesive adjuncts, or with tissue adhesive. The latter two are an especially attractive alternative method of wound closure if the patient is at risk to develop keloids or hypertrophic scars. Skin folds, skin creases, and the hairline should be approximated with great precision.

EYELID LACERATIONS

The objective of eyelid repair is the restoration of normal alignment and anatomic function. Eyelid lacerations are classified as marginal if they cross the eyelid margin or extramarginal if they do not cross the eyelid margin.[7] **A careful history and a thorough physical examination looking for concealed injury or foreign bodies is imperative.** The examination must specifically address and exclude canthal injuries, lacrimal apparatus (most commonly canalicular) injuries, and/or injuries to deep structures. Injuries medial to the lacrimal punctum must prompt the Emergency Physician to explicitly address the possibility of a lacrimal apparatus or canalicular injury. Consult an Ophthalmologist for a probe evaluation of the lacrimal apparatus. Failure to identify canalicular interruptions can compromise outcome, as canalicular repair delayed beyond several days is less successful than primary repair. A delay of 2 to 3 days may be advantageous, as the cut medial ends may become edematous, whitened, and easier to locate.[8,9]

Recognition and management of injuries to deep structures—including the lacrimal apparatus, orbicularis oculi muscle, levator palpebrae muscle, tarsal plates, and medial or lateral canthal tendons—is necessary to prevent dysfunctional tearing, lid malalignment, ptosis, functional abnormalities, and cosmetic defects. Awareness of the eyelid's complex anatomy is essential to the proper recognition and repair of less-evident impairment due to injury. Certain key features are reviewed here as they are necessary to prevent overlooked injury and understand proper repair.

The eyelid's skin is the thinnest in the body, with that of the upper eyelid being thinner than that of the lower eyelid. The skin moves freely over the deeper tissues and is easily mobilized with forceps. Surface landmarks include—from posterior (nearest the globe) to anterior (nearest the skin)—the mucocutaneous junction, the orifices of the meibomian glands, the gray line, and the lash line. The gray line is a key landmark. It is located on the palpebral edge and consists of an isolated strip of pretarsal orbicularis oculi muscle just anterior to the tarsus (Riolan's muscle). Lacerations through the gray line require diligent reapproximation and should be referred to an Ophthalmologist.[10] There are three or four irregular rows containing approximately 100 lashes on the upper eyelid and two or three rows of approximately 50 lashes on the lower eyelid.

The levator palpebrae muscle arises from the roof of the orbit. It inserts into the midtarsus and overlying skin, intimately associating with the orbicularis oculi muscle. Suspect levator injuries with any horizontal laceration of the upper eyelid. Improper repair or failure to repair a laceration may result in ptosis or a deformity of the supratarsal fold.

Canthal injuries must be actively sought. Determine whether the medial or lateral canthal tendon is injured. Apply lateral traction on the eyelid. Displacement of the punctum laterally may be due to a disruption of the medial canthal tendon. Such a disruption is likely to be associated with nasal fractures, orbital fractures, ethmoid fractures, and canalicular injuries.[11] Apply medial traction on the eyelid. Displacement of the lateral canthus medially is due to a disruption of the lateral canthal tendon. Inspection and/or probing through the wound may confirm a canalicular interruption. Early repair is preferred, as the tissue becomes more difficult to identify and repair when swollen. However, the value of early repair of canalicular lacerations is debated.[12] Early repair may exacerbate the degree of canalicular damage, the risk of stenosis, and may result in damage to other parts of the canalicular system.[12] Consult an Ophthalmologist, as meticulous repair is mandatory to avoid damaging the lacrimal apparatus.

The orbicularis oculi muscle closes the eyelids tightly. Failure to properly repair the levator muscle, the tarsal fascia, or the orbicularis muscle in a deep upper eyelid laceration may result in ptosis. Consult an Ophthalmologist for all deep upper eyelid lacerations.

There are at least six published variations on the techniques described for repair of the eyelid margin with less than one-third of tissue loss measured horizontally, yet there is no literature comparing outcomes.[7,13–19] The experience and skill of the practitioner are vital. Each minor variation aims for precise apposition to avoid malalignment or notching of the eyelid margin. Each technique varies the sequence, number, or type of margin sutures or the order of margin sutures (final or temporary) versus tarsal suture placement and closure (if required).

A recently published edition of a major Emergency Medicine text maintains that only Ophthalmologists or Oculoplastic Surgeons should close marginal lacerations. Consult an Ophthalmologist prior to repairing any marginal lacerations. Repair requires considerable experience, the use of magnification, and the placement of deep sutures.

Eyelid lacerations without marginal involvement are considered "superficial." Approximate these lacerations with interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene), which should remain in place for 3 days.[10] The skin and orbicularis muscle may be closed in one layer. Consult an Ophthalmologist or Oculoplastic Surgeon for lacerations involving the tarsal plates.

Eyelid lacerations with tissue loss require individualization.[13,20] Wound edge loss of less than 25% of the horizontal length of the eyelid can often be closed primarily. Approximate the wound edges with a toothed forceps to evaluate wound tension. Freshen ragged edges without loss of tissue. Avoid penetration to the conjunctival surface to avoid contact with the cornea. Accurate repair of the

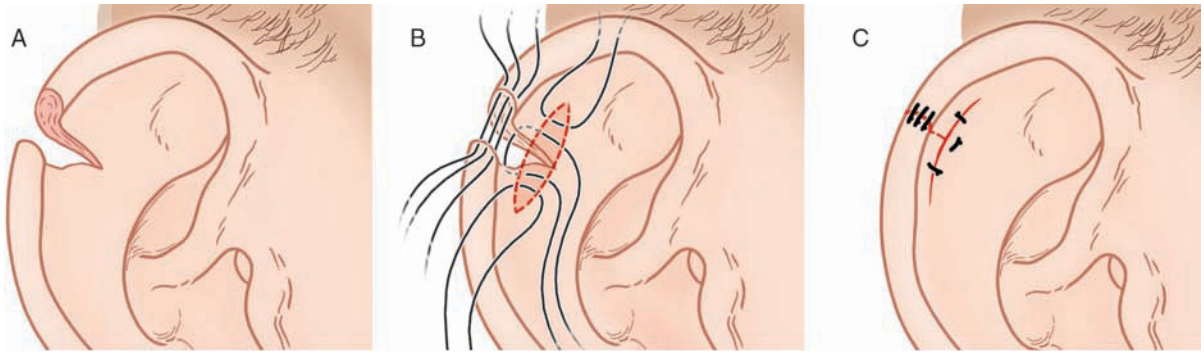


FIGURE 96-1. The wedge excision and repair technique for auricular lacerations. **A.** Excise a full-thickness triangle of tissue. **B.** Place interrupted nonabsorbable sutures through the skin and perichondrium. **C.** Approximate the wound edges by tying the sutures.

tarsus is vital because it forms the skeleton of the eyelid. Remove sutures in 5 days. Tissue loss of greater than 25% may require a canthotomy, cantholysis, or a tissue flap. Refer these injuries to an Ophthalmologist or Oculoplastic Surgeon. Older patients with skin laxity may be able to tolerate a greater than 25% loss with adequate cosmesis.[13,20]

Some eyelid lacerations without eyelid margin involvement may involve the levator muscle. Evaluate horizontal lacerations of the upper eyelid for levator interruption. Visible fat indicates orbital septum penetration and raises the suspicion of levator involvement. These lacerations should be repaired with fine absorbable suture to avoid ptosis.[10,13] **An eyelid crease and/or minimal levator function suggests an intact levator.[13]**

The orbital septum lies deep to the orbicularis oculi muscle. The levator palpebrae muscle lies deep to the orbital septum. The septum is rigidly attached to the orbit and does not move on traction with a forceps. Grasp the levator muscle with a forceps and instruct the patient to look up. A brief pull will be felt as the muscle contracts. It is crucial to distinguish between the levator apparatus and the orbital septum. Injuries involving the orbital septum carry a higher risk of globe injury, intraorbital foreign body, and orbital cellulitis. **The septum must not be included in a repair of the levator, as it will restrict movement of the levator.** Consult an Ophthalmologist or Oculoplastic Surgeon for deep extramarginal lacerations with suspected levator muscle involvement, in addition to a computed tomographic scan to evaluate for potential transorbital fascia/septal involvement.[21]

Complications associated with eyelid repair include malalignment, missed canalicular lacerations with attendant tearing dysfunction, missed foreign bodies, corneal abrasions, missed globe injury, missed canthal interruption, and missed fractures with entrapment. Unless an Emergency Physician has adequate familiarity with the techniques, referral to an Ophthalmologist or Oculoplastic Surgeon is recommended.

EAR LACERATIONS

Ear lacerations can result from blunt or sharp trauma to the auricle. The primary goals are to preserve the normal contours of the auricle, to prevent chondritis, and to prevent hematoma formation.[22,23] The skin of the ear is extremely vascular. The underlying auricular cartilage is avascular and receives its nourishment from the overlying skin. **Minimize any debridement of the auricular soft tissues to ensure that the repair covers all exposed cartilage.** Auricular laceration repair follows the same principles as other laceration repair techniques. Differences to be appreciated include the importance of debriding as little soft tissue as possible, always covering exposed cartilage, splinting the ear appropriately after the repair, and recognizing the indications for consulting a Plastic Surgeon (cartilage defects > 5 mm, inability to cover exposed cartilage, and amputation injuries).

Examine the area for signs of an acute hematoma or other associated traumatic injuries, (e.g., hemotympanum or Battle's sign).[10] Clean, prepare, and anesthetize the auricle. Refer to Chapter 168 regarding the techniques of auricular anesthesia.[24] Consider local infiltration for small, isolated wounds without cartilage involvement or an auricular block for complicated or extensive lesions. Use only a local anesthetic agent without epinephrine to prevent potential complications. Close simple lacerations primarily with interrupted 6-0 nonabsorbable suture (e.g., nylon or Prolene).

Wounds involving soft tissue and cartilage loss of less than 5 mm should be closed with a wedge excision and repair technique (**Figure 96-1**). The auricular skin does not stretch to allow coverage of defects. Thus, the wedge excision technique allows a primary closure that would otherwise have been difficult to achieve without distortion or buckling the anatomy of the auricle due to the underlying cartilage.

Excise a full-thickness triangle of tissue in the antihelix with a #15 scalpel blade (**Figure 96-1A**). **Approximate the skin on the anterolateral surface followed by the posterior surface** with interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene). **Carefully approximate the ridges and valleys to minimize the cosmetic defect. Place the sutures through the skin and perichondrium, not the cartilage.** The skin and underlying cartilage are so adherent to each other that it is not necessary to close the cartilage separately. A preferred technique by some, who believe that the cartilage fragments will be drawn together and heal much better, is to place numerous interrupted sutures through the skin and perichondrium on either side of the wound (**Figure 96-1B**) and then approximate the wound edges (**Figure 96-1C**).

Auricular lacerations can involve one or all layers without any loss of tissue. The cartilage may protrude into the wound further than the overlying skin (**Figure 96-2A**). This type of wound is difficult to close primarily without debridement as the skin does not stretch to cover the cartilage. Use a #15 scalpel blade to carefully trim the cartilage back to the level of the skin or so that the skin overhangs the cartilage by 1 mm (**Figure 96-2B**). This allows the skin edges to be everted when closed. Approximate the skin and perichondrium with interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene).

Extensive lacerations of the auricle are managed in a similar manner. Trim any protruding cartilage as described above. Place interrupted 6-0 absorbable sutures (e.g., Vicryl or Dexon) through the perichondrium to approximate the cartilage at important landmarks

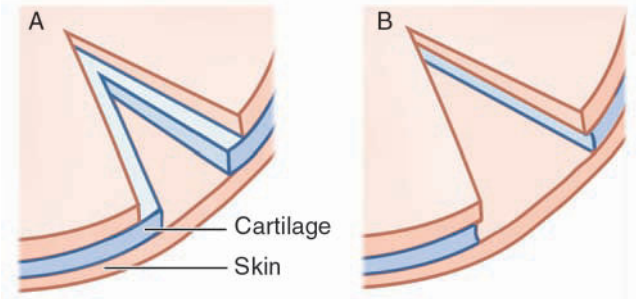


FIGURE 96-2. Repair of an auricular laceration. **A.** The skin has retracted and the cartilage protrudes into the wound. **B.** Trim the cartilage so that it is level with the skin or so that the skin overhangs the cartilage by 1 mm.

and remove tension from the wound edges. Approximate the skin and perichondrium with interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene).

Lacerations of the external auditory canal require repair only if the underlying cartilage is exposed. This is done in an attempt to prevent a chondritis. Otherwise, pack the external auditory canal with a nonabsorbent wick (e.g., petrolatum gauze wrapped around a cotton ball) to approximate the wound edges and speed the healing process.

Consult a Plastic Surgeon for wounds with tissue loss of greater than 5 mm, wounds with exposed cartilage that cannot be covered without sacrificing greater than 5 mm of cartilage, complete or almost complete ear avulsion injuries, and injuries with obvious devitalization of the auricle. **Care for the avulsed auricle as an "amputated part" to preserve viability should the consultant desire to pursue reimplantation.**

Uncomplicated wounds not involving the auricular cartilage require local wound care and suture removal in 4 to 5 days. Larger wounds and those involving the auricular cartilage require oral antibiotics to cover skin flora and a dressing that conforms to the anatomic configuration of the auricle. The dressing will provide support and prevent an auricular hematoma from forming. Refer to Chapter 168 regarding the details of placing this dressing. Sutures should be removed in 3 to 5 days in children, 4 to 5 days in adults.[22]

The complications following ear laceration repair are similar to those occurring after all wound repairs. Specific problems include the development of a chondritis, which is much more likely if the auricular cartilage is left exposed. Deformities can be due to the injury itself, poor repair techniques, or the development of an auricular hematoma secondary to poor ear splinting. Antistaphylococcal antibiotic coverage is recommended in cases where cartilage has been exposed or a hematoma has been drained. Hematomas that have been drained should be rechecked in 24 hours to evaluate for reaccumulation.[22] Refer to Chapter 168 for a complete discussion of these complications.

NASAL LACERATIONS

Important points to note in dealing with nasal lacerations are the extent of the laceration and the structures involved. Cartilage involvement increases the likelihood of developing a subsequent infection. Lacerations are difficult to close because the skin is inflexible and lacks redundancy. Associated injuries, such as nasal fractures and septal hematomas, must also be managed. Suturing back a totally avulsed nose is unnecessary as it will most often fail.[25]

The repair of nasal lacerations requires local anesthesia, which can be achieved using an infraorbital nerve block (Chapter 126), a nasal block (Chapter 170), or direct infiltration of local anesthetic solution without epinephrine. The nasal mucosa can be anesthetized using cocaine-soaked pledgets (Chapter 170).

Lacerations limited to the outer aspect of the nose (i.e., skin lacerations and not through-and-through lacerations) can be repaired as simple lacerations. Minimize any debridement, as the lack of redundancy of nasal skin can result in disfiguring scarring.[26]

Lacerations involving the nasal cartilages require a thorough cleansing, minimal if any debridement, and a multilayered closure. **Do not place stitches through the avascular nasal cartilages, as this increases the chances of a postrepair infection.** Approximation of the nasal mucosa, subcutaneous tissues, and skin will appose the cartilage edges. **It is crucial to have proper alignment of the alar rim and columella in order to achieve good cosmetic results[25] and to avoid the postrepair complication known as "notching."** The repair proceeds from inside outward. Approximate the nasal mucosa with interrupted 5-0 or 6-0 absorbable sutures (e.g., Vicryl, Dexon, or gut). Approximate the subcutaneous tissues with interrupted 5-0 or 6-0 absorbable sutures (e.g., Vicryl or Dexon). Approximate the skin with 5-0 or 6-0 nonabsorbable sutures (e.g., nylon or Prolene).

ORAL MUCOSAL LACERATIONS

Lacerations of the oral mucosa generally heal without intervention. Wounds requiring repair are those large enough to trap food particles (greater than 2 to 3 cm) and wounds with a tissue flap that falls between the occlusive surfaces of the teeth. Some physicians prefer to place 4.0 silk sutures, as they are not irritating to the patient and do not tempt the patient to "play" with them with their tongue or bite through them. The disadvantage of silk sutures is that they require a return visit for removal. Absorbable sutures (e.g., plain gut or chromic gut) are thus preferable, especially in children to avoid the task of suture removal.[25] However, the choice of using absorbable versus silk sutures remains physician-dependent. Tissue flaps that fall between the occlusal surfaces of the teeth may be approximated or excised. A diet of soft foods and liquids is recommended for the first 2 to 3 days after the repair. The mouth should be rinsed gently two or three times a day and after meals with chlorhexidine solution. Some authors recommend the use of prophylactic antibiotics although this practice is controversial.[27]

LIP LACERATIONS

Attention to detail is essential for attaining a good cosmetic result in repairing lip lacerations, as they can result in devastating cosmetic defects if not repaired properly. Malalignment of the vermilion border or the "white line" (the border between the skin of the face and the red part of the lip), by as little as 0.5 to 1 mm will be easily noticeable.

Anesthetize the lip using a nerve block to avoid tissue distortion and allow proper tissue apposition (Chapters 126 and 176). Avoid using epinephrine with anesthesia, as this will blunt the vermilion border landmark.[28] Close the vermilion border first, using 6-0 nonabsorbable sutures (e.g., nylon or Prolene) (**Figure 96-3A**). Close the orbicularis muscle layer next using 5-0 plain gut or chromic gut suture (**Figure 96-3B**). Close the mucosal border with the same type of suture. Close the skin with interrupted 6-0 nonabsorbable sutures (e.g., nylon or Prolene) (**Figure 96-3C**).

Adhering to this plan will allow the best cosmetic result possible. Other anatomic areas that require careful approximation to attain good cosmesis include the mucosal border (separating the intraoral and extraoral portions of the lip) and the orbicularis oris muscle. Through-and-through lip lacerations often violate all three of these structures. In these cases, consider debridement of irregular borders.[28]

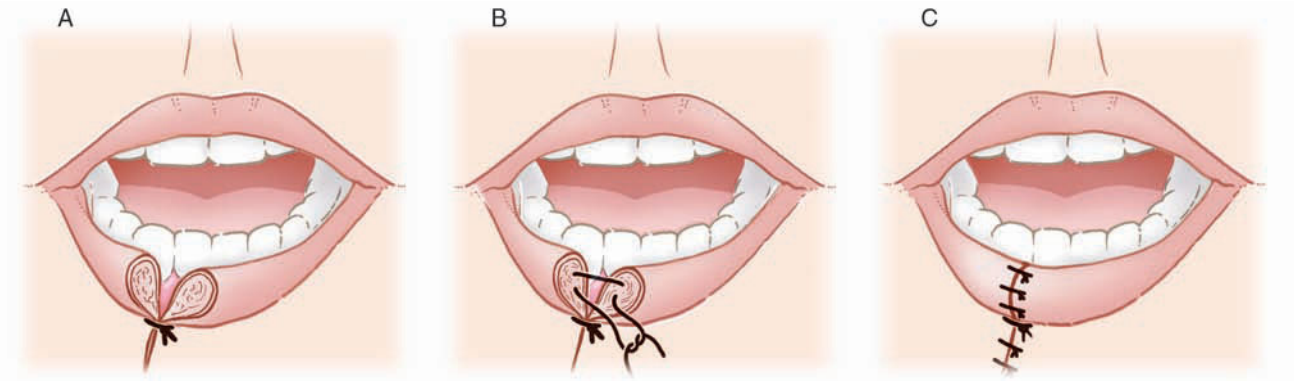


FIGURE 96-3. Lip laceration repair. **A.** Always approximate the vermillion border first. **B.** Approximation of the orbicularis oris muscle. **C.** Approximation of the mucosal surface and the skin.

The aftercare for a sutured lip laceration is much the same as for oral mucosal lacerations. Instruct the patient to avoid bringing excessive pressure to bear on the suture line. Remove the skin sutures in 4 to 5 days to avoid scarring. Parents should be instructed to distract their children from biting the sutures off while they are still anesthesized.[28]

TONGUE LACERATIONS

The majority of tongue lacerations are the result of oral trauma and tongue biting, and heal well without intervention.[29] Lacerations that do not require repair are generally small, linear, and superficial lacerations located in the central tongue region or small flaps on the edge of the tongue that can be excised. The tongue's generous blood supply allows these wounds to heal well, yet can also cause serious hemorrhage and potential airway compromise.[29] Therefore, patients who have tongue lacerations that require repair should also be evaluated for potential airway problems, and the need for procedural sedation or possibly general anesthesia (especially in children).[28] Some wounds require closure and can be very challenging to repair.[30–33] These may include large lacerations (>1 cm), gaping wounds, actively bleeding lacerations, U-shaped lacerations, wounds that bisect the tongue, and large flaps on the tongue edge. The main problem is not the repair itself but achieving control of the area to facilitate the repair.

Anesthetize the tongue via local wound infiltration or a lingual nerve block for the anterior two-thirds of the tongue (Chapter 176). These can be supplemented with procedural sedation techniques (Chapter 129). Instruct an assistant to gain control of the tongue. Grasp the anesthetized tip of the tongue with a towel clip, a suture through the tip of the tongue, or a gauze square. Consider inserting a bite block to further protect the patient and the Emergency Physician from injury during the repair process. Thoroughly irrigate the wound. Close the laceration using absorbable 4-0 plain gut or chromic gut sutures. Take large bites that include the mucosal and muscular layers of the tongue. Buried or deep sutures are not required when taking large bites. Multiple well-secured sutures are preferred to prevent the untying of suture material with tongue motion.[34]

Extensive complex tongue lacerations are at a greater risk for infection and should be treated with prophylactic antibiotics that cover normal oropharyngeal flora.[34] Children with tongue lacerations may chew off the stitches, and so parents should be made aware of this and be instructed to distract the child until the local anesthesia wears off.[28] Aftercare instructions are similar to those for oral mucosal lacerations.

GINGIVAL LACERATIONS

Gingival lacerations differ from other lacerations in that there is often no subcutaneous tissue available to anchor the flap. Small gingival lacerations tend to heal well without intervention because of the extensive blood supply in this area. Repair wounds that are large, actively bleeding, gaping open, or that fall onto the occlusive surface of the teeth.

Flap lacerations exposing the alveolar ridge and tooth roots pose a special problem, as there is no subcutaneous support to anchor the mucosa. The technique requires the placement of a 4-0 or 5-0 absorbable suture that first runs circumferentially around and then is tied posterior to the tooth.[35] Place the suture 2 to 3 mm proximal to the gingival margin (**Figure 96-4A**). Place the suture through the gingiva so that it passes circumferentially around the tooth to secure the flap (**Figure 96-4B**). Loosely tie the suture on the inner aspect of the tooth so that the knot does not irritate the lip or strangulate the tissues (**Figure 96-4B**). The aftercare is the same as described under "Tongue Lacerations" in this chapter.

SUTURING THROUGH HAIR

It is inadvisable to shave hair bordering the edges of a laceration, as this only serves to increase the likelihood of a wound infection.[36] Instead of shaving the hair, brush it aside or mat it down using petroleum jelly or antibiotic ointment prior to wound repair. **It is of particular importance never to shave eyebrows or eyelashes, as they will take months to grow back if they grow back at all.** Always debride an eyebrow laceration oblique to the hair follicles

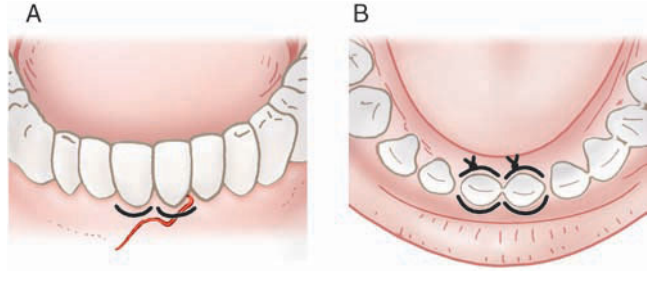


FIGURE 96-4. Gingival laceration repair. **A.** Place the suture 2 to 3 mm proximal to the gingival margin. **B.** Place the suture through the gingiva and circumferentially around a tooth to secure the flap.

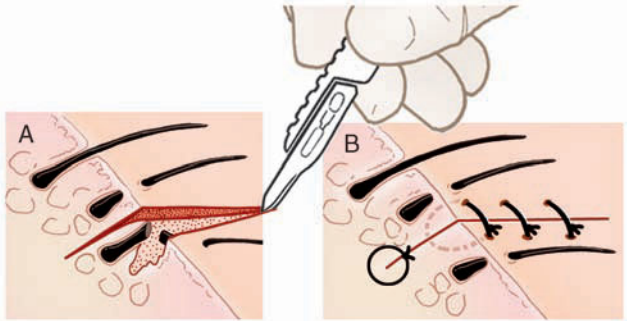


FIGURE 96-5. Repair of eyebrow lacerations. **A.** Debride the wound edges obliquely and parallel to the hair follicles and not perpendicular to the wound edges. **B.** Approximate the wound edges.

and not perpendicular to the skin edge (**Figure 96-5**). This will reduce the loss of hair follicles.

MUSCLE LACERATIONS

The repair of muscle lacerations begins with a careful assessment of the extent of injury and the level of contamination prior to repair. Large and/or grossly contaminated muscle injuries require operative management. All other muscle injuries may be managed in the Emergency Department. Treatment should focus on repair or reconstruction of a muscle using its long tendons of origin and insertion to anchor the repair, as the muscle tissue alone is inadequate for suture repair.[37]

Lacerations of the fascia surrounding a muscle are common. Thoroughly cleanse the area and debride any devitalized tissue. Approximate small violations of the muscle fascia with interrupted 3-0 or 4-0 absorbable sutures (e.g., Vicryl or Dexon). Closing small rents will prevent symptomatic herniation of muscle tissue through them in the future. Do not repair large violations of the muscle fascia. Anecdotal reports of muscle compression and compartment syndromes after such repairs abound.

Lacerations through the muscle require a thorough cleansing and debridement of any devitalized tissue. Repair the laceration with 3-0 or 4-0 absorbable sutures (e.g., Vicryl or Dexon). **Place horizontal mattress stitches to close the laceration.** Interrupted sutures are not effective, as they tend to pull through the muscle fibers and not hold.

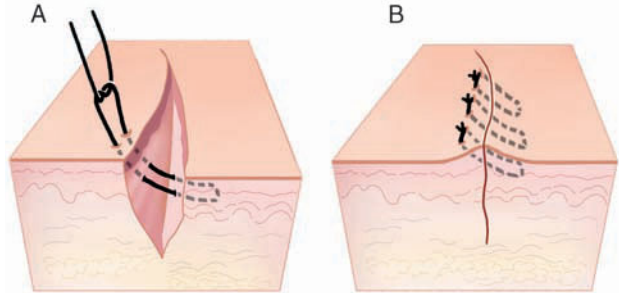


FIGURE 96-6. Closing a wound with edges of unequal thickness using half-buried horizontal mattress sutures.

INCOMPLETE LACERATIONS

Lacerations involving the epidermal and superficial papillary layers of the skin but sparing the deep papillary layer are referred to as incomplete lacerations. Excise the loose epidermal pieces of skin. Cover the wound with petrolatum gauze and a pressure dressing.

WOUNDS OF UNEQUAL THICKNESS

Wounds of unequal thickness are not suited for repair with simple interrupted sutures. Unequal tissue loss on each edge of a wound creates a thick edge–thin edge wound. **The depressed edge must be elevated to the level of the nondepressed edge in order to attain proper wound apposition and cosmesis.**

There are two techniques to repair wounds with edges of unequal thickness. The first technique utilizes a half-buried horizontal mattress suture (**Figure 96-6**).[38] Place the suture through the thick edge of the wound, across the wound and buried into the subcutaneous tissue of the thin edge, and back out the skin of the thick edge (**Figure 96-6A**). Apply traction to the suture and tie it to approximate the wound (**Figure 96-6B**). Apply an ointment-based compressive dressing.

The second technique requires undermining both wound edges at the same depth in the subcutaneous tissue plane (**Figure 96-7**).[39] Make an incision in the subcutaneous tissues of both wound edges and at the same level (**Figure 96-7A**). Undermine the area to free the tissue flaps (**Figure 96-7B**). Grasp the subcutaneous tissue flap from the thicker side and insert it under the thinner side beneath the undermined area (**Figures 96-7B & C**). Place a buried

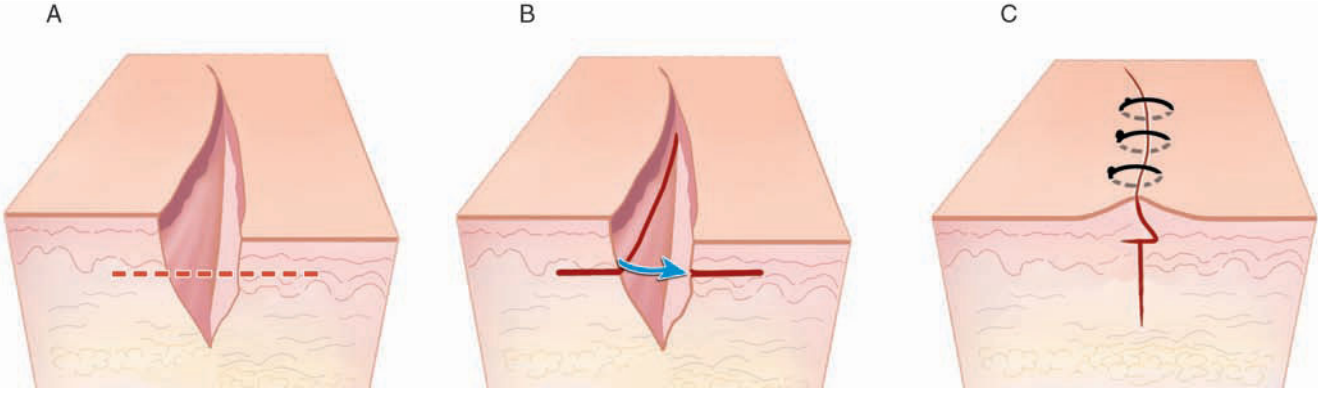


FIGURE 96-7. An alternative technique to close a wound with edges of unequal thickness. **A.** Make an incision in the subcutaneous tissue of both wound edges. **B.** Undermine the edges. Transpose the subcutaneous tissue of the thicker side into the undermined area of the thinner side (*arrow*). **C.** Approximate the wound edges using interrupted sutures.

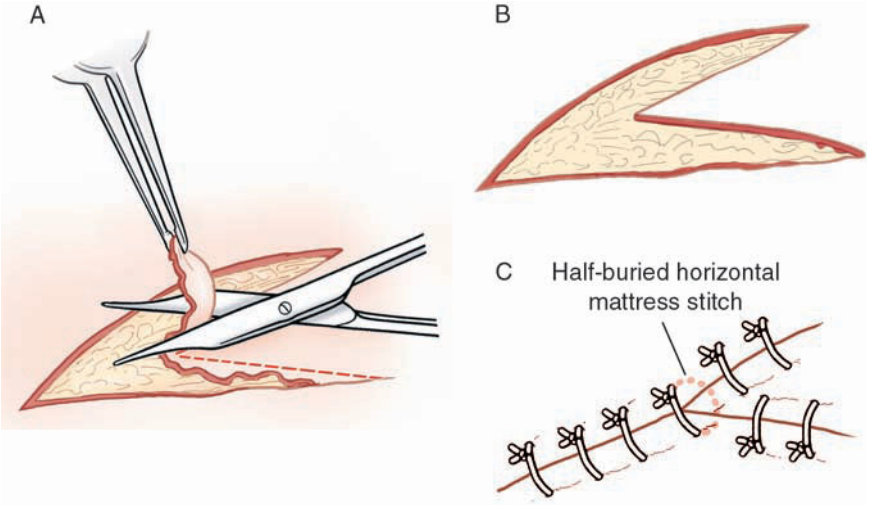


FIGURE 96-8. Repair of a flap laceration. **A.** Sharply debride the edges. **B.** The resultant defect. **C.** Approximation of the wound edges. First place a half-buried horizontal mattress suture to close the tip of the flap. Approximate the remaining wound edges with interrupted sutures.

horizontal mattress suture to maintain the flaps in position. This "flap" elevates the depressed wound edge and facilitates appropriate wound approximation (**Figure 96-7**).[39] Place interrupted sutures to approximate the wound edges (**Figure 96-7C**).

Tangential flap lacerations over thin skin, such as the dorsum of the hand or the pretibial area, where there is very little subcutaneous tissue can be approximated with a specially placed simple interrupted suture. Insert the needle through the tip of the thin edge, across the wound, into the dermis of the thick edge, and out the skin of the thick edge. Apply traction to the suture to pull the thick edge up to meet the thin edge, producing good approximation rather than overlap of the edges. Apply an ointment-based compressive dressing.

FLAP LACERATIONS

Flap lacerations occur when shearing forces to the skin tear the dermis from the underlying subcutaneous tissues. This type of laceration is problematic. The flap is now separated from its blood supply except for the blood entering through the base. This makes the flap susceptible to necrosis and infection. As a general rule, a flap will remain viable if the base of the flap is three times its length.[40] Flaps with a ratio of less than 3:1 are less likely to survive intact; therefore, alternative methods of closure should be entertained.

A flap can easily be repaired primarily if it has viable edges and meets or exceeds the 3:1 ratio of base to length. Anesthetize, clean, and prepare the area. Trim the excess fatty tissue from the underside of the flap. This will improve the chances of healing. Place a half-buried horizontal mattress suture as the first stitch to close the corner or the tip of the flap. Approximate the sides of the flap with interrupted sutures or half-buried mattress sutures.

Some viable flaps have nonviable edges that must be debrided prior to closure to ensure proper cosmesis and survival of the tissue. Debride the nonviable edges sharply with a #15 scalpel blade or an iris scissors (**Figures 96-8A & B**). Place a half-buried horizontal mattress suture as the first stitch to close the corner. This is necessary to close the flap, as the debridement has left the flap too small to close the wound. Approximate the sides of the flap with simple interrupted sutures, mattress sutures, or half-buried mattress sutures.

Some flaps may be too small after debridement or be under too much tension to stretch across the wound. These flaps can be closed by forming a Y-shaped closure instead of a v-shaped closure (**Figure 96-8C**). Place a half-buried horizontal mattress suture to close the tip of the flap. Approximate the base and arms of the Y with interrupted sutures.

A flap laceration may present difficulties. It may not be possible to revise and repair it or it may be obviously nonviable. It is often possible to "ellipse" the flap (**Figure 96-9**). Excise the tissue defect to form a circle. Excise a surrounding ellipse of tissue centered about the circle (**Figure 96-9A**). The ellipse must be 2½ to 3 times as long as its greatest width. Undermine the edges of the ellipse. Approximate the center of the resulting defect using a locked vertical mattress stitch, which allows approximation of the remainder of the wound with minimal extrinsic tension. Approximate the remainder of the resulting defect with deep sutures, if required, and cutaneous sutures (**Figure 96-9B**).

In some cases, there is simply not enough tissue to cover the defect, no matter what technique is attempted. These wounds may be left to heal by secondary intention if small or referred to a Plastic Surgeon for skin grafting. The only complication unique to the repair of flap lacerations is the possibility that the flap may not survive, requiring referral and revision or skin grafting.

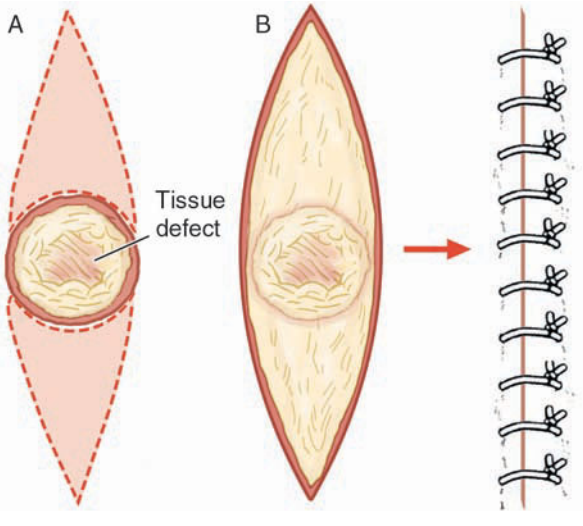


FIGURE 96-9. Closure of a tissue defect. **A.** Excise the defect and a surrounding ellipse. **B.** Approximation of the wound edges with deep and cutaneous sutures.

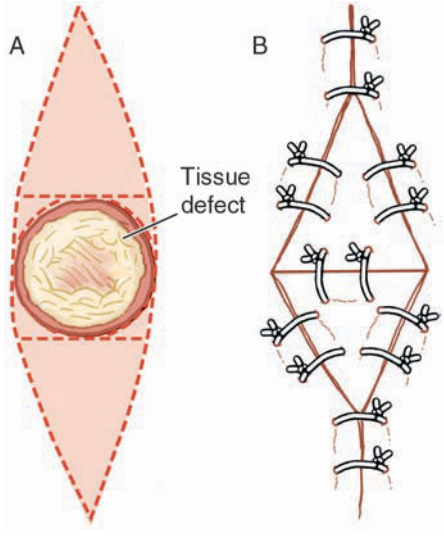


FIGURE 96-10. The double V-Y closure to repair a tissue defect. **A.** Create an ellipse centered about the tissue defect. Remove the tissue defect and form straight edges at the bases of the triangular flaps. **B.** Approximate the bases of the triangular flaps followed by the arms and bases of the Y's, using interrupted sutures.

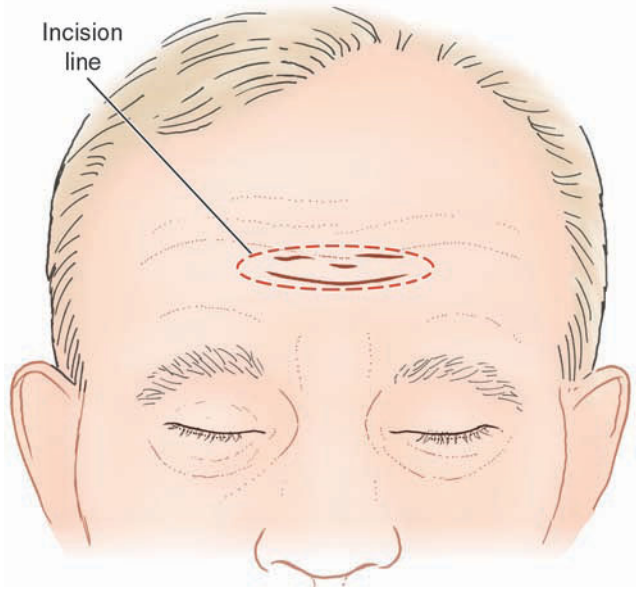


FIGURE 96-11. Repair of multiple small lacerations. Excise the lacerations as a group to form a single wound that can be closed primarily.

AVULSION INJURIES

The treatment of tissue avulsion injuries varies depending on the amount of tissue lost and its depth. Allow full-thickness defects less than 1 to 2 cm^2 to heal by secondary intention after debridement. Full-thickness defects greater than 2 cm^2 require a different approach utilizing skin grafts, flaps, or converting the wound to one that can be closed primarily. Treat avulsed tissue as an "amputated part" that may be used in the repair process. Consider consulting a Plastic Surgeon for a large avulsion that cannot be closed primarily or to convert it into a wound that can be closed primarily.

Some defects can be closed primarily. Examples include circular defects or triangular defects that are converted to ellipses (**Figure 96-9**).[41] This technique is described above under "Flap Lacerations."

Larger defects require the use of a double V-Y closure, which converts the flap to a different shape prior to the repair and thus increases the chances of successful primary closure (**Figure 96-10**).[41] Create two sliding pedicle flaps with a #15 scalpel blade. **Incise the skin and dermis, but not the underling subcutaneous tissue,** to form an ellipse centered about the tissue defect (**Figure 96-10A**). Remove the tissue defect and debride the tissues at the base of the flaps to form two straight edges (**Figure 96-10A**). Gently undermine the edges of the ellipse. **Do not undermine the triangular tissue flaps, so that their vascular supply is preserved.** Slide (advance) the flaps on their subcutaneous pedicles until the bases are touching. Approximate the base of one flap to the other using simple interrupted nonabsorbable sutures (e.g., nylon or Prolene) (**Figure 96-10B**). Approximate the arms and bases of the Y using interrupted nonabsorbable suture (e.g., nylon or Prolene).

MULTIPLE SMALL SKIN FLAPS

Numerous small skin flaps that are bunched up, as commonly seen when a patient's forehead shatters a windshield, are difficult to repair individually. Excise them as a group to form a single laceration that can be repaired primarily (**Figure 96-11**). Larger and more "spread out" groups of flap lacerations can be repaired in a manner similar to that described under "Multiple Forehead Lacerations," above.

DISTAL FINGERTIP AMPUTATIONS

Injuries of the distal fingertip rank among the most frequently injured parts of the hand.[42] Amputations of the fingertip are defined as loss of the tissues distal to the insertions of the extrinsic flexor and extensor tendons on the distal phalanx, distal to the level of the lunula. These injuries may include skin, pulp, bone, the nail matrix, or the nail plate.[42] Treatment options have evolved remarkably over the past 30 years, though change in clinical practice has lagged. Multiple treatment modalities exist and depend on whether the amputated part was retrieved, its condition, the character of the injury, the patient's preference and underlying health status, as well as the availability and sophistication of consultants.

For amputations with pad loss of less than 1 cm, with and without bone exposure, conservative nonsurgical management with serial dressing changes of nonadherent gauze is appropriate.[43,72] Nonoperative open management has been shown to be at least as effective as primary closure, local and distant tissue-transfer flap procedures, and grafts.[44–51,73] Conservative management is advocated in children less than 12 years of age, as they have greater regenerative potential than do adults.[42] Anatomic classification schemes for the level of injury are multiple and make literature comparisons problematic. Therefore, it is best to describe injuries related to anatomic landmarks.

Amputations proximal to the lunula are less common. Those who address the issue specifically recommend shortening and primary closure without discussion or data. These injuries require emergent consultation for possible re-implantation. Injuries from the flexor digitorum profundus insertion to approximately the level of the mid-nail can be replanted if the amputated part is available.[52–54] The purpose of replantation is the restoration of cosmesis and function. The patient's perception may be that replantation will restore functional and cosmetic normality. Inform the patient that this is doubtful.

Conservative therapy usually provides acceptable preservation of contour and better salvage of two-point discrimination than grafts, is cheaper than replantation, is associated with a virtual absence of postsurgical infections, and limits joint stiffness. It is equivalent to other techniques in terms of functional use, preservation of length, and time absent from work. Moreover, eventual patient satisfaction may be even greater than with surgical techniques. Patients may have to be convinced that closure by secondary intention is both rational and, in fact, optimal. A set of photographs demonstrating this is often helpful.

Clean, prep, and anesthetize the finger. Fingertip amputations tend to bleed profusely. Achieve hemostasis with direct pressure using a nonadherent dressing while the hand is raised above heart level for several minutes. Do not remove the dressing if this is successful. Consider the application of sterile compression sponge covered with a nonadherent dressing and the application of pressure if the bleeding continues. Attempts at cauterizing bleeding vessels are usually unsuccessful because of the tissue's vascularity. Apply a sterile Penrose drain as a tourniquet, without excessive constriction, to provide a dry field if debridement of devitalized tissue is required.

The presence of protruding bone poses several treatment options. Some physicians rongeur any significantly protruding bone until it is flush with the wound surface and thereafter continue open treatment. There is no published evidence supporting rongeuring of protruding bone in adults. Anecdotal statements supporting this technique exist in texts.[45,51] Published reports support not shortening protruding bone in children under the age of 12.[49,55] Consider trimming the nail bed back to the bone margin if a remnant overhangs or is not supported by adequate bone.

Dress the wound with either a bulky hand dressing or tube gauze and a four-pronged disposable (metal or plastic) splint. There is no documented benefit for the use of topical or oral antibiotics. Refer all patients to a Hand Surgeon or primary care provider in 24 to 48 hours. Inform all patients of the 30% to 50% incidence of sensory impairment (i.e., diminished sensation, cold intolerance, and dysesthesia), impaired function, or cosmetic deformity.[44,46,50,51,56] Document this in the medical record. The possibility of a wound infection is very small with conservative treatment.[48,74] Healing may be prolonged if protruding bone is not debrided or if it is debrided at a later time.

ANIMAL BITES

Animal bites must be carefully explored to rule out underlying fractures, retained teeth, penetrated joints, tendon injuries, nerve injuries, and/or vascular injuries. Consideration must also be given to prevention or treatment of local bacterial infection, and prevention, recognition, and management of subsequent systemic illness.[57] Infections following a bite wound are polymicrobial. The most frequent bacteria isolated from infected dog and cat bites are *Pasteurella*, staphylococci, streptococci, and anaerobes. Human bites result in infections due mainly to anaerobes and less commonly staphylococci, streptococci, and *Eikenella corrodens*.[58,59]

Any bites to the hand, especially clenched-fist injury human bites, are the most likely to be complicated by infection. Human bites in other locations do not have higher rates of infection than other types of lacerations. *E. corrodens* is isolated from a significant percent of clenched-fist injury human bites, may cause a septic arthritis or osteomyelitis, and can be resistant to several commonly prescribed antibiotics (e.g., clindamycin and penicillinase-resistant penicillin).

Severe infections occasionally develop after bite wounds.[59] Consider the presence of *Capnocytophaga canimorsus* infection in dog bites, *E. corrodens* in human bites, and *Bartonella henselae* in cat bites with persistent lymphadenopathy and/or drainage. There are no prospective studies confirming the indications for repairing bite wounds. Primary closure with subsequent antibiotic therapy of head and neck wounds from dogs, cats, and humans have low infection rates in studies of small numbers of patients. Suturing head and neck lacerations within 6 hours of a dog bite, following a meticulous debridement and irrigation protocol, was successful without subsequent antibiotic use.[60] Therefore, some bite wounds can be safely closed primarily while others are left open for delayed primary closure (**Table 96-1**). The issue of closure applies only to wounds of cosmetic significance. Allow wounds without notable cosmetic significance to be left open for delayed primary closure or healing by secondary intention. **Do not primarily close puncture wounds, hand wounds, human bites, extremity wounds, wounds less than 2 cm in size, facial wounds more than 12 to 24 hours old, or nonfacial wounds more than 6 to 12 hours old. Limit the use of buried sutures, as they can increase the infection rate of a repaired bite wound.**

Preparation of the wound for closure is of the utmost importance. Obtain radiographs of the bite wound if there is the possibility of a fracture, a retained tooth, or penetration of a joint. Debride any devitalized tissue, compromised tissue, or dirty wounds. Gently scrub the surrounding skin, and not the wound, with povidone iodine, chlorhexidine solution, or soap and water. **Copiously irrigate the wound. Antibiotic coverage is no substitute for meticulous wound cleansing.** Refer to Chapter 92 for a complete discussion of wound irrigation principles and techniques. Some studies report

TABLE 96-1 The Repair of Laceration-Type Bite Wounds

Location	Dog bites	Cat bites	Human bites
Face	PC	PC	PC
Scalp	PC	PC	PC
Neck	PC	PC	PC
Trunk	PC if >2 cm DPC if <2 cm	PC if >2 cm DPC if <2 cm	PC or DPC
Arm	PC if > 2 cm DPC if <2 cm	PC if >2 cm DPC if <2 cm	PC if >2 cm DPC if <2 cm
Hand with foreign body, extensor tendon injury, joint capsule injury, or bone involvement	Hand Surgeon consultation, exploration, and intravenous antibiotics	Hand Surgeon consultation, exploration, and intravenous antibiotics	Hand Surgeon consultation, exploration, and intravenous antibiotics
Hand with only soft tissues involved	DPC or secondary closure	DPC or secondary closure	DPC or secondary closure
Leg	PC if >2 cm DPC if <2 cm	PC if >2 cm DPC if <2 cm	PC if >2 cm DPC if <2 cm
Foot	DPC	DPC	DPC

Key: PC, primary closure; DPC, delayed primary closure.

lower infection rates when wounds have been irrigated with a topical antibiotic.[61] However, this cannot be recommended as standard practice.

Bites to the hand require radiographs to rule out a fracture, retained teeth, or air in the joint cavity. Bite wounds, especially human bite wounds, involving a joint cavity or tendon require operative debridement and parenteral antibiotics. Bite wounds not involving a joint or tendon can be cleaned, debrided, splinted, watched expectantly on an outpatient basis, and treated with oral antibiotics.[62] Instruct the patient to keep the hand elevated and return in 12 to 24 hours for a reevaluation.

The use of antibiotics for an infected bite wound is beneficial. However, there is little concurrence regarding the routine use of prophylactic antibiotics. Data demonstrating effectiveness are limited. Differences in wound care, antibiotic regimens, and the severity of wounds make comparison of studies problematic. Prophylactic treatment should ideally allow infection rates to be less than 5%.[63] The only significant benefit that has been shown was for dog or cat bites of the hands.[57] As a result there is a trend toward benefit for the prophylactic antibiotic treatment of hand wounds and bites presenting more than 8 hours after the injury.[59,62,64]

High-risk wounds include puncture wounds (as opposed to laceration-type wounds), cat bites, bites to the hands, severe crush injuries, wounds in immunocompromised patients, and bites requiring surgical repair. The relative risk of infection can be reduced with prophylactic antibiotics (**Table 96-2**). Dog bites have the lowest associated infection rate of all bite wounds (5%-6%) which is similar to the rate found with lacerations from non-bite mechanisms.[57,59,62,64] Higher rates of infection in cat bites (60%-80%) may be due to the fact that a greater proportion of cats have narrower, sharper teeth than dogs, and thus the ability to deliver infectious agents deep into a small-bore puncture wound.[57] It is unclear whether all cat bites require prophylactic antibiotic treatment. It may eventually be proven that superficial laceration-type cat bites may not require treatment beyond irrigation and debridement.[65] Recommended treatment regimens for prophylaxis are 5 to 7 days for all bites with a beta lactam–beta lactamase inhibitor antibiotic (i.e., amoxicillin/clavulanate). Penicillin or ampicillin provides adequate coverage for *Pasteurella multocida* infections, and thus is a logical lower cost option for prophylaxis of cat bites. Penicillin-allergic patients can receive doxycycline or cefuroxime for cat bites, and clindamycin plus a fluoroquinolone for dog bites. Cephalexin, dicloxacillin, erythromycin, and clindamycin do not cover *Pasteurella* species and therefore should not be used alone.[57]

Immunoprophylaxis may be required. Administer tetanus immune globulin and tetanus toxoid as indicated. With any animal bite, consider rabies postexposure prophylaxis. In North America, bites from bats, raccoons, skunks, and foxes carry a special risk. Consult the local public health department for guidelines and the incidence of rabies in your community.

The discharge instructions are just as important as the Emergency Department management. Provide the patient with a written copy of a wound care sheet, regardless of whether the wound was closed primarily. Instruct the patient to elevate any involved extremity, even with antibiotic treatment.[66] Arrange follow-up within 24 to 48 hours for a reevaluation of the wound. Physical therapy following a hand infection may be required and initiated 3 to 5 days after the infection resolves.[59]

TABLE 96-2 Indications for Prophylactic Antibiotic Therapy for Bite Wounds

	Dog bites	Cat bites	Human bites
Puncture wound	Yes	Yes	Yes
Hand bites	Yes	Yes	Yes
Facial bites	No	Consider	No
Non-hand-laceration-type bites	No	Consider	No
Immunocompromised patients*	Yes	Yes	Yes
Surgical closure	Yes	Yes	Yes
Severe crush	Yes	Yes	Yes

*Immunocompromised includes patients with age > 50, diabetes, alcoholism, asplenia, and patients with any other illness associated with an impaired immune status.

DEBRIDEMENT OF GUNSHOT WOUNDS

The lack of primary literature on this subject makes it a controversial area. Wounds created by low-velocity bullets tend to cause damage only along the bullet track. Debridement is unnecessary for wounds created by bullets with muzzle energy of less than 400 foot-pounds, as many consider bullets to be sterile.[67] Devitalized and contaminated tissue are more likely to result from shotgun wounds and high-velocity bullets.[68] The shock wave created by the bullet damages tissue distant from the track of the bullet.[68] Consider these wounds for debridement.[68] The debridement of gunshot wounds requires exposure of the entire bullet track and treatment as a delayed closure, followed by referral for skin grafting if needed.

Clean, prep, and anesthetize the skin overlying the path of the bullet (or shotgun blast). Incise the wound with a #11 scalpel blade to expose the area. Sharply debride any devitalized and contaminated tissue. Repeated staged exploration should be undertaken at 24 and 48 hours to remove necrotic or devitalized tissues.[69] Treat with prophylactic antibiotics; cefazolin, 1 g intravenously every 8 hours, is satisfactory.[69] Treat the area with delayed closure techniques, giving priority to reestablishment of bony relationships, followed by soft tissue coverage.[69] Consider skin grafting for large areas of tissue destruction for adequate closure.

ABRASIONS

An abrasion is a skin wound created by tangential trauma to the epidermis and dermis. The skin is forced against an abrasive surface in a rubbing fashion and the resultant injury resembles a thermal burn. The goals of managing an abrasion include the prevention of infection, promotion of healing, and prevention of "tattooing" with retained foreign bodies. Large and heavily contaminated abrasions are best managed in the operating room, as the volume of local anesthetic required to achieve anesthesia would likely exceed toxic limits.

Prepare the wound. Anesthesia may be required prior to wound management. EMLA cream, which contains lidocaine and prilocaine, produces anesthesia of the intact skin but it must be in place for about 60 minutes in order to provide significant benefit.[70] Perform a field block or regional nerve block (Chapter 126) as appropriate. Large abrasions may be anesthetized by applying 5% lidocaine gel topically for 5 to 10 minutes. Remove any dirt or debris, using a sterile scrub brush and surgical soap (or saline). Consider imaging (i.e., plain radiographs) to evaluate for potential foreign bodies.[28] Use the tip of a #11 scalpel blade to remove deeply embedded and larger particles from the wound. Apply petroleum jelly or antibiotic ointment to remove embedded tar.[71] Apply an antibacterial ointment to the wound.

Instruct the patient to cleanse the wound three to four times a day. The wound may also be covered with petrolatum gauze and sterile gauze. Instruct the patient on how to properly cleanse the wound and reapply the bandage. Provide the patient with wound care supplies prior to discharge from the Emergency Department.

97 Subcutaneous Foreign Body Identification and Removal

Samuel J. Gutman and Michael B. Secter

INTRODUCTION

Wounds with retained foreign bodies are a frequent presenting complaint to Emergency Departments. Up to 38% of embedded objects are missed on the initial assessment.[1] Identification and removal of debris and foreign bodies promote optimal healing of traumatic wounds. **The presence of an unrecognized foreign body can lead to complications that include infection, pain, loss of function, joint injury, tenosynovitis, tendon rupture, and osteomyelitis.[2–5] Patients presenting with chronic, recurrent, or delayed skin infections should be assessed for the presence of an unrecognized foreign body.** Failure to diagnose and treat a foreign body is a common cause of litigation against Emergency Physicians. **The presence of a foreign body may not be obvious. A high index of suspicion and careful methodical examination, including appropriate imaging, must be undertaken to identify a foreign body.**

It is important to be familiar with the characteristics of different types of foreign bodies and the interactions they may have with a host patient. This information is crucial in determining the urgency or necessity of removal (not all implanted objects require removal), the appropriate imaging techniques, the approach to removal, and whether specialty referral is required. The removal of foreign bodies from subcutaneous tissue can be a frustrating and time-consuming endeavor when it is ill conceived. **The successful removal of a foreign body requires a directed history and physical examination, appropriate imaging, adequate light, anesthesia, exposure, hemostasis, patient cooperation, an uninterrupted time period for attempted removal, appropriate wound care, and assured postprocedural follow-up.**

ANATOMY AND PATHOPHYSIOLOGY

Only a small percentage of wounds actually contain concealed foreign bodies.[6] The mechanism of injury may give some idea of the likelihood of a retained object.[1] Crush wounds and puncture wounds, especially those involving the sole of the foot, as well as wounds deeper than 5 mm involving adipose tissue are associated with a higher incidence of foreign bodies that are often difficult to find.[6] Wounds caused by objects that shatter, splinter, or break in the process of causing injury have a higher risk of having a retained foreign body.[7] Lip or facial lacerations associated with dental fractures must be explored for pieces of teeth. Thorns, spines, or slivers tend to penetrate deeply and break. Broken-off needles are common foreign bodies in injection drug users. Objects greater than 4.5 mm in diameter that penetrate the skin may push fragments of epidermis deep into the wound producing an epidermal inclusion cyst, which can act as a foreign body.[8]

Depending upon the type of material retained and the physical form of the foreign object, excess inflammation may result. This can delay healing or destroy surrounding soft tissues. Retained organic foreign bodies trigger the most severe inflammatory reactions and can lead to chronic granulomatous reactions, periosteal reactions, osteolytic lesions, or severe infections such as necrotizing fasciitis.[8–10] The presence of soil in wounds markedly lowers the concentration of bacteria required to cause an infection by its interaction and interference with white blood cells.[11] Wounds tend to be resistant to antibiotics when a foreign body is present[2,3,12] and it may be impossible to eradicate the infection until the foreign body is removed.[2,3,12] Metals that oxidize may cause mild to moderate inflammation. Some retained foreign bodies, like lead, have the potential to produce systemic effects, especially when in contact with pleural, peritoneal, cerebrospinal, or joint fluid.[13] Inert objects with smooth, nonporous surfaces like glass or plastic elicit minimal tissue reaction. Retained foreign bodies that are not dissolved or extruded by the body's defenses become encapsulated, after which the inflammation will subside.[13]

HISTORICAL AND PHYSICAL ASSESSMENT

Patients presenting after an injury require a focused history including the details of the incident, the wounding agent, and the mechanism of injury. This information may suggest the presence of a retained foreign body and direct which imaging study is required.[14,15] Historical features that may signal unusual circumstances or difficult wound healing and management include diabetes, renal failure, immunosuppression, lymphedema, or peripheral vascular disease.[16] Past anesthetic history and the potential for aspiration should be assessed if procedural sedation is to be considered.[17] Medications and allergies should be queried. Assess the patient's tetanus immunization status. Provide booster doses and tetanus immune globulin as needed (**Table 92-2**).

A directed physical examination should begin with a brief inspection and documentation of the distal neurovascular status and function. An injured extremity must be carefully examined through a full range of motion to ensure the integrity of the tendons. Discoloration of the skin may suggest a foreign body.[8] Palpation may reveal superficial foreign bodies. Sharp localized pain with palpation over a puncture wound may suggest a retained foreign body. Adequate anesthesia, lighting, and good hemostasis are required to allow a thorough examination of the wound. **The examiner must avoid probing only superficially since the subcutaneous tissue can reapproximate and give the appearance of a superficial wound.** The wound edges should be extended with a scalpel to facilitate inspection if there is concern regarding a retained foreign body and direct visualization is difficult.

A retained foreign body can be ruled out with a negative predictive value of 96% for wounds less than 5 mm deep if the bottom of the wound is visible.[6] **Never insert a gloved finger to probe the wound cavity, as this can result in injury from sharp foreign bodies.** Gentle blind probing with a hemostat is an acceptable and preferred alternative. A grating sensation that can be appreciated by the examiner is produced if the probe strikes a metallic or glass foreign body. **Avoid blind grasping within a wound with a hemostat.** Direct visualization is preferable when examining wounds of the face, feet, or hands.

RADIOLOGIC ASSESSMENT

Imaging is indicated in most cases where a retained foreign body is suspected but not found during wound exploration, when thorough exploration of the entire wound cavity is not possible, or if the patient feels that there is a retained foreign body.

PLAIN RADIOGRAPHY

Most foreign bodies missed during the initial clinical examination can be seen on plain radiographs.[14] Plain radiographs are readily available. Some authors suggest radiographic evaluation of nearly any penetrating wound involving an extremity.[1,4,18] Standard anteroposterior and lateral radiographs should be performed using an underpenetrated "soft-tissue technique" to increase the contrast between the foreign body and the surrounding tissue.[3] Visibility of foreign material in

soft tissues is dependent upon its composition, relative density, configuration, size, and orientation.[19,20] Oblique and other views can be added to avoid superimposition of the object over bony structures. Radiopaque foreign bodies may be invisible if they are projected over or impacted within bone.[21] Metal, bone, teeth, pencil graphite, certain plastics, gravel, sand, and aluminum are all visible on plain radiographs.[3,20,22] Glass fragments have been thought to require lead or heavy metal content to be visible. However, glass fragments as small as 0.5 mm appear on two-view plain radiographs if not obscured by bone fragments; and glass fragments as small as 2 mm appear in the presence of overlying bone regardless of lead content.[23,24]

Organic materials and plastics are not reliably detected on plain radiographs. They may be indirectly shown as a radiolucent filling defect when the object is less dense than the surrounding tissue, making plain radiography worthwhile even in cases of suspected nonradiopaque foreign bodies.[25,26]

It is important to examine the entire radiograph for the appearance and location of an unexpected foreign body.[27] The evaluation can be terminated after adequate wound exploration and plain radiographs for a known radiopaque foreign body, if nothing is found. Other imaging modalities are required if there is a strong suspicion for a retained foreign body of the type that is not usually demonstrated on plain radiographs.

The advantages of plain radiographs include their universal availability, low cost, and familiarity to most Emergency Physicians. The disadvantages include the inability to resolve objects with densities similar to body tissues. Plain films do not demonstrate anatomic structures that may be intervening between the skin and foreign body along the planned surgical approach. It may be difficult to accurately judge the depth of a foreign body using two-dimensional radiographs.[8] Despite these drawbacks, standard radiographs remain the most clinically practical means of screening for foreign bodies.[19]

ULTRASOUND

Radiography alone is not sufficient to detect nonradiopaque foreign bodies. Bedside ultrasound has become available in many Emergency Departments. The lack of radiation exposure or harm to patients and its ease of use dictates an assessment with bedside ultrasound by the Emergency Physician as a screening tool when foreign bodies are suspected or not found on plain radiography.[28]

Many recent studies have shown ultrasonography to have a higher sensitivity for nonradiopaque foreign bodies than plain radiography.[28,29] High-resolution real-time ultrasound using a 7.5 MHz or greater linear array probe or transducer, in the hands of a skilled and experienced operator, can detect radiolucent superficial foreign bodies with a similar radiographic density as the surrounding tissue.[8,30–34] This can include wood, small glass fragments, fish bones, sea urchin spines, and other vegetative material.[8,34–38] Wood foreign bodies can act as a source for infection and should be evaluated with ultrasound in patients where radiographs are negative.[35] This is especially important in the Emergency Department where wood foreign bodies make up as much as 34% of all foreign bodies and plain radiographs have a sensitivity as low as 7.4% for organic material.[36] Patient perception of a retained foreign body and the use of bedside ultrasound can localize a retained object with a sensitivity of 88.9% and a specificity of 76.5%.[37] One study showed that the accuracy of detection was above 80% for radiolucent objects by ultrasound technologists, Radiologists, and Emergency Physicians.[38]

Ultrasound has the ability to localize a foreign body within three dimensions, thus helping to establish its relation to adjacent bone, muscle, tendons, and tendon sheaths.[32] Preoperative ultrasound results in less damage to the surrounding tissues, reduced operative time, and reduced postoperative morbidity.[32,39]



FIGURE 97-1. A sonographic image of a subcutaneous thorn. The foreign body is hyperechoic (white) with an acoustic shadow deep to it.

The procedure for locating a subcutaneous foreign body with ultrasound begins with selecting the highest available transducer frequency.[40] Higher frequency transducers have better resolution for superficial structures. The use of a standoff pad or gel filled glove (with the air and talc carefully removed) can act as a dead zone for objects that would normally be too superficial to fall within the focal zone of the transducer.[41,42] Adjust the focus to the required depth and proceed to scan the field in two orthogonal planes.[40] The scanning beam must be oriented parallel to the long axis of a hemostat, which can be directed toward the long axis of the foreign body.[31] Please refer to Chapter 98, Ultrasound-Guided Foreign Body Identification and Removal, for more complete details.

The sonographic appearance of foreign bodies is related to the surface characteristics and not its composition.[43,44] Metals and needles are often hyperechoic with reverberation artifact or comet tails. Gravel is usually hyperechoic and shows dense posterior acoustic shadowing. Organic materials such as wood have a characteristic appearance and are ideal for ultrasonographic evaluation. Wood is most often hyperechoic with a posterior acoustic shadow (**Figure 97-1**). Furthermore, the foreign body is often surrounded by a hypoechoic halo[37,42,44] (**Figure 97-2**). This is



FIGURE 97-2. A sonographic image of several shards of glass in the palm. Note the hyperechoic (white) foreign bodies surrounded by an echo-poor (black) signal consistent with either a hematoma or edema.

frequently a zone of edema, granulation tissue, or abscess.[40] While this hypoechoic halo can represent an inflammatory response, it may not be visible within 24 hours of the wound.[35] Doppler ultrasound shows a hypoechoic (black) ring around a hyperechoic (white) foreign body. Doppler also shows marked hyperemia around the periphery of a foreign body, something considered to be a reliable secondary sign.[45]

Once a foreign body has been located on ultrasound, both ends of the object should be marked.[46] This is often done by inserting paperclips between the skin and the transducer and connecting both ends with a marked dotted line. Meticulously scan along the entire length of the suspected object and also visualize the foreign body perpendicular to the transducer.

There are several disadvantages when using ultrasound, including the level of skill required for its use in diagnosing musculoskeletal foreign bodies.[46–49] Studies assessing the accuracy of ultrasound have shown a sensitivity of 30% to 100% and a specificity of 70% to 90%.[49] These values have been mostly demonstrated in referred patients studied by Radiologists and certified technicians.[50,51] Ultrasound by Emergency Physicians has a specificity of only 59% under conditions that replicate a typical Emergency Department situation.[51] Another disadvantage is that false positives can occur with tendons, old scar tissue, calcifications, fresh bleeding, sutures, air in wounds, sesamoid bones, ossified cartilage, or keratin plugs.[8,35,42] Ultrasound localization may also be difficult if the object is close to bone or deep to subcutaneous gas.[43] **As such, Emergency Physicians with a high suspicion for a retained subcutaneous foreign body not identified by bedside ultrasound should request a formal diagnostic imaging study.**

COMPUTED TOMOGRAPHY (CT) SCAN

CT imaging should be requested in cases where radiography and ultrasonography have failed to demonstrate suspected foreign bodies such as nonradiopaque material or those that cannot technically be located by ultrasound due things like overlying bone or gas.[52] CT is valuable because it is more sensitive in differentiating densities and thus is capable of detecting more types of foreign bodies.[14,53–56] The modality can also be used in high-risk wounds when there is potential for infection or joint involvement. CT images can be created in multiple planes and can demonstrate the relationship of a foreign body to important anatomic structures.[53,57] CT-guided percutaneous placement of a catheter or needle can guide surgical dissection to a foreign body, aiding in the subsequent removal.[53,57] The disadvantages of CT scanning include its higher cost, radiation dosage, the need for patient cooperation, and availability. Additionally, organic foreign bodies become less visible over time due to absorption of body fluids.[28]

MRI

MRI appears to be more accurate than any other modality for identifying wood, glass, plastic, spines, and thorns.[14,53] It is superior to CT scanning in detecting the presence and extent of edema, hemorrhage, and infection surrounding foreign bodies.[14,53] Wood foreign bodies often show linear hypointensity with an associated surrounding inflammatory response.[28] MRI's other advantages include the high resolution and contrast between adjacent tissues. It allows the precise localization of foreign bodies in three dimensions to aid in surgical planning and assessment of the need for advanced exploration, debridement, and irrigation. It does not expose the patient to any radiation.[58]

The disadvantages of MRI include its lack of availability and high cost. Patients must be assessed to rule out a magnetic foreign body due to the risk of movement of the foreign body during MRI scanning.[59] Prior history of an ocular or other metallic foreign bodies must also be sought prior to MRI scanning to prevent iatrogenic injury. This requires a thorough screening history and plain radiographs prior to MRI scanning. Gravel and ferromagnetic substances produce significant artifact.[14] Differentiating scar tissue, tendons, and calcifications from an actual foreign body can be challenging.[60] MRI is better suited to evaluate the complications of foreign bodies and is not used routinely in the Emergency Department.

INDICATIONS

Every effort should be made to identify foreign bodies, even if they are not likely to be removed. It must be decided whether a foreign body needs to be removed immediately, electively, or at all once identified. Factors that influence the decision to proceed with attempted removal include the size and reactivity of the foreign body, its proximity to vital structures, and associated injuries. These must be weighed against the potential for further tissue damage and contaminating the wound.

A foreign body requires immediate removal if it is likely to provoke significant tissue inflammation or injury.[3,61,62] Contaminated objects such as teeth, soil, or foreign bodies located in the presence of an established infection should be immediately removed.[3,11] Allergenic foreign bodies, toxic foreign bodies, or those causing hemorrhage or ischemia should be immediately removed.[3,62] Foreign bodies interfering with sensory or motor function, or having the potential for migration, should be urgently removed.[3] Foreign bodies in the hands and feet usually require removal as they may cause persistent pain and can sever nerves or tendons much later.[5] The foreign body may require removal for cosmetic or psychological reasons in some cases.[1]

CONTRAINDICATIONS

The foreign body should be urgently removed under ideal conditions by an appropriate Surgeon when it is associated with a neurovascular injury or is located near tendons, nerves, or blood vessels.[1,3] Deep exploration of the hands or feet should be avoided to prevent injuring the intricate structures. Large, deep, and impaled foreign bodies are assumed to be tamponading hemorrhage, should initially be left in place, and urgently removed in the Operating Room.[27] Foreign bodies associated with fractures or located within a joint require prompt surgical debridement to prevent osteomyelitis or septic arthritis.[62] Urgent surgical intervention is required for all high-pressure injection injuries. These injuries may initially appear innocuous but often cause extensive damage and carry a significantly high risk of complications.[62] Consider referral based on one's own experience, anticipated problems related to the foreign body's location or depth of penetration, the duration of retention, or other patient factors likely to complicate the procedure or follow-up.

A deeply embedded, inert object not near any vital structures can be left in place. The difficulty of removal is usually not worth the potential tissue damage. These patients can be referred for elective removal, if necessary.[1,62] **If the decision is made not to remove a foreign body, the patient must be informed and the issues discussed including the potential for migration and infection. Document this discussion in the medical record.**

EQUIPMENT

- 18 gauge needles
- 27 gauge needles
- 10 mL syringes
- Povidone iodine or chlorhexidine solution

- Lidocaine (1%) with and without epinephrine
- Topical 4% liposomal lidocaine
- Depilatory wax, rubber cement, or hardening facial gel
- #11 scalpel blade on a handle
- #15 scalpel blade on a handle
- Nylon suture, 1-0 or 2-0
- Methylene blue
- Paper clips
- Wire grid
- Eye magnet
- Hemoclips
- Hemoclip applier
- Fluoroscopy unit
- Hemostats, two sizes
- Forceps
- 22 gauge needles for foreign-body localization
- Magnification eye loupes
- Normal saline
- 19 gauge blunt-tip needle or angiocatheter
- 35 mL syringe
- Blood pressure cuff or Penrose drains
- 4 × 4 gauze squares
- Adhesive tape
- Bedside ultrasound with high frequency transducer
- Standoff pad or gel filled glove

PATIENT PREPARATION

Foreign body removal can be frustrating and time consuming, even when performed under ideal conditions. It is appropriate to set a time limit that is reasonable based upon the staffing and volume of the Emergency Department. Approximately 10 to 30 minutes is appropriate to find and remove an embedded foreign body. Inform the patient of the planned time limit at the outset. The search should be discontinued and the patient referred to a Surgeon after expiration of the predetermined time.

Apply povidone iodine or chlorhexidine to the skin site surrounding the wound. Avoid spilling the solution into the wound cavity as both are toxic to wound defenses and may increase the incidence of a subsequent wound infection.[12] Obtain a bloodless field for the examination. Place a blood pressure cuff proximal to the injury. Elevate the extremity for at least 1 minute and then inflate the cuff to a pressure greater than the patient's systolic blood pressure. Although it will cause some discomfort, this is safe for up to 2 hours.[63] A local vasoconstrictor can be used with the anesthetic to control localized capillary bleeding if no contraindications exist. A 0.25 to 0.50 in. Penrose drain can be wrapped tightly around a finger or toe and secured in place with a hemostat.

Adequate anesthesia is crucial to the procedure. A field block or regional nerve block, depending upon the location of the foreign body, best accomplishes anesthesia without distorting the wound further by local infiltration.[64] Consider using topical anesthetics in the pediatric population. Liposomal lidocaine (4%), for example, has a very fast onset and is associated with higher success rates, reduced procedure time, and less pain.[65,66] The techniques of topical and regional anesthesia are described in Chapters 124 through 127. Procedural sedation (Chapter 129) or general anesthesia may be required, especially in children where cooperation may not be otherwise possible.

TECHNIQUES

SUPERFICIAL WOOD OR ORGANIC SPLINTER REMOVAL

Very fine foreign bodies can be difficult to visualize. One method to help localize them is to spread soft soap very lightly over the skin.[67] Only superficial organic splinters and foreign bodies should be pulled out with forceps as they often come apart leaving a fragment that is more difficult to remove.[3,68] Occasionally, cactus spines or wood splinters lie superficial and parallel to the skin surface. Make an incision parallel to the long axis of the foreign body and then lift it out of the wound. Enlarge the skin entrance wound with a scalpel so that the foreign body can be grasped and withdrawn with a hemostat under direct visualization if it is lodged in the subcutaneous tissue.

Small cactus spines may be difficult to locate and remove directly. Application of a depilatory wax, rubber cement, or a water-soluble facial gel with a brush can successfully aid in the removal of small fine spines.[61] Apply the wax, rubber cement, or facial gel over the skin containing the protruding spines. Apply a layer of gauze over the wet substance. Allow the substance to dry onto the skin and the gauze. Remove the gauze to lift off the dried substance and attached spines. Repeat this process as required to remove the remaining spines.

PUNCTURE WOUNDS

Puncture wounds of the foot are commonly seen in Emergency Departments. Punctures frequently, drive pieces of clothing, shoes, or other debris deep into the wound resulting in an infection rate of approximately 10%.[69,70] Although technically difficult, puncture wounds in the distal foot may profit from debridement and irrigation.

Puncture wounds can be trimmed or ellipsed to remove contaminated and/or embedded foreign bodies (**Figure 97-3**).[3] This

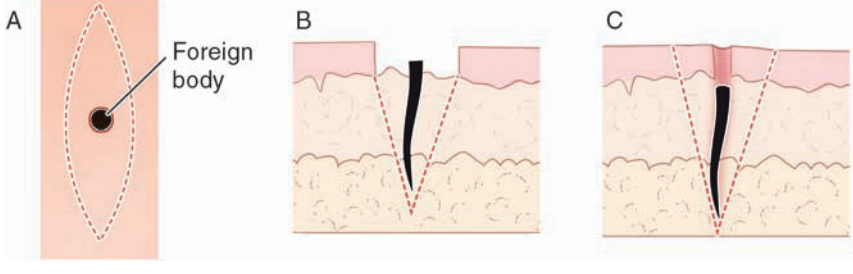


FIGURE 97-3. Creating an ellipse to remove a contaminated or embedded foreign body. **A.** An ellipse is made in the skin surrounding the foreign body. **B.** The epidermis is removed to expose the foreign body. A block of subcutaneous tissue (dotted line) can be removed if the foreign body is difficult to visualize. **C.** The skin, the subcutaneous tissue, and the foreign body can be removed en bloc.

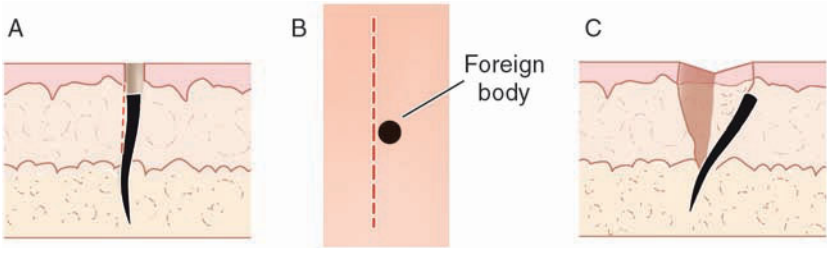


FIGURE 97-4. Removal of a foreign body embedded perpendicular to the skin. **A.** The embedded foreign body. The dotted line represents the proposed incision line. **B.** A linear incision is made 1 mm lateral to the foreign body. **C.** The incision is spread open to visualize and remove the foreign body.

technique also works well for foreign bodies that are difficult to localize. Make an ellipse in the skin surrounding the foreign body with a #15 scalpel blade (**Figure 97-3A**). Lift up the ellipse of skin and separate it from the underlying dermis (**Figure 97-3B**). The foreign body may be visible. Grasp it with a hemostat or forceps and remove it from the tissue.

If unable to exactly localize the object, the foreign body and the ellipsed puncture wound can both be extracted in a block of tissue (**Figure 97-3B**, dotted line).[64] **First ensure that no nerves, blood vessels, or tendons will be injured.** Alternatively, make the skin ellipse and extract the block of tissue containing the foreign body without dissecting the skin from the subcutaneous tissue (**Figure 97-3C**). Both techniques allow for the removal of foreign bodies and better cleaning of the wound. Puncture wounds of the foot require careful follow-up due to the risk of infection.

There are several alternative techniques if removing an ellipse of skin and/or tissue is contraindicated or if the Emergency Physician is not comfortable with this technique (**Figures 97-4 & 97-5**). A foreign body may be embedded perpendicular to the skin (**Figure 97-4A**). Make a linear incision that passes 1 mm to the side of the puncture wound with a #15 scalpel blade (**Figures 97-4A & B**). Spread the incision open. Visualize the foreign body, grasp it with a hemostat, and remove it.

The final technique of removing a foreign body from a puncture wound involves making a superficial skin incision and manually expressing the foreign body (**Figure 97-5**). Make an elliptical incision surrounding the foreign body or a linear incision over the foreign body (**Figure 97-5A**). Remove the ellipse of skin or spread the linear incision. Undermine the subcutaneous tissues surrounding the foreign body (**Figure 97-5B**). Apply digital pressure over the undermined areas to displace the foreign body into the center of the wound and upward (**Figure 97-5B**). Grasp the foreign body with a hemostat and remove it.

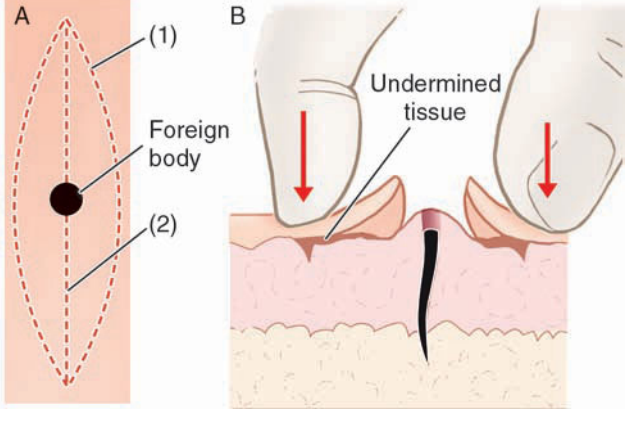


FIGURE 97-5. An alternative technique to remove a foreign body from a puncture wound. **A.** Incise and remove an ellipse of epidermis (1). Alternatively, make a linear incision centered over the foreign body (2). **B.** Undermine the subcutaneous tissue surrounding the foreign body. Apply digital pressure (*arrows*) to visualize and express the foreign body.

NYLON SUTURE LOCALIZATION

One technique described for use in fresh wounds involves the localization of a foreign body by marking its entry tract with a nylon suture.[71] Grasp a piece of 1-0 or 2-0 nylon suture between the thumb and index finger. Rotate the suture while pushing it into the wound so that it follows the tract made by the foreign body. It is reported that the foreign body is easily felt when the nylon contacts the foreign body.[71] Leave the suture in the wound tract. Open the wound tract by cutting alongside the nylon suture until the foreign body is reached, at which time it is removed. A 92% success rate up to 48 hours after the time of injury has been reported with this technique.[71]

GEOMETRIC APPROACH FOR A NEEDLE IN THE FOOT

A technique that is useful for the removal of a needle in the plantar surface of the foot involves the use of standard anterior, posterior, and lateral radiographs to identify the cutaneous site corresponding to the location of the needle.[72] The incision site is determined by bisecting the midpoint of the needle, as seen in each projection, by a line drawn at right angles to the long axis of the needle. The ideal plane of dissection is perpendicular to the needle's midpoint, which is correlated with the surface anatomy of the foot.

Prepare and anesthetize the skin after determining the dissection plane. Make a 0.5 to 1.0 cm skin incision in the plane perpendicular to the needle in its midpoint. Advance an iris scissors into the incision and along the dissection plane with the blades slightly open. Advance the scissors 1 to 2 mm and close the blades. Withdraw the scissors slightly. Open the blades of the scissors, advance them 1 to 2 mm, and close the blades. **Care must be taken to avoid cutting the flexor tendons, although they are located deep and in close association to the bones of the foot.** Continue this process of advancing and closing the blades until the needle prevents closure of the scissors. Advance a hemostat into the wound and over the blades of the scissors. Grasp and secure the needle. Pull the hemostat out of the wound to simply back the needle out of its entry tract. This procedure is reported to have a 100% success rate and takes approximately 10 minutes.[72]

DYE LOCALIZATION

Methylene blue may be used to track the location of a foreign body.[73] Identify the presence of a needle or foreign body on plain radiographs. Clean and prepare the skin. Sterilely inject 0.1 to 0.2 mL

of methylene blue very gently through the entrance wound of the foreign body. The dye will travel along the path of least resistance, that is, the path of the foreign body. Make an A-, U-, V-, or Y-shaped incision from the point of entry and raise a flap of tissue. The blue dot of dye serves as a guide to the location of the foreign body. This procedure is often complicated by seepage of dye and is therefore of limited value.

PAPER CLIP X-RAY LOCALIZATION

Simple paper clips may be used to locate a foreign body.[74,75] Obtain plain radiographs to demonstrate the presence of a radiopaque foreign body. Bend two or more paperclips into different shapes. Place the ends over the wound entry site. Secure the paper clips in position with tape. Obtain two plain radiographs taken at right angles to each other. Examine the radiographs to determine the cutaneous location of the foreign body in relation to the paper clips and note its depth from the skin surface. Mark the exact cutaneous location of the foreign body on the patient's skin with a permanent ink pen. Remove the paper clips.

Clean, prepare, and anesthetize the skin. Make a stab incision at a 90° angle to the middle of the foreign body, taking the shortest distance between the skin and the foreign body, and following the method discussed for the geometric approach for a needle in the foot. Insert a small hemostat into the incision. Advance the hemostat allowing localization of the object with minimal probing. Grasp and remove the foreign body.

WIRE GRID LOCALIZATION

This technique follows a similar approach to the paper clip method.[76] Place a wire grid over the skin. Obtain radiographs in two planes to locate the object within the grid system. Mark the skin and remove the grid. Remove the foreign body as discussed for the paper clip technique.

NEEDLE GRID LOCALIZATION

The grid principle may also be used to remove superficial and nonlinear radiopaque foreign bodies after they have been identified on plain radiographs. Clean, prep, and anesthetize the skin. Insert three 25 gauge, 1.5 in. needles into the skin near the estimated location of the foreign body and at right angles to each other. Obtain two orthogonal plain radiographs. This process can be repeated, each time moving the needles slightly until one is superimposed on the foreign body. Determine the cutaneous position of the foreign body by noting its position within the needle grid. Mark this position on the skin. It must be remembered that this technique does not provide a true three-dimensional image since divergence and parallax distortion of images occur on the radiographs.[3]

The Emergency Physician must recall that tendons and other structures may block the planned path to the object.[7] Make a 0.5 to 1.0 cm incision in a plane perpendicular to the long axis of the foreign body to an appropriate depth or dissect along the path of the closest needle.[27] Identify and remove the foreign body. A drawback of this technique is the potential for dislodging of the needles with attendant repeated trips to the Radiology Department. The use of a portable fluoroscopy unit will prevent this problem.

Another similar technique involves the placement of three to four needles of different gauges at 90° to each other in the anesthetized subject.[77] Obtain repeat radiographs to identify which needle is closest to the object. Remove all but the closest needle. Make an incision down to the estimated depth where the foreign body is located. Identify and remove the foreign body.

EYE MAGNET

Another technique reported to have a good success rate in removing metallic foreign bodies utilizes a hand-held eye magnet.[78] Confirm the presence of a radiopaque foreign body with plain radiographs. Prepare, drape, and anesthetize the area. Slightly enlarge the entry wound to permit entrance of the magnet tip. Apply a sterile ultrasound probe cover or glove over the magnet. Gently probe the wound track with the magnet until a "click" is appreciated. Withdraw the magnet with the foreign body attached to the magnet. Perform further and more directed wound exploration with the magnet if resistance is met. This technique is likely of limited value.

TAGGED HEMOCLIPS

It can be difficult to find foreign bodies once the dissection actually begins since the tissues may be distorted by retraction, edema, or local anesthesia; even with the most elaborate marking system using grids or needles. The tagged Hemoclip method was developed to address this problem.[79] It requires a skin incision and dissection down to where the physician believes the foreign body to be, based as observed on plain radiographs. Prepare two or three Hemoclips with a long silk suture attached to each one. Place them into the Hemoclip applier. Dissect down to where the foreign body is believed to be located. Place two or three Hemoclips into the depths of the wound. Obtain repeat radiographs to show the relationship of the foreign body to the Hemoclips. Remove all but the closest Hemoclip. Dissect towards the Hemoclip and the foreign body. Identify and remove the foreign body. Remove the Hemoclip. If the foreign body is not readily found, repeat the procedure after placing two or three additional Hemoclips. Follow the trail of Hemoclips to the foreign body.

ULTRASONOGRAPHIC REMOVAL

There are a multitude of different approaches to the ultrasound-guided removal of subcutaneous foreign bodies.[37,40–42,46,80] A detailed working knowledge of the pertinent anatomy is essential. Locate and mark the location of the foreign body. Clean, prep, and anesthetize the skin. Insert a needle under ultrasonographic guidance. The ultrasound monitor screen will display a hyperechoic linear object with posterior reverberation effect. Guide the needle under ultrasound until it touches the foreign body. Make a skin incision down to the foreign body. The addition of a second needle in a perpendicular plane can enhance the objects localization.[41] Inset a closed hemostat to approach the foreign body.[41,80] Ideally, the hemostat should be inserted along the plane of the foreign body. Open the jaws of the hemostat under sonographic guidance to reveal two echogenic structures, the jaws of the hemostat, with posterior reverberation effect. Once the object is within the hemostat's grasp, it can be removed under sonographic guidance. Always rescan the area after the foreign body is removed in order to ensure that no additional fragments remain. Patients should be instructed to return if there are any signs of infection.[46] A more detailed description of ultrasound-guided foreign body removal is available in Chapter 98.

FLUOROSCOPIC TECHNIQUES

Fluoroscopy offers an excellent aid in the removal of radiopaque foreign bodies.[81] Make an incision over the foreign body as judged from plain radiographs. Localize the foreign body under fluoroscopy. Guide a curved hemostat to the foreign body with brief intermittent exposures of the fluoroscopy unit.[82] Grasp and remove the foreign body. This procedure exposes the operator's hands to radiation and may risk damaging structures in the wound by blind manipulation of the hemostat.[83]

The grid and needle localization techniques described previously can be applied under fluoroscopy. Rotate the site of injury under the fluoroscope to visualize the foreign body between the markers. This may improve the ability to judge the location of the foreign body in three dimensions and aid in its removal. Intermittent exposure with a fluoroscope can allow repositioning of the needles until the foreign body is localized between two needles or at the tip of a single needle. Make a small incision carried down to the foreign body and remove it.[83,84]

Additional techniques using fluoroscopy and neurosurgical stereotactic devices have been described.[3] The cost, availability, and practicality make these approaches unattractive in the Emergency Department and are therefore not discussed further.

AFTERCARE

It is often prudent to take postextraction radiographs to ensure complete removal of the foreign body, especially if multiple objects are involved or if there is concern about the object fragmenting.[77] Carefully irrigate and debride the wound of all epidermal fragments.[3] The most effective form of wound preparation and cleansing is jet lavage irrigation with normal saline to decrease the bacterial load in the wound and the risk of developing infection.[85] This can be performed with a commercially available device or a 35 mL syringe armed with a 19 gauge angiocatheter or blunt needle.[12] Studies of simple pediatric wounds has found that using drinkable tap water to irrigate wounds is a good alternative to saline, as it shows similarly low infection rates.[86] The quality of mechanical cleaning is important to wound prognosis.[1] Clean, thoroughly irrigated, and debrided wounds with a good blood supply do not require antibiotics and may be sutured closed after removal of the foreign body. Patients should be followed up in 5 to 7 days for suture removal.

If complete cleansing of the wound is not assured or if the wound is at significant risk for infection for other reasons, delayed primary closure or healing by secondary intention should be considered.[12,87] Delayed primary closure involves packing the wound open for 4 to 5 days, after which it is reassessed and closed primarily if the edema has resolved, no infection is present, and exudate has been removed. This technique results in minimal tissue damage. It is especially useful in clean contaminated and contaminated wounds, achieving a 90% success rate in appropriate patients.

Antibiotic therapy may be considered in those with wounds that are at significant risk for infection. **But, antibiotics are not a replacement for proper wound care.** Infection rates for traumatic wounds range from 4.5% to 6.3%. Those patients who are immunocompromised, have puncture wounds, crush injuries, open fractures, bites, burns, frostbite, or wounds that involve tendons and cartilage as well as those wounds contaminated with feces, soil, saliva should be considered high risk and should be considered for antibiotic therapy.[88,89] Close follow-up is especially important in these patients. Prophylaxis for endocarditis is not recommended unless foreign body removal is undertaken through an area of an established infection.[90] Splint the involved extremity if the foreign body is near a joint, a highly mobile region, or a vital structure to prevent injury and/or migration of the foreign body if the patient is referred for delayed removal.[8] A more complete discussion on wound cleansing, wound irrigation, and the general principles of wound management can be found in Chapter 92.

TETANUS PROPHYLAXIS

Tetanus prophylaxis must be considered for wounds involving foreign bodies. Wounds contaminated with feces, soil, or saliva, puncture wounds, avulsions, and wounds resulting from missiles, crushing, burns, and frostbite are considered to be tetanus prone. Recent studies have found that up to 26% of those patients reporting they were up to date with tetanus vaccination were confirmed not to be, while a further 30.2% were indeterminate.[91] In the Emergency Department, it is vital to investigate a patient's tetanus status and vaccinate according to the accepted guidelines.[40,92] For patients who have had three or more doses, those who received their previous dose within 5 to 10 years presenting with a nonclean and minor wound should receive the Tdap booster (preferred over the Td booster). Those patients who have gone more than 10 years since their last dose should also receive the booster regardless of wound type. All patients who have fewer than three doses or an uncertain vaccination history should receive the vaccine booster. Of these patients, those with complicated or contaminated wounds (such as those due to a puncture) should receive the tetanus immunoglobulin (TIG) in addition to the vaccine booster.[92] Please refer to Chapter 92 for more complete details regarding tetanus prophylaxis.

COMPLICATIONS

The removal of embedded foreign bodies is relatively free of complications if properly conceived. **Care must be taken to document the functional and neurovascular status prior to and after any significant manipulations.** Appropriate referral of complicated cases, including those with foreign bodies located deep in the hands, the feet, or near vital structures will lessen the risk of unfavorable outcomes. Infection remains the most common complication of a retained foreign body, even when the object itself is not contaminated. Aseptic technique and avoidance of excessively prolonged manipulation and searching for embedded foreign bodies are important to prevent introducing infection into a previously sterile area. In cases where the foreign body cannot be found, it may be necessary, although less than ideal, to wait for abscess formation in order to pinpoint the location of an object at a later time.[3] Referral for additional imaging and removal may be appropriate. The patient must be advised in detail of the likely course, and follow-up must be assured and documented.

SUMMARY

Virtually all embedded subcutaneous foreign bodies should be identified and located with rigorous assessment of each and every traumatic wound and a high index of suspicion. The history and physical examination should guide the search for retained foreign bodies and the approach to locating them. The majority of foreign bodies are visible on plain radiographs. Wounds for which a radiopaque foreign body may be retained should be imaged with standard radiographs utilizing a soft tissue technique. Bedside ultrasound should be utilized to assist in the identification and removal of subcutaneous foreign bodies. Additional diagnostic imaging with CT, ultrasound, or MRI may be indicated if the suspected foreign body is likely to be radiolucent or is not adequately identified. Once identified and located, several techniques are available to aid in localization and removal. A decision must be made regarding the necessity of immediate or urgent removal in the Emergency Department or by referral to a specialist. Inert foreign bodies that are unlikely to cause long-term complications may be left in situ with information provided to the patient explaining the reasoning behind this conservative approach. Appropriate wound care is crucial to satisfactory healing, and postprocedure follow-up must be assured.

98 Ultrasound-Guided Foreign Body Identification and Removal

Daniel S. Morrison

INTRODUCTION

Retained foreign bodies are associated with up to 1.9% of all wounds.[1] The presence of a foreign body in a wound increases the incidence of a wound infection.[2] Retained foreign bodies are also a major cause of litigation against Emergency Physicians.[3,4] A high index of suspicion for a retained foreign body must be maintained whenever there is the potential for a foreign body in a wound.[5,6] This chapter focuses on ultrasound-guided identification and removal of subcutaneous foreign bodies.

Foreign bodies may be small, leave no skin entry marks, and consist of many different types of material. Almost any object (solid, liquid, or gas) can become a foreign body and present itself in a location where it should not reside. Standard radiographs and fluoroscopy are good at identifying radiopaque objects such as metal, gravel, and glass.[7–13] The ability of these techniques to identify a foreign body varies by the size and composition of the foreign body.[9] MRI and CT are useful to detect foreign bodies.[12,14,15] These are expensive imaging modalities and the images vary depending upon the length of time the foreign body has been present.[15] Certain foreign bodies may produce artifacts that diminish the MRI and CT image qualities.[12] Plastic, hair, vegetative material, and rubber are not radiopaque and are not routinely identified on radiographs.[6–8,10–13,16–18] Ultrasound (US) is able to identify radiopaque foreign bodies. US can also detect foreign bodies that are not radiopaque due to their different echotextures in relation to surrounding structures.[6,8,14–30]

ANATOMY AND PATHOPHYSIOLOGY

Foreign bodies can be present in almost any part of the body. Foreign bodies can be detected with US even when they are found in nontraditional places. They have been identified in the eye,[31] esophagus,[29] and tongue[32] with US. Foreign bodies isolated to small spaces, such as in the web spaces of the hand, may not be identified due to the size of the US probe footprint and the difficult anatomic location to scan.[26]

Not diagnosing foreign bodies can be dangerous for the patient and lead to an increased risk of complications. Legislation to introduce an aluminum penny into circulation in the United States in 1973 was defeated in part by Pediatricians and Pediatric Radiologists concern that these new coins would not be easily identified on radiographs.[33] Patients with retained lead foreign bodies can have statistically significant elevated blood lead levels as compared with matched controls.[34]

Foreign bodies have specific US characteristics. Smooth and flat surfaces typically produce a dirty shadowing or reverberation artifact.[35,36] Irregular surfaces with a small radius or curvature produce a more clean shadow (**Figure 98-1**). Glass and metal typically produce a ring-down or reverberation artifact[11,23,28,29,35,37] (**Figure 98-2**). A wood foreign body produces a bright echogenic reflection with a strong acoustic shadow[6,11,29,38] (**Figure 98-3**). Foreign bodies residing in soft tissue longer than 24 hours can cause an inflammatory reaction, which creates a hypoechoic rim around the echogenic foreign body (**Figure 98-4**).[35]

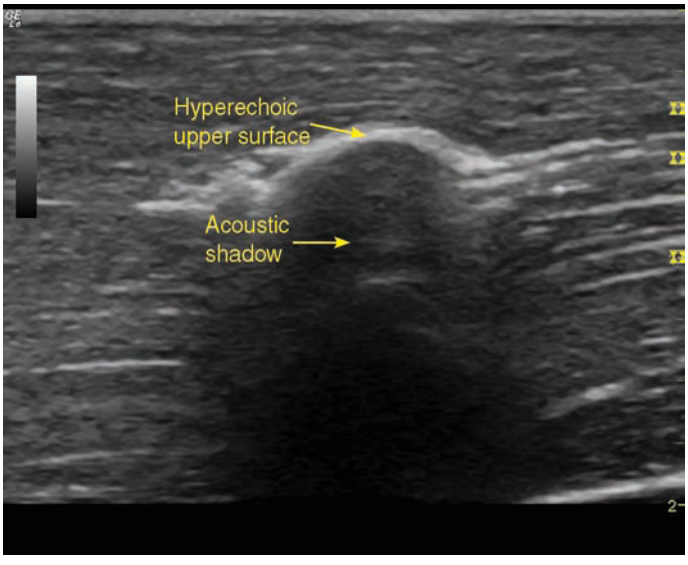


FIGURE 98-1. US image of a subcutaneous pebble. Notice the hyperechoic short radius and tight curvature. The pebble casts a strong acoustic shadow as it blocks transmission of the US beam.

INDICATIONS

Patients with a foreign body sensation or soft tissue mass should be considered to have a foreign body until ruled out.[5,16] Foreign bodies can migrate great distances from the original insertion site requiring the Emergency Physician to maintain a high index of suspicion for a foreign body.[39] Any patient in which the Emergency Physician has any index of suspicion for a foreign body should have additional investigations. Wood, thorns, spines, vegetative foreign bodies, dirt, clothing, and heavily contaminated foreign bodies should be removed immediately, as should those with potential for migration or entrance into the systemic circulation. It is generally believed that glass, metal, and plastic are inert and can be removed electively as they tend to be encysted by scar tissue. Their removal is dependent on the specific situation, physician preference, and patient characteristics. Patients who have

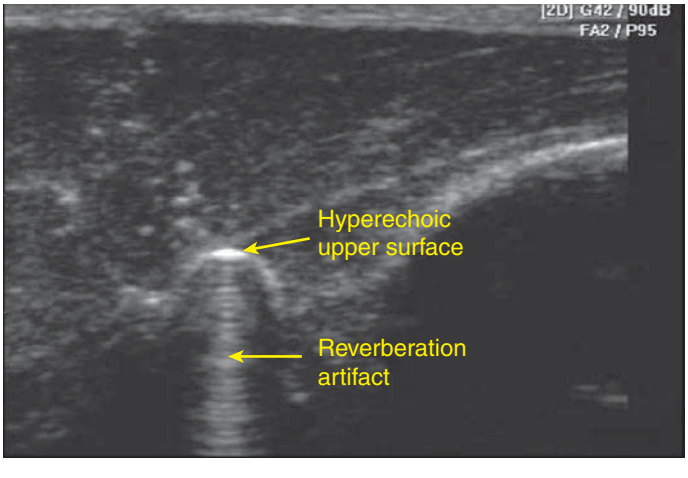


FIGURE 98-2. US image of a subcutaneous metallic BB. The BB is hyperechoic and produces a reverberation artifact.

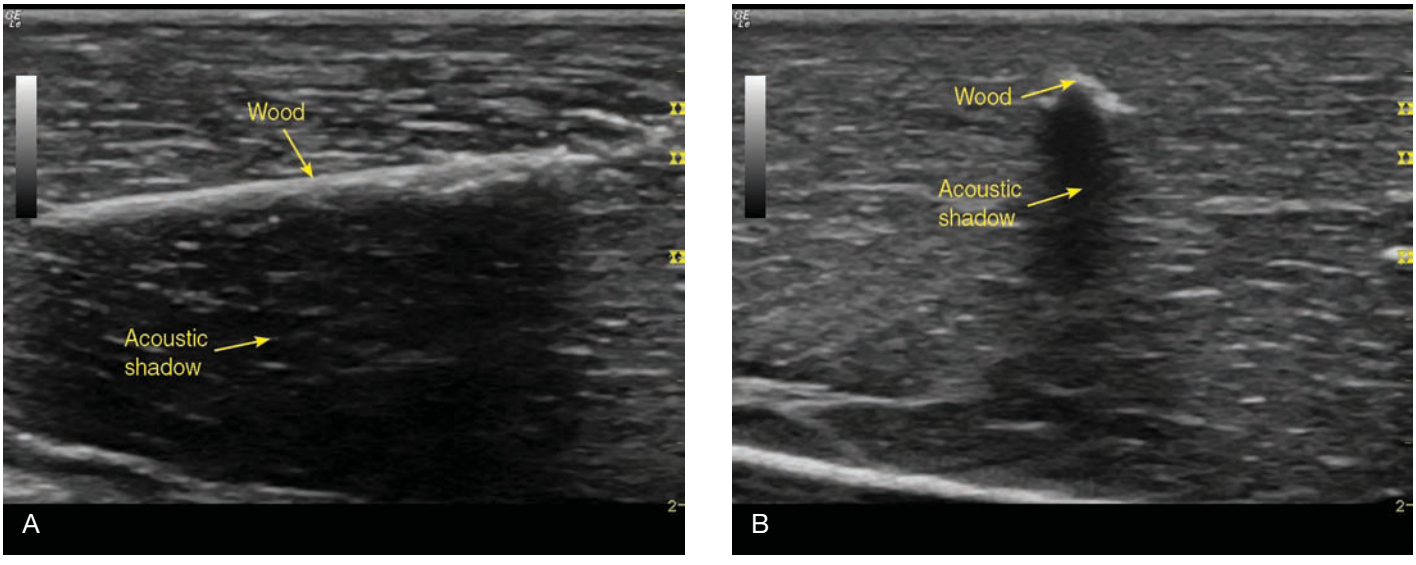


FIGURE 98-3. US image of a subcutaneous wood foreign body. The wood produces a strong hyperechoic reflection and a hypoechoic acoustic shadow. **A.** Long axis US view. **B.** Short axis US view.

persistent pain, neuropraxia, impairment of function, limitation of range of motion of a joint, or psychological distress should have the foreign body removed. Foreign bodies adjacent to bone can cause osteomyelitis and should be removed within 96 hours.[40] Any patient in whom a foreign body, especially wood, was removed should have a further investigation to ensure there are no additional foreign bodies or a fragment of the removed foreign body present.[18]

CONTRAINDICATIONS

US is a safe imaging modality without any known ionizing radiation. There are no known contraindications to using US to identify and remove a foreign body.

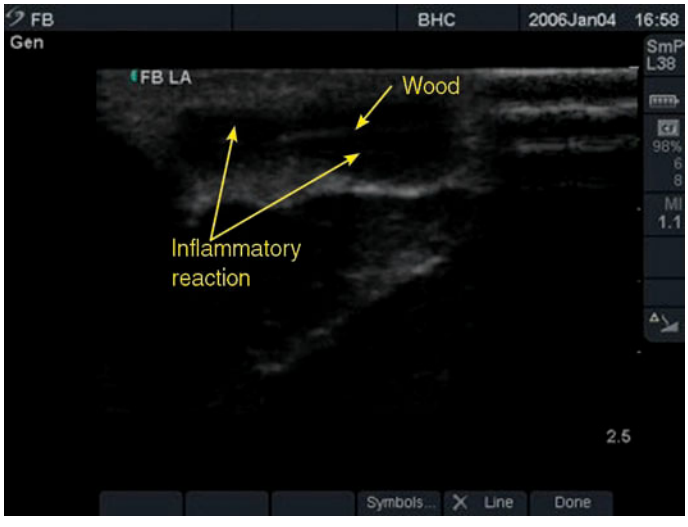


FIGURE 98-4. US image of a subcutaneous wood foreign body that has been in place for over 24 hours. The inflammatory reaction forms an anechoic rim around the foreign body (Courtesy of James W. Tsung, MD, MPH).

EQUIPMENT

- US machine
- High frequency linear US probe
- Sterile US probe cover or glove
- Skin cleansing solution (chlorhexidine or povidone iodine)
- Sterile US gel (or other type of sterile gel, i.e., Surgilube)
- #11 scalpel blade
- Suture kit or individual components (sterile drape, gauze pads, hemostat, and forceps)
- Local anesthetic solution, usually lidocaine
- 5 mL syringes
- 27 gauge needles
- 18 gauge needle to draw up local anesthetic solution
- Skin marking pen
- Paperclips
- Stand-off pad (or a 50 mL or 100 mL saline bag)

PATIENT PREPARATION

Obtain informed consent in which the risks, benefits, and any alternative treatment modalities are discussed. Cleanse the skin of any dirt and debris. Apply a liberal amount of US gel over the area in which the foreign body is suspected. Use a high frequency linear US probe to search for the foreign body. Look for signs of the foreign body such as reverberation artifact, comet-tail artifact, acoustic shadowing, a hypoechoic rim surrounding an echogenic structure, or any other signs associated with foreign bodies.

Foreign bodies may be very superficial. It may be necessary to change the focal zone on the US machine. An acoustic interface may assist in locating a superficial foreign body. Apply a stand-off pad over the site of the foreign body. This can be either a commercially available stand-off pad, a small saline bag in which the air is removed, or a glove filled with saline or US gel.[17,41] The water bath technique works well for the hands and feet. Place the body part

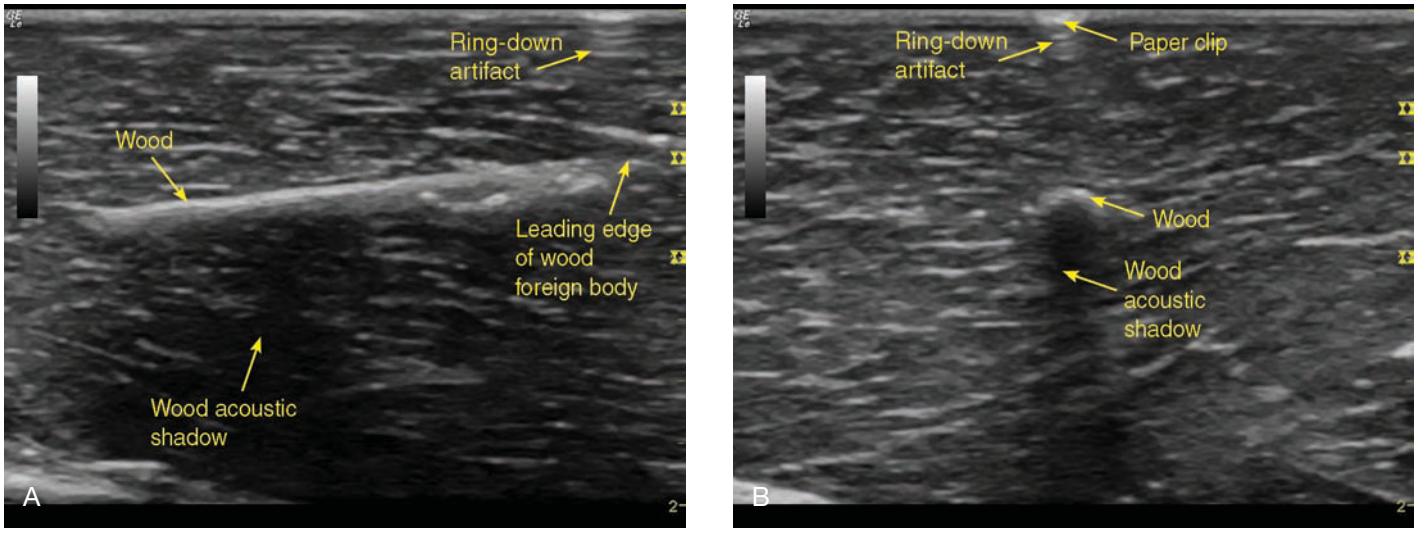


FIGURE 98-5. Paper clip localization of a foreign body. The wood foreign body has a bright echogenic reflection and casts an acoustic shadow. The paper clip casts a ring-down or reverberation artifact that is lined up over the leading edge or most superficial aspect of the foreign body. **A.** Long axis US view. **B.** Short axis US view.

in a water-filled container. Place the US probe in the water-filled container without actually contacting the patient's skin. Identify the presence of a foreign body. Once identified, it must be localized to make removal easier for the patient and the Emergency Physician.

TECHNIQUE

PAPER CLIP LOCALIZATION AND REMOVAL

Since the foreign body is located under the skin, its location should be marked on the patient's skin. It is helpful to use a metal foreign body, such as a paper clip, to create a shadow to locate the foreign body. The metal paper clip will cast a distinct shadow.

Identify the foreign body on US. Place the US probe on the patient's skin above the foreign body. Turn the US probe so its long axis is aligned with the long axis of the foreign body. Insert the tip of an unfolded paper clip between the US probe and the skin surface. Slowly advance the paper clip until the shadow it casts aligns with the leading edge (the most superficial aspect) of the foreign body (**Figure 98-5**). Use a skin marker to mark this location on the patient's skin. Rotate the US probe 90° to visualize the short axis or cross-sectional view of the foreign body. Insert the tip of the unfolded paper clip between the US probe and the patient's skin. Mark the location on the patient's skin where the shadow cast by the paper clip aligns with the leading edge of the foreign body. The intersection of these two lines is where the leading edge of the foreign body resides under the skin.

Prepare to remove the foreign body. Prepare a 5 mL syringe with a 27 gauge needle and local anesthetic solution. Cleanse the patient's skin with chlorhexidine or povidone iodine solution and allow it to dry. Apply sterile drapes to form a sterile field. Inject local anesthetic solution subcutaneously around the skin markings over the leading edge of the foreign body.

Prepare the US probe. Apply US gel to the footprint of the US probe. Apply a sterile probe cover or a sterile glove over the US probe. Squeeze any air out of the space between the US probe and the cover. Apply sterile US gel on the probe cover.

The Emergency Physician should don sterile gloves. The use of a hat, face mask, and sterile gown is not necessary for this procedure. Grasp the US probe with the nondominant hand. Align the long axis of the US probe along the long axis of the foreign body, and approximately 3 to 4 mm proximal to the skin markings. Aim the syringe containing the local anesthetic solution downward and in the direction of the foreign body. Slowly insert and advance the needle through the skin mark under US guidance while slowly injecting a small volume of local anesthetic solution. The injection of local anesthetic solution around the foreign body creates a hypoechoic halo that helps with the identification of the foreign body. Stop advancing the needle when the tip reaches the foreign body. Remove the needle without moving the US probe.

Use a #11 scalpel blade to make a small skin incision just proximal to the skin mark and in an area that has been previously anesthetized. Insert the jaws of a closed hemostat or the arms of a closed alligator forceps into the skin incision. Advance the instrument under US guidance and bluntly dissect down to the foreign body. Align the tip of the instrument with the leading edge of the foreign body (**Figure 98-6**). Open the instrument, grasp the foreign body, and remove it.

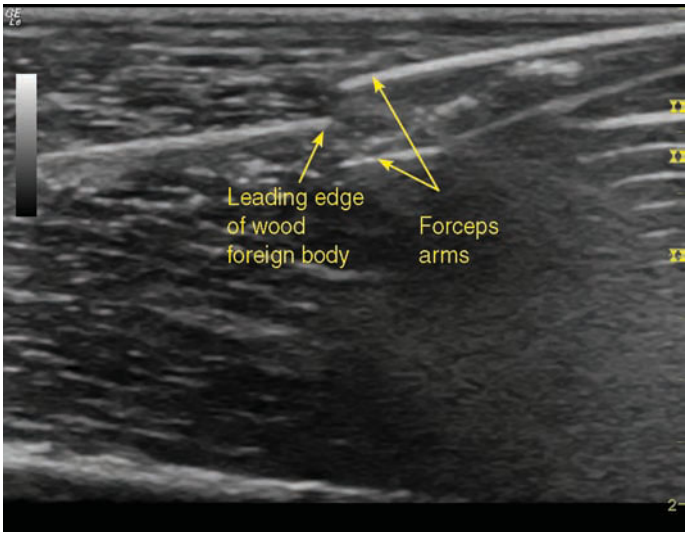


FIGURE 98-6. Retrieval of the foreign body. US image of the forceps approaching a wood foreign body. Note that the arms of the forceps are open and in line with the foreign body.

NEEDLE LOCALIZATION AND REMOVAL

Identify the foreign body using US. Cleanse the skin, apply sterile drapes, prepare the syringe, and prepare the US probe as described above. Infiltrate local anesthetic solution subcutaneously in the area overlying the foreign body. Align the long axis of the US probe with the long axis of the foreign body. Insert a 27 gauge needle in front of the US probe. Slowly advance the needle under US guidance until its tip is against the foreign body. Release the needle with the dominant hand and grasp a #11 scalpel. Insert the #11 scalpel blade along the needle until the tip of the blade is at the tip of the needle. Remove the scalpel blade and needle without moving the US probe. Insert a forceps, hemostat, or alligator forceps along the incision track under US guidance. Open the instrument, grasp the foreign body, and remove it.

ASSESSMENT

It is important to rescan the area after removal of the foreign body to ensure there is no additional foreign body or a retained piece of the original foreign body which needs to be retrieved. Foreign bodies may not be removed in their entirety. A second foreign body may be present in an injury and not visible on the initial US scans.

AFTERCARE

Ensure that the foreign body is completely removed. There are many different thoughts on the care of wounds. Copiously irrigate the area. A review of the Cochrane Database indicates that there is no evidence that using tap water to cleanse acute wounds in adults increases infection; while some evidence suggests that it reduces infection rates.[42] There is no strong evidence that cleansing wounds per se increases healing or reduces infection.[42] Close any lacerations from the wound itself or from the procedure to remove the foreign body. There is no strong evidence to support the use of antibiotics in simple non-bite wounds.[43] Wounds associated with foreign bodies are at an increased risk for infection. Instruct the patient to be aware of the signs and symptoms of an infection. In one review, 44.4% of all subjects with a foreign body removed were prescribed antibiotics.[44] However, when consultants were utilized in the care of these patients, this number rose to 84.4%.[44] A short course of antibiotics may be appropriate to prevent iatrogenic septic complications or sequelae caused by mobilization of the foreign body.[45]

COMPLICATIONS

Foreign bodies, as well as the procedures to remove them, have been associated with infections (e.g., flexor synovitis, cellulitis, gas gangrene, abscesses, osteomyelitis, fungal infections, and lymphangitis), laceration of adjacent structures (e.g., nerves and tendons), neuropraxia, inclusion cysts, fractures, arthritis, and even an angiosarcoma.[13,23,40,46,47] Even though attempts are made to identify and remove all foreign bodies, some of them may be missed. A retained foreign body can lead to similar symptoms at a later time.[48] **Therefore, it is important to investigate and remove foreign bodies in a timely manner.**

SUMMARY

Foreign bodies are a major source of physician litigation. They are often not detected on standard radiographs and can be associated with complications. A high index of suspicion must be maintained when the patient has a laceration, soft tissue mass, or foreign body sensation. US can be used to identify and guide the removal of foreign bodies in the Emergency Department.

99 Tick Removal

Zach Kassutto

INTRODUCTION

Ticks are blood-feeding external parasites (**Figure 99-1**). Ticks are a significant infectious disease problem in the United States as well as worldwide. They have been implicated as vectors in the transmission of many diseases including Lyme disease, ehrlichiosis, babesiosis, Rocky Mountain spotted fever, tularemia, tick paralysis, and tick-borne relapsing fever. Disease transmission is postulated to occur when stomach contents and saliva from the tick are introduced into the host during the blood-feeding process. There is significance in how long a tick has been attached and how quickly a feeding tick can be removed to the transmission of tick-borne diseases. Early removal is felt to limit the transmission of disease. For example, current entomological thinking suggests that the tick must be attached for at least 24 hours in order to transmit *B. burgdorferi*, the spirochete responsible for Lyme disease.[1]

ANATOMY AND PATHOPHYSIOLOGY

There are two main families of ticks.[2] Hard body ticks belong to the Ixodidae family. Soft body ticks belong to the Argasidae family. Hard body ticks are responsible for the transmission of the majority of human diseases and will be the focus of this chapter. Hard ticks pass through four life cycle stages from birth (egg, larva, nymph, and adult). They require a blood meal in order to progress into the next stage of their development.

The bite of a tick is painless and often goes unnoticed unless the tick is found attached to the skin. Ticks are often encountered in the late spring, summer, and early fall. Ticks are more prevalent in rural and wooded areas. They like to feed in dark (covered) and moist areas of the body such as the axilla, groin, or scalp.

Ticks have specialized mouthparts that make their removal difficult (**Figure 99-2**).[2] They screw their mouthparts into the skin in a clockwise direction. Mouthparts include the palps, the chelicerae, and the hypostome. The chelicerae are used to cut through the host's epidermis and allow passage of the tick's hypostome, through which the feeding takes place. Ticks attach themselves to their host by inserting the rod-like hypostome into the skin. The hypostome

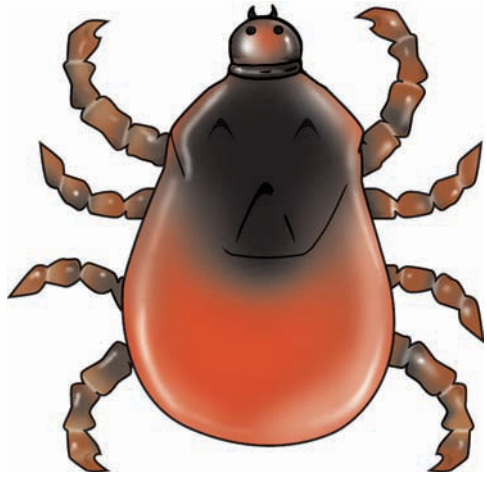


FIGURE 99-1. The tick.

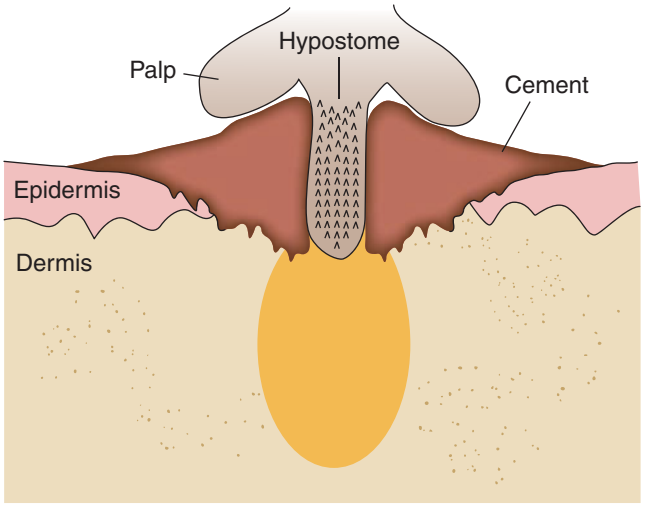


FIGURE 99-2. The specialized mouthparts of the tick.

has many backward pointing sharp barb-like projections that prevent it from being pulled out. Additionally, some ticks secrete a cement-like material around the hypostome to secure its attachment to the host while it feeds. The longer the tick is attached, the more difficult it becomes to remove it intact. The tick releases its mouthparts from the host after the meal is complete. It can take anywhere from hours to days for an adult tick to finish its blood meal and detach from its host.[4]

INDICATIONS

Any tick found attached to the skin should be removed. Transmission of bacteria, spirochetes, viruses, or other infectious agents is directly related to length of time of attachment. Ticks attached less than 24 hours are very low risk for transmission of disease.[3]

CONTRAINDICATIONS

There are no absolute or relative contraindications to the removal of a tick.

EQUIPMENT

Required Equipment

- Povidone iodine solution, chlorhexidine solution, or isopropyl alcohol swabs
- Gloves
- Fine forceps or mosquito hemostat

Optional Equipment

- Magnifying headlamp
- 18 gauge needle
- Local anesthetic solution
- 3 mL syringe with a 27 gauge needle
- Skin biopsy punches
- #15 surgical scalpel blade on a handle
- 5-0 nylon suture
- Specimen container with isopropyl alcohol
- Commercial tick removal device[10]

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Risks include failure to remove all tick parts and infection. Obtain an informed consent for the procedure. Clean any dirt and debris from the skin. Apply povidone iodine or chlorhexidine solution to the skin surrounding the tick and allow it to dry. An alcohol swab can be used as a substitute.

TECHNIQUE

Direct mechanical removal of the tick is the only recommended technique.[4] Grasp the tick tightly with a fine forceps or mosquito hemostat at the tick's head or mouthparts, as close to the patient's skin as possible (**Figure 99-3A**). **Do not crush, puncture, squeeze, or tear the ticks' abdomen.** Apply firm and upward pressure to remove the tick (**Figure 99-3B**). **Carefully examine the skin for any remaining portions of the tick's mouthparts.** Gently grasp and remove any retained parts of the tick with a fine forceps or tease them out with the tip of a sterile needle.

Direct traction is the preferred method, although some have suggested that a rotary counterclockwise movement combined with the firm pull may be more effective.[4] Another technique that has been described suggests first rotating the tick two complete revolutions around its axis to loosen its attachment prior to pulling it away from the skin.[5] The premise is that the twisting action will disengage the tick's mouthparts. There is not enough information to recommend or refute these methods.

ALTERNATIVE TECHNIQUES

Some Emergency Physicians prefer a surgical technique to remove the tick and its attachment to the skin to ensure that no fragments of the tick mouthparts remain within the patient. Clean and prep the skin. Inject 0.25 to 0.50 mL of local anesthetic solution subcutaneously immediately underneath the tick's mouthparts. Apply povidone iodine or chlorhexidine solution to the skin and allow it to

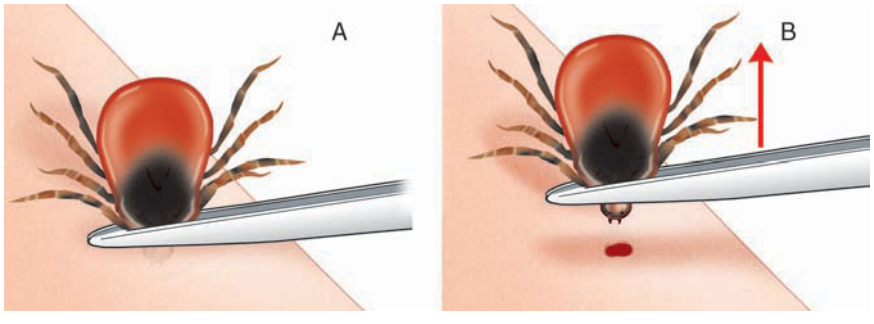


FIGURE 99-3. Removal of the tick. **A.** The tick is grasped as close to the skin as possible. **B.** Firm upward pressure is applied to remove the tick.

dry. Stretch the skin on each side of the tick with the nondominant hand. Apply the skin biopsy punch perpendicular to the skin. Make sure that the tick is centered within the skin biopsy punch. Advance the skin biopsy punch downward using a twisting (clockwise–counterclockwise) motion until a loss of resistance is felt. The loss of resistance indicates that the skin biopsy punch is through the epidermis and at the level of the dermis. Remove the skin biopsy punch. Grasp and lift the punched skin plug with a forceps. Cut the plug at the dermal-epidermal junction with an iris scissors or a #15 scalpel blade. Alternatively, remove the tick and skin with a #15 surgical scalpel blade. At the Emergency Physician's discretion, close the skin site with a single 5-0 nylon suture or leave it open to granulate and heal.

Patients or their family members may use variety of folk/home therapies in their efforts to either passively or actively remove ticks. Techniques that involve coating the tick with noxious materials such as kerosene, lidocaine, or nail polish to cause the tick to voluntarily withdraw its attachment have not been shown to be successful.[4,6] Techniques that attempt to suffocate the tick with petroleum jelly are also not felt to be useful due to the low respiratory rate of 3 to 10 breaths per hour in a feeding tick.[5] The use of a heated object, e.g., a match tip or piece of metal, applied to the abdominal surface of the tick has not been shown to effect rapid tick detachment and presents a risk of burning the patient. Subcutaneous injection of local anesthetic solution at the attachment site was studied and was found to be ineffective in stimulating tick detachment.[7] There are specific devices that are commercially available and advertised to aid in manual tick removal. Some of these devices have been tested and are not felt to offer any advantage over forceps removal.[8–10]

ASSESSMENT

After removing the tick, carefully inspect the bite site to ensure no foreign material has been retained. Ticks can usually be discarded as testing of the tick is usually not indicated. If testing is desired, place the tick in a specimen container with isopropyl alcohol until testing can be performed by a laboratory or the local public health department.

AFTERCARE

Cleanse the area with a mild disinfectant or soap and water. Administer tetanus prophylaxis if the patient's immunization history is not up-to-date. The appearance of any rash or the occurrence of any febrile illness 2 to 12 days after a documented tick exposure should prompt further medical follow-up. Provide the patient information regarding the signs and symptoms of Lyme disease and/or other tick-borne diseases seen in your specific geographical area. The patient should inspect the site twice a day for signs of an infection. They should return to the Emergency Department or their Primary Care Physician if they develop redness, tenderness, swelling, a discharge, or a rash at the bite site.

A detailed discussion identifying the types of ticks or the indications for prophylactic antibiotic therapy is beyond the scope of this chapter. Consult the current medical literature or an Infectious Disease Specialist regarding these questions. The use of prophylactic oral antibiotics to cover typical skin flora or Lyme disease is not routinely recommended. If antibiotics are prescribed, options include 5 to 7 days of: doxycycline (100 mg bid), tetracycline (500 mg qid), amoxicillin-clavulanate (400 to 875 mg bid), levofloxacin (500 mg qd), or erythromycin (125 to 500 mg qid). Do not prescribe doxycycline, tetracycline, or levofloxacin in children and pregnant women to avoid associated complications.

Patients should be educated about ticks and preventative measures to avoid tick bites. Prevention is the best protection. When outdoors, patients should be advised to wear clothes to cover their arms, legs, and torso; tuck the cuffs of pants into boots; apply a repellent (chemical or botanical in origin) or an insecticide to clothes and exposed skin; and physically check for the presence of ticks at the end of the activity or the end of the day.

COMPLICATIONS

The major complication of the direct removal technique is the separation of the tick body from the embedded head. Leaving foreign material in the wound can serve as a site for subsequent infection.[5] Any remaining pieces of the tick should be removed using an 18 gauge needle, a skin biopsy punch, or sharp dissection with a #15 scalpel blade.

Inadvertent crushing of the tick may allow stomach contents or saliva from the tick to enter the wound. It is theorized that grasping the tick too distal to its head, across its thorax/abdomen, could induce regurgitation of stomach contents into the wound and increases the risk of disease transmission.[5]

Local complications include bleeding and infection. The application of direct pressure will control any bleeding. A cellulitis presents a few days after the bite and is often due to the ticks feeding process, skin contamination entering the bite site, or retained mouthparts. Carefully inspect the bite site to ensure there are no retained mouthparts. If unsure, use a skin biopsy punch to remove the bite site. Treat the cellulitis with oral antibiotics that cover typical skin flora.

SUMMARY

Ticks are a vector for numerous serious diseases and should be removed from the skin as soon as they are identified. Disease transmission is felt unlikely if the tick has been attached less than 24 hours. The only recommended technique for tick removal is manual detachment using forceps.

100 Fishhook Removal

Eric F. Reichman and Renee C. Hamilton

INTRODUCTION

Depending on practice location and season of the year, the presentation of a fishhook embedded in the subcutaneous tissue can be common. The patient or a well-meaning bystander will often have already attempted removal that was prevented by the hook's barb. The ensuing tissue trauma and patient anxiety can complicate the task for the Emergency Physician. Removal can be difficult as a fishhook is designed not to pull out of a fish's mouth. Several methods of removal have been described.[1–9] The method chosen depends on the type and size of the hook, the depth of penetration, and the anatomical location of injury.

ANATOMY AND PATHOPHYSIOLOGY

Most fishhooks become embedded in the skin and subcutaneous soft tissue. The anatomy of a fishhook is simple (**Figure 100-1**). The long, straight section is known as the shaft. The proximal end of the shaft has a closed circle, the eyelet, where the fishing wire attaches. The distal end of the shaft curves in a semicircle known as the belly of the fishhook. The belly tapers into a sharp point with a barb. The

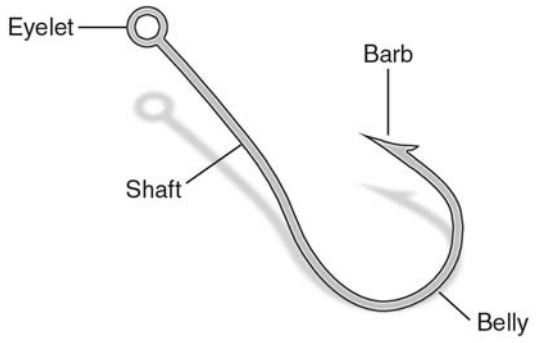


FIGURE 100-1. Anatomy of a fishhook.

barb is usually located on the inner surface of the hook, pointing away from the tip. The barb, once pierced through the skin, becomes embedded within the tissue and prevents removal of the fishhook. Additional barbs may be located along the shaft of the fishhook.

INDICATIONS

Any embedded fishhook must be removed from the body. There is no reason a fishhook should not be removed by the Emergency Physician if no contraindication exists.

CONTRAINDICATIONS

There are no absolute contraindications to fishhook removal. Occasionally, the procedure should be referred to a consultant. Globe perforation or laceration requires emergent consultation with an Ophthalmologist. Place the patient supine with a shield, not a patch, over the eye. Please see Chapter 161 for the complete details regarding eye patching and eye shields. **Penetration of, or near, vital structures (e.g., the neck, groin, or major neurovascular structures) should be given consideration for the appropriate surgical consultation prior to removal of the fishhook.**

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Local anesthetic solution without epinephrine
- 3 mL syringe armed with a 25 gauge needle
- Wire cutter
- Needle driver
- Hemostat
- 18 gauge needle
- #11 scalpel blade on a handle
- String, fishing line, or a strong silk tie, at least 50 cm in length
- Tongue depressors
- Safety glasses/goggles or a face mask with an eye shield

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Ask the patient to describe the type of fishhook embedded, especially in regards to the number and location of the barbs. Ask the patient to draw a picture of the fishhook or provide you with a similar one to examine. The number and location of the barbs will help in determining the appropriate removal technique. Obtain a signed consent form prior to beginning the procedure. Cleanse the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the skin surrounding the embedded fishhook and allow it to dry. **The Emergency Physician should wear eye protection when removing a fishhook to prevent injuring themself.** At minimum, wear safety glasses or goggles. If available, a face mask with an eye shield is preferred.

TECHNIQUES

PULL-THROUGH TECHNIQUE

This is the traditional method that is used for larger sized hooks embedded in the soft tissue with the barb near the skin surface. This is the preferred technique for fishhooks embedded in the ear, a joint, or in the nasal cartilages. Experienced fishermen often perform this technique in the field, as they would hate to lose prime fishing time to go to the Emergency Department.

Identify the barbed end of the fishhook, located under the skin surface. Inject 0.5 to 1.0 mL of local anesthetic solution into the subcutaneous tissue overlying the barbed end of the fishhook to raise a skin wheal (**Figure 100-2A**). Allow 3 to 4 minutes for the local anesthetic solution to take effect. Grasp the shaft of the fishhook with a needle driver (**Figure 100-2B**). Advance the fishhook until the barbed end protrudes through the anesthetized skin (**Figure 100-2B**). **Securely clamp a hemostat over the barb.** This

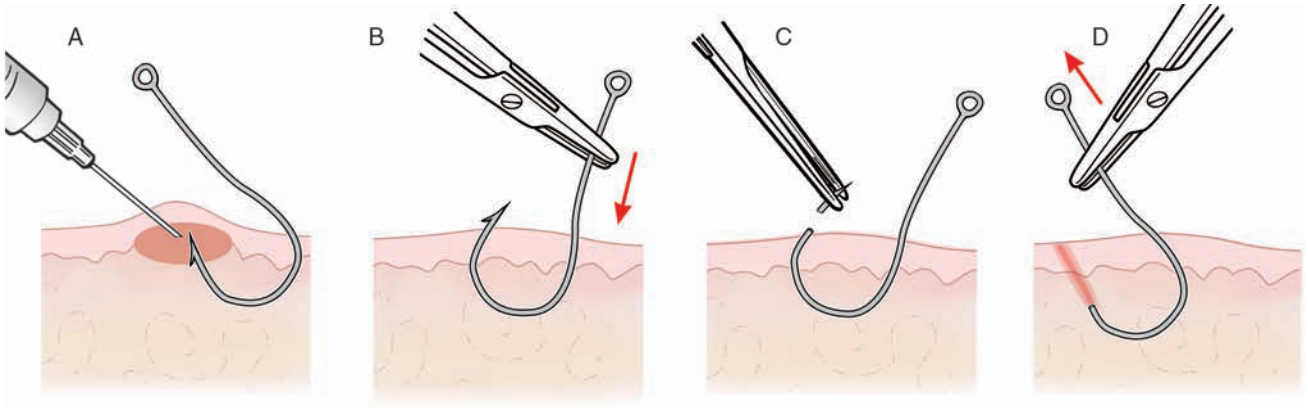


FIGURE 100-2. The pull-through technique for fishhook removal. **A.** Subcutaneous anesthetic is placed over the barb. **B.** The fishhook is advanced until the barb protrudes from the skin. **C.** A hemostat is placed over the barb before it is cut off with wire cutters. **D.** The fishhook is removed.

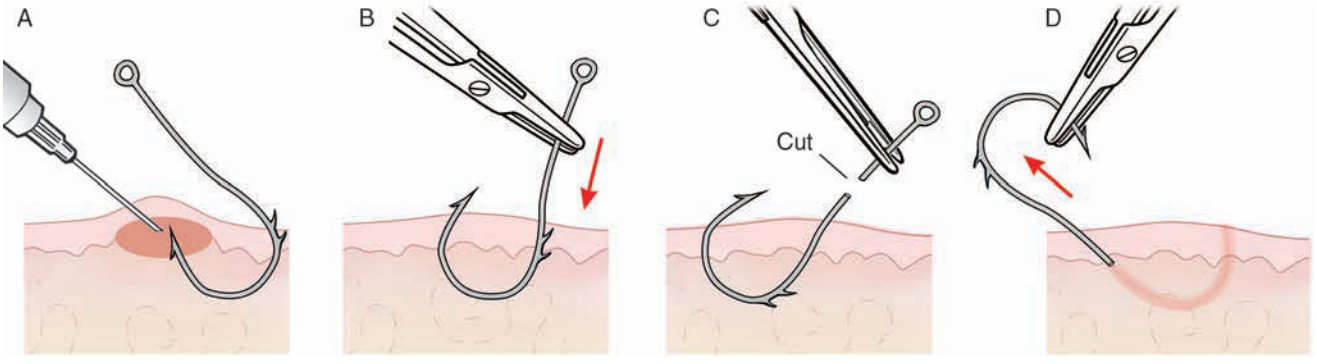


FIGURE 100-3. An alternative pull-through technique for the removal of a multibarbed fishhook. **A.** Subcutaneous anesthetic is placed over the barb. **B.** The fishhook is advanced until all of the proximal barbs are under the skin. **C.** The shaft is cut. **D.** The fishhook is removed.

will prevent it from becoming a projectile when cut and injuring someone. Cut the belly of the fishhook just proximal to the barbed end with a wire cutter (**Figure 100-2C**). Grasp the shaft of the fishhook with the needle driver and withdraw it along its direction of entry (**Figure 100-2D**).

Occasionally, fishhooks may have additional barbs on the shaft or the belly (**Figure 100-3**). Inject 0.5 to 1.0 mL of local anesthetic solution into the subcutaneous tissue overlying the barbed end of the fishhook (**Figure 100-3A**). Allow 3 to 4 minutes for the local anesthetic solution to take effect. Grasp the shaft of the fishhook with a needle driver (**Figure 100-3B**). Advance the fishhook until the barbed end protrudes through the anesthetized skin (**Figure 100-3B**). Continue to advance the fishhook until all the barbs on the belly and shaft are below the skin surface (**Figure 100-3B**). Securely clamp a hemostat over the proximal shaft of the fishhook (**Figure 100-3C**). Cut the shaft of the fishhook at the level of the skin with a wire cutter (**Figure 100-3C**). Grasp the fishhook just proximal to the barbed end with the needle driver and pull the remainder of the fishhook out of the tissues (**Figure 100-3D**).

BARB-SHEATH TECHNIQUE

This method is reserved for small fishhooks embedded near the skin surface. This technique should not be used for fishhooks in the ear, nose, or a joint cavity. Inject 0.5 to 1.0 mL of local anesthetic solution to form a wheal subcutaneously around the area where the fishhook enters the skin. Insert an 18 gauge needle along the entrance wound and aimed toward the barb (**Figure 100-4A**). The bevel of the needle should face the barb with the goal being to engage and cover the barb. Advance the needle and engage the barb in the core of the needle (**Figure 100-4B**). Gently twist and pull the hook back through the entrance wound while the needle covers the barb (**Figure 100-4C**).

An alternative method is to insert a #11 scalpel blade parallel to the shaft of the fishhook at the site it enters the skin. Advance the scalpel blade until it is adjacent to the barb. Withdraw the fishhook and scalpel through the tract. The barb will be resting against the scalpel blade and not get embedded in the subcutaneous tissues. This method is not recommended due to the blind insertion of a scalpel blade into the soft tissues and the potential for secondary injury.

STRING-YANK TECHNIQUE

This method has been extensively described and is often performed by experienced fishermen in the field. It is rapid, effective, easy to perform, and relatively painless. This technique should not be used for fishhooks in the ear, nose, or a joint cavity. **The Emergency Physician should take caution for themselves, the patient, and bystanders. The hook often forcibly flies out of the patient. Ensure the suspected path of the fishhook is clear. Eye protection is recommended with this technique for both the Emergency Physician and the patient.**

Place the body part that the fishhook entered firmly on a flat surface. Local anesthetic solution can be infiltrated, at the Emergency Physicians discretion, into the area where the fishhook enters the skin. Wrap the midpoint of a long string around the belly of the fishhook at the site it enters the skin (**Figure 100-5A**). The string ends should be firmly wrapped around and secured to the index and middle fingers of the Emergency Physician's dominant hand. Use the gloved nondominant thumb or index finger to firmly depress the shaft of the fishhook against the skin, until slight resistance is met (**Figure 100-5B**). The shaft should be parallel to the skin and touching the skin. This will disengage the barb from the soft tissues. Quickly and firmly jerk the string (**Figure 100-5C**). This maneuver will release the fishhook from the subcutaneous tissues and pull it out through the entry wound.

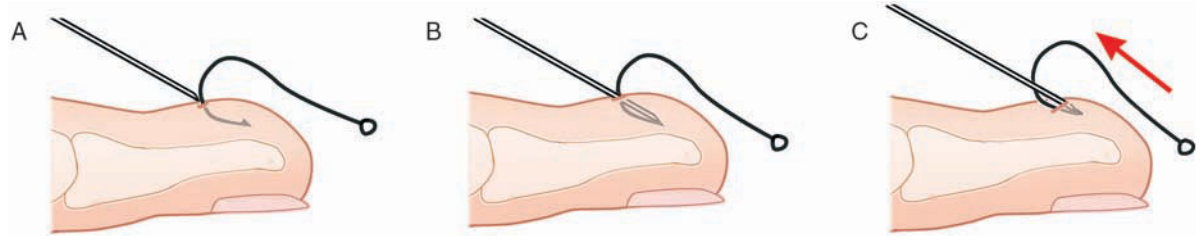


FIGURE 100-4. The barb-sheath technique for fishhook removal. **A.** Insert the needle through the entrance wound and aimed toward the barb. **B.** Advance the needle through the entry site to catch the barb in the core of the needle. **C.** The needle and fishhook are removed as a unit.

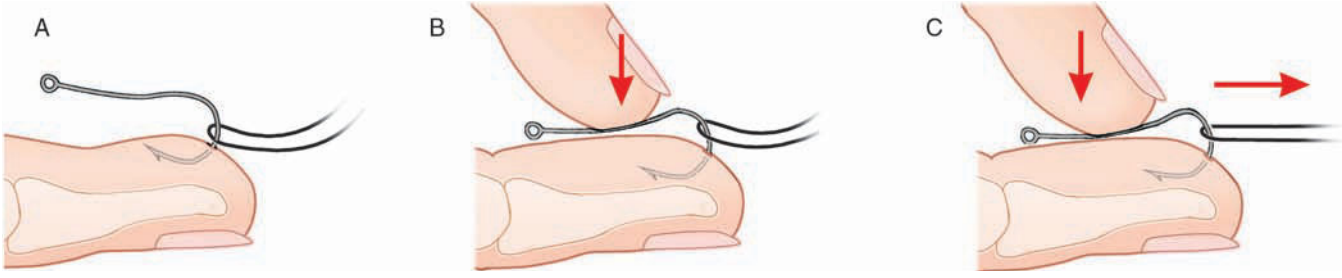


FIGURE 100-5. The string-yank technique for fishhook removal. **A.** A string is wrapped around the belly of the fishhook. **B.** The shaft of the fishhook is depressed until resistance is encountered. The shaft should be parallel to the skin and touching the skin. **C.** A quick tug on the string will remove the fishhook.

Alternatively, the Emergency Physician may use two tongue depressors to provide secure traction to the string. Wrap each end of the string around one tongue depressor. Instruct an assistant to gently depress the fishhook shaft against the skin while the Emergency Physician jerks the string.[6]

AFTERCARE

The wound should be cleaned of any blood and a dry dressing applied. Administer tetanus prophylaxis if the immunization history is not up-to-date. A radiograph is indicated if there is any suspicion of a retained foreign body. Acetaminophen or nonsteroidal anti-inflammatory drugs will provide any required analgesia. Instruct the patient to clean the area with warm soapy water three times a day and to keep the wound covered until healed. Instruct the patient as to the signs of infection. They should return to the Emergency Department, or their physician, if signs of an infection develop. Routine follow-up is often not required unless the fishhook penetrated the ear, nose, or a joint.

Antibiotic prophylaxis remains controversial.[1,2] The use of antibiotics is left to the discretion of the Emergency Physician and should include consideration for the anatomic site of injury, depth of penetration, evidence of gross contamination, and factors that may compromise the patient's immunity (e.g., diabetes mellitus, HIV infection, steroid use, or malignancy). If antibiotic prophylaxis is chosen, prescribe a broad spectrum antibiotic such as trimethoprim-sulfamethoxazole or doxycycline. These will provide good coverage against gram-negative organisms typically associated with water recreation injuries, as well as some coverage against MRSA and other community acquired infections.[7] Adding ciprofloxacin for pseudomonas coverage may also be considered, as pseudomonas and its subtypes are commonly found in soil and freshwater.[6]

COMPLICATIONS

Complications include infection or damage to the surrounding tissue. Infection is often due to either the contaminated fishhook inoculating the tissues or the fishhook penetrating contaminated skin. Using proper removal techniques will minimize, but not eliminate, any damage to the soft tissues.

Use caution when extracting fishhooks to avoid secondary injury to bystanders, the patient, or the Emergency Physician. Protective eyewear should be worn with all three techniques of fishhook extraction. Ocular injury has been reported to occur during this procedure.[2] Fishhooks have been surgically extracted from the hypopharynx and the intestine.[8,9] A surgical face mask with a face shield is another mode of protection that we recommend. When using the pull-through technique, clamping a hemostat to the exposed portion of the fishhook that is to be cut off will prevent flying shrapnel.

SUMMARY

Fishhook removal can be accomplished by one of several simple techniques. It can be performed in the Emergency Department, the office, or the field with minimal supplies. Almost painless removal is possible in most cases. This procedure is gratifying both for the patient and the Emergency Physician.

101 Ring Removal

Steven H. Bowman

INTRODUCTION

The need to remove a ring is not uncommon in the Emergency Department. Patients may present with an initial primary complaint that they can no longer remove a ring or that a ring has become painful. A variety of conditions may necessitate the urgent removal of a ring, including swelling from extremity trauma, infections or burns, increases in total volume status, and allergic reactions. Swelling of the digit can rapidly progress, causing the ring to become a constricting band and compromise blood flow to the digit. Critically ill patients undergoing admission to intensive care settings or emergency surgery may need to have rings removed urgently. **The Emergency Physician's goal is to remove the ring in a timely manner and not cause additional injury.** The information in this chapter applies to rings on the fingers and toes.

ANATOMY AND PATHOPHYSIOLOGY

The second through fourth digits receive their blood supply through four vessels: the palmar radial digital arteries, the palmar ulnar digital arteries, the dorsal radial digital arteries, and the dorsal ulnar digital arteries. The thumb receives its blood supply from the dorsalis pollicis and princeps pollicis arteries. Blood returns from the digits via the dorsal digital veins. When the digit is compressed for prolonged periods by a tight-fitting ring, which acts as a tourniquet, venous return is impeded and swelling ensues. The swelling results in greater compression and further propagation of this cycle. In theory, the increased swelling will eventually impede the arterial supply to the digit.

The greatest circumference of the finger is at the proximal interphalangeal (PIP) joint. Rings usually become entrapped proximal to the PIP joint. Skin breakdown and tissue necrosis occur if the constricting ring is not removed. Left untreated, the digit is at risk

for infections such as cellulitis, tenosynovitis, and osteomyelitis. In severe cases, the digit's viability may be threatened. There are several case reports of rings that have become embedded in the soft tissue of the digits.[1–5]

Most patients will experience pain and seek medical attention prior to the development of severe complications. Patients with an altered mental status, psychiatric illness, peripheral neuropathies, peripheral vascular disease, or other chronic disability may present later with complications.[1,2,4,5]

INDICATIONS

Rings are usually removed to prevent ischemia of a digit. Remove a ring if the digit shows any signs of neurovascular compromise such as decreased capillary refill, decreased pulse wave on pulse oximetry, mottling, paleness, paresthesias, or diminished sensation. Rings should be removed whenever patients complain that a ring is causing pain. Generally, even a tight-fitting ring will not be painful. Rings must be removed from any injured digit where edema is a possible consequence. Examples include sprains, contusions, fractures, lacerations, crush injuries, and burns. Rings should be removed from all digits on the involved side for any extremity injury above the digits and where edema of the distal extremity is a possible consequence. Other nontraumatic conditions that may necessitate emergent ring removal include infections of the upper or lower extremity, acute increases in volume status, and allergic reactions. A patient may present and request a ring be removed that is tight and can no longer be taken off. Consider the need for urgent ring removal with markedly decreased levels of consciousness and in all critically ill patients, particularly those being admitted to intensive care settings or undergoing emergent surgery.

CONTRAINDICATIONS

There are no absolute contraindications to removing a ring. It is important to note that certain techniques may be more applicable than others, depending on the individual patient.

EQUIPMENT

Metacarpal Block

- Povidone iodine or chlorhexidine solution, or an isopropyl alcohol swab
- 3 mL syringe
- 25 or 27 gauge needle, 1 in. long
- 3 to 5 mL local anesthetic solution without epinephrine

Lubricant and Caterpillar Techniques

- Lubricant (K-Y jelly, Surgilube, petrolatum, mineral oil, or liquid soap)

String Technique

- String (1-0 silk suture, cotton umbilical string, tracheal tape, Penrose drain, or intravenous tourniquet)
- Mosquito hemostat

Rubber Band Technique

- 3 to 4 mm wide rubber band
- Lubricant (K-Y jelly, Surgilube, petrolatum, mineral oil, or liquid soap)
- Mosquito hemostat

Glove Technique

- Rubber gloves
- Lubricant (K-Y jelly, Surgilube, petrolatum, mineral oil, or liquid soap)
- Mosquito hemostat
- Scissors

Ring Cutter Technique

- Ring cutter, manually operated or battery-powered
- Steinman pin cutter if a ring cutter is not available
- Two large hemostats or needle drivers
- Pliers (optional)

Vice-grips Pliers Technique

- Medium size vice-grip pliers

Miscellaneous Supplies

- Ice water
- Penrose drain or IV tourniquet
- Basin or zip-lock bag for ice water

PATIENT PREPARATION

Place the patient sitting upright or in a semi-recumbent position. Position their hand on a bedside procedure table. Explain the procedure to the patient and/or their representative. A signed informed consent is not required for the removal of a ring. Analgesia should be provided in the form of a metacarpal block for patients who are complaining of pain. Refer to Chapter 126 for the complete details regarding a metacarpal block.

The removal of a tight ring should be considered a two-step process: first reduce the edema in the finger, then remove the ring.[6] Instruct the patient to elevate the affected hand or foot to reduce edema prior to any attempts at ring removal. Use a finger trap to elevate the affected extremity if the patient has difficulty or cannot keep the extremity elevated. Consider soaking the hand or foot in ice water for 5 to 10 minutes to reduce edema. A Penrose drain, piece of tape, gauze, or elastic bandage can be wrapped around the finger, from distal to proximal, to further reduce swelling.

The simplest and most effective way to remove a ring from a finger is simply to cut the ring using a ring cutter. Reassure the patient that cut rings can be repaired by a jeweler. However, patients may still be reluctant to have expensive rings or rings with sentimental value removed in such a way. The practitioner must consider time, the individual circumstances regarding the entrapment, and which alternative techniques may be effective.

TECHNIQUES

LUBRICANT TECHNIQUE

This technique works for mild cases of ring entrapment with minimal swelling and without significant trauma. Many patients will attempt to remove the ring using some type of lubricant at home prior to presenting to the Emergency Department. Despite this, the same technique may also be tried in the Emergency Department prior to attempting other techniques. Liberally apply a lubricant (e.g., K-Y jelly, Surgilube, petrolatum, mineral oil, or liquid soap) to the digit and beneath the ring. Attempt to advance the ring over the PIP joint with steady traction.

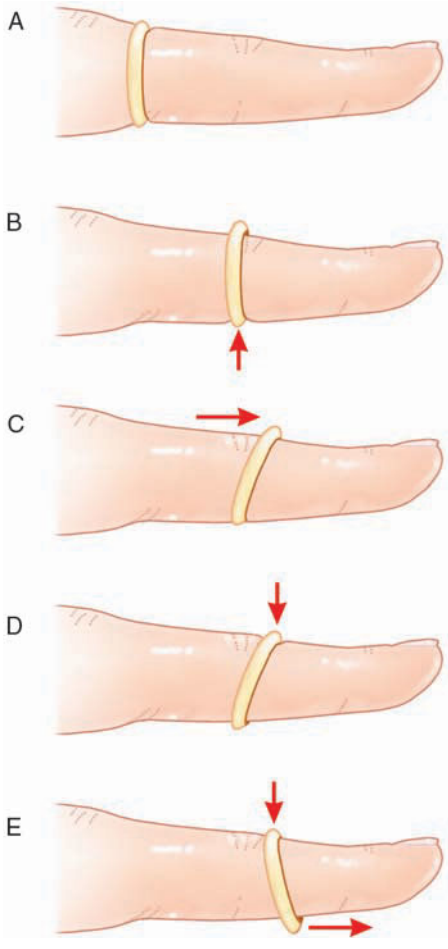


FIGURE 101-1. The caterpillar technique. **A.** The entire finger is lubricated. **B.** The ring has been pushed down the proximal phalanx until it reaches the PIP joint. Push the bottom of the ring up firmly while maintaining pressure. **C.** Swing the top portion of the ring distally over the joint while maintaining upward pressure. **D.** Push down firmly while maintaining downward pressure. **E.** Swing the bottom portion of the ring proximally over the joint and remove the ring.

CATERPILLAR TECHNIQUE

This recently described technique is useful in that it requires no additional materials other than lubricant (**Figure 101-1**).[7] Liberally apply a lubricant to the finger (**Figure 101-1A**). Slide the ring down the proximal phalanx and just proximal to the PIP joint. Apply and maintain upward pressure on the bottom of the ring (**Figure 101-1B**). Simultaneously swing the upper portion of the ring distally (**Figure 101-1C**). Pull the top of the ring over the PIP joint. Apply and maintain downward pressure on the top of the ring (**Figure 101-1D**). Simultaneously swing the lower portion of the ring distally to free it (**Figure 101-1E**). Remove the ring from the finger. This "caterpillar motion" allows the ring to be slowly advanced distally and ultimately removed.

STRING TECHNIQUE

Several authors have extensively described the string technique and its modifications[5,6,8,17] (**Figure 101-2**). This technique consists of using a "string" to compress the edematous tissue, exsanguinate the digit, and then facilitate the passage of the ring over the PIP joint. This technique should be avoided if the patient has an associated finger laceration, finger fracture, or an embedded ring.[8,9]

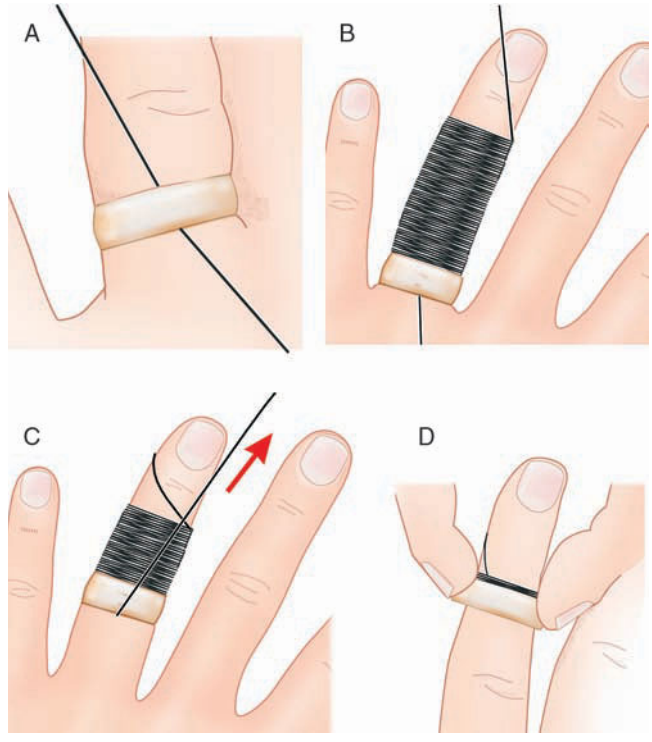


FIGURE 101-2. The string technique. **A.** A string is passed between the ring and the finger. **B.** The string distal to the ring is wound tightly around the finger and continued distally to the level just below the PIP joint. **C.** The string proximal to the ring is slowly unwound and moves the ring distally. **D.** When the ring passes the PIP joint, it usually comes off without effort.

Pass a length of 1-0 silk suture or a piece of string underneath the ring (**Figure 101-2A**). Avoid monofilament sutures and smaller-size sutures as they may break or inadvertently cut the patient if wound too tightly. Passage of the string or suture may be facilitated with the use of a mosquito hemostat.[8–10] Wind the distal portion of the suture tightly around the digit in a closed spiral (**Figure 101-2B**). **There should be no interposition of skin between the turns of the suture material so as to ensure even compression of the skin and soft tissue.** Continue the spiral distally to just beyond the PIP joint. Grasp the proximal end of the suture. Unwind the suture while maintaining traction in the distal direction (**Figure 101-2C**). The ring will be pushed distally as the suture unwinds. The ring is easily removed once it clears the PIP joint (**Figure 101-2D**).

Other materials—such as umbilical tape, cotton gauze, rubber intravenous tourniquets, or Penrose drains—have also been used.[6,11,12] These materials have certain practical advantages. Since they are wider than sutures, shorter lengths and fewer turns are required to encircle the finger. It is easier to wind these materials around the digit without interposition of the skin between the turns (**Figure 101-3**).

Insert the umbilical tape under the ring, from distal to proximal, with the aid of a mosquito hemostat (**Figure 101-3A**). Pull 6 to 7 cm of the umbilical tape proximal to the ring (**Figure 101-3B**). Wind the distal portion of the umbilical tape tightly around the digit in a closed spiral (**Figure 101-3C**). There should be no interposition of skin between the turns of the umbilical tape. Continue to spiral distally to just beyond the PIP joint (**Figure 101-3C**). Grasp the proximal end of the umbilical tape. Unwind the proximal end of the umbilical tape while maintaining traction in a distal direction

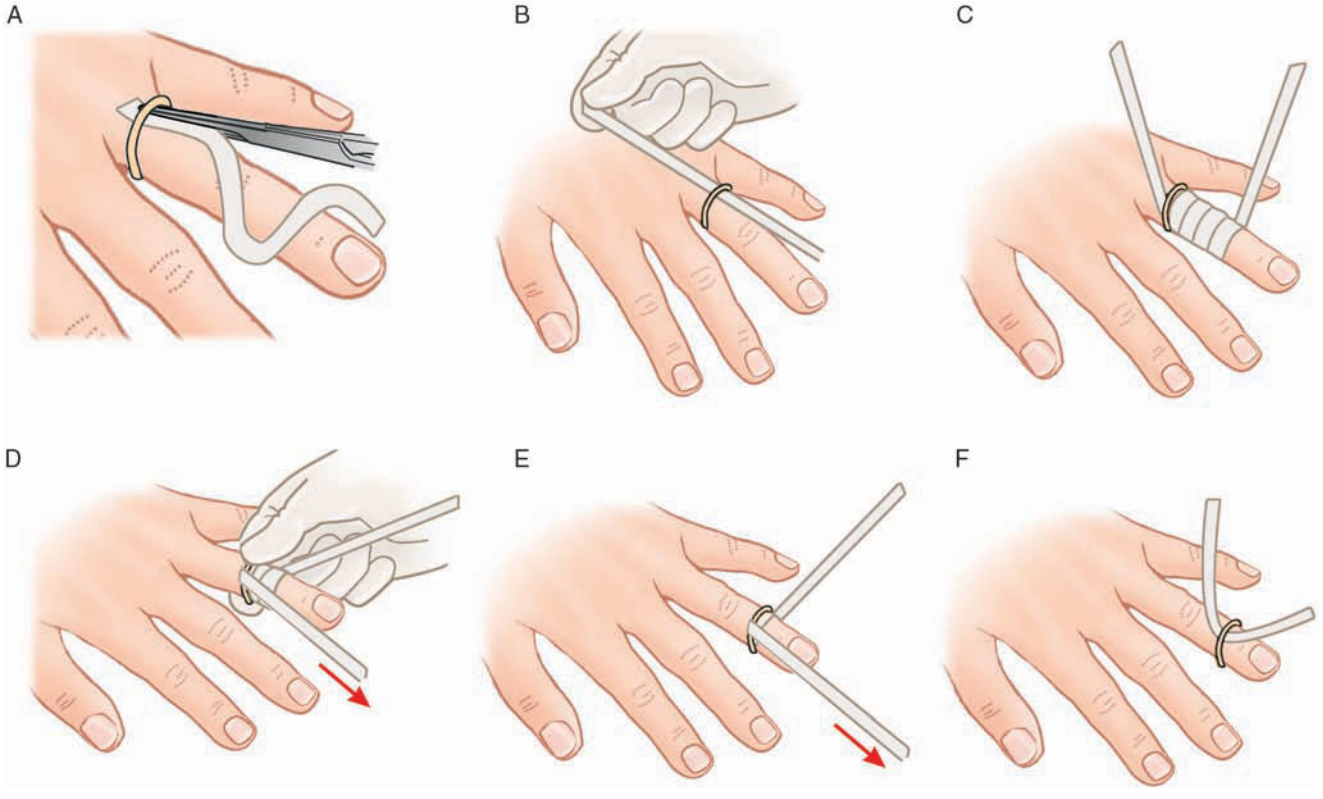


FIGURE 101-3. The string technique with umbilical tape. **A.** The umbilical tape is inserted under the ring with a mosquito hemostat. **B.** The umbilical tape is pulled through to the other side of the ring. **C.** The umbilical tape distal to the ring is wound tightly around the finger to the level just below the PIP joint. **D.** The umbilical tape proximal to the ring is slowly unwound and moves the ring distally. **E.** The ring passes the PIP joint. **F.** The ring is free and usually comes off without effort.

(**Figure 101-3D**). Continue to unwind the umbilical tape until the ring passes the PIP joint (**Figure 101-3E**). The ring is easily removed once it clears the PIP joint (**Figure 101-3F**).

RUBBER BAND TECHNIQUE

This technique utilizes a 3 to 4 mm wide rubber band, which is used to apply traction on the ring to facilitate its passage over the PIP joint[10] (**Figure 101-4**). Though success has been reported using rubber bands, this technique should be reserved for less severe ring entrapments. Avoid this technique if the patient has a laceration, a fracture, or an embedded ring.

Lubricate the finger liberally, as described above. Pass the rubber band beneath the ring using a mosquito hemostat (**Figures 101-4A & B**). Position the rubber band so that equal lengths are on each side of the ring (**Figure 101-4C**). Insert a finger through both loops of the rubber band (**Figure 101-4D**). Pull the loops of the rubber band distally while simultaneously moving them circumferentially between the ring and the finger (**Figure 101-4D**). Continue the motion until the ring is removed (**Figure 101-4E**).

GLOVE TECHNIQUE

This technique has been advocated for use in patients with underlying soft tissue injury to the finger.[13,14] Its success is anecdotal. The glove technique uses a finger cut from an appropriately sized rubber glove (**Figure 101-5**). The glove finger provides mild compression, acts as a barrier to protect damaged soft tissue, and provides a "leading edge" to guide the ring over the damaged tissues. Despite these theoretical advantages, the glove technique may be no more effective than any other in cases of severe finger edema.

Choose a glove that fits the patient snugly. Use the patient's other hand to aid in choosing the right size glove. Cut the finger from a glove to match the finger of the patient (**Figure 101-5A**). Cut off the tip of the finger of the glove to create a cylinder (**Figure 101-5A**). Slide the cylinder onto the patient's finger. Advance the proximal portion of the cylinder beneath the ring using a mosquito hemostat (**Figure 101-5B**). Lubricate the cylinder and the ring with K-Y jelly, Surgilube, petrolatum, mineral oil, or liquid soap. Pull the proximal edges of the latex cylinder distally, with your fingers or mosquito hemostats, to advance the ring distally (**Figure 101-5C**). Continue to pull on the proximal cylinder until the ring moves past the PIP joint and falls off the finger.

RING CUTTER TECHNIQUE

The definitive method for ring removal is cutting the ring. The ring should be cut if the patient presents with an underlying injury, severe swelling, an embedded ring, or entrapment with nonjewelry items. Cutting a ring is generally rapid and safe. A ring cutter can be used to cut rings made of gold, plastic, platinum, silver, stainless steel, and titanium.

Many devices will cut rings. The standard rotary ring cutter should be available in every Emergency Department (**Figure 101-6**). The ring cutter's blade should be periodically inspected and it should be sharp. Battery-powered ring cutters are also available (**Figure 101-7**) (Mooney & Co., Ashland, OR). The advantage of the powered ring cutters is that they are easy to use, lightweight, fast, powerful, can easily cut nonjewelry items, and do not rely on the strength of the healthcare provider to use them. In the absence of a ring cutter, another medical device that has been used successfully to cut rings is the Steinman pin cutter.[15] Our

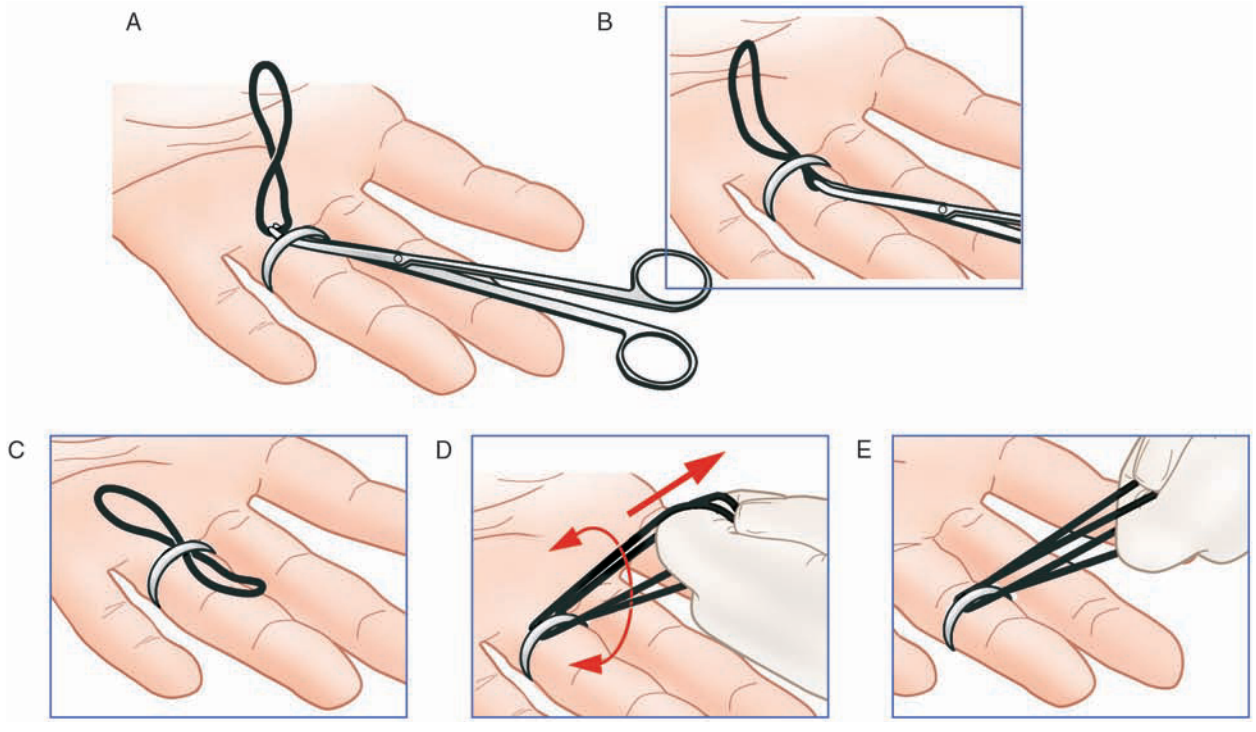


FIGURE 101-4. The rubber band technique. **A.** A mosquito hemostat is passed below the ring and grasps the rubber band. **B.** The rubber band is pulled beneath the ring and out the other side. **C.** The rubber band is positioned with equal lengths of loop on each side of the ring. **D.** Both loops of the rubber band are grasped and pulled distally while it is simultaneously rotated circumferentially. **E.** When the ring passes the PIP joint, it usually comes off without effort.

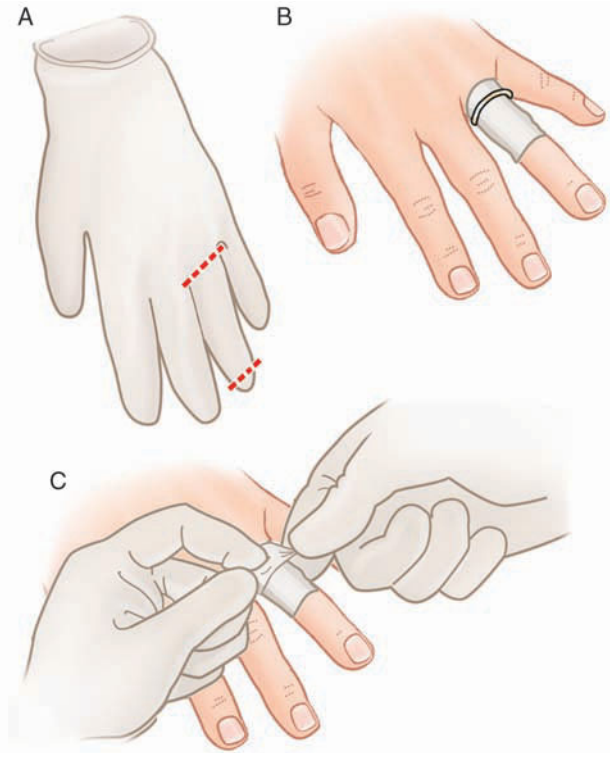


FIGURE 101-5. The latex glove technique. **A.** The finger matching the one on which the ring is lodged is cut from an examination glove. **B.** The latex cylinder is put on the finger. The proximal edges of the cylinder are pulled under and proximal to the ring using a mosquito hemostat. **C.** The proximal edges of the latex cylinder are slowly pulled distally to roll the ring off the finger.

Emergency Department also maintains a sharp pair of diagonal pliers that can be effective at cutting small rings.

Pass the finger guard of the ring cutter between the ring and the digit at the thinnest part of the ring (**Figure 101-8**). Care should be taken to place the ring cutter correctly and avoid additional injury. The ring may be squeezed using a heavy needle driver, hemostat, or pliers to change its shape from round to oval to facilitate passage of the finger guard (**Figure 101-9**). This additional distortion of the ring will not further exacerbate the entrapment.[15] Lower the cutting blade onto the ring. Turn the turn key to rotate the blade while maintaining pressure on the ring. Continue turning the turn key until the blade completely cuts through the ring. Pry the ring open with two hemostats or needle drivers once it is completely cut through and remove the ring. An alternative to one cut and prying the ring open is to make two cuts on opposite sides of the ring so that it falls apart in two pieces.

If an open wound is present, it should be irrigated with normal saline to remove any small metal fragments that may result from the cutting process. There has been a case report of a foreign body granuloma caused by metal particles left in a finger wound in a patient following ring removal.[16]

VICE-GRIP PLIERS TECHNIQUE

Many rings cannot be removed with the previously described techniques. These rings can be of a material that also cannot be cut with a carbide, diamond, or metal cutting disk on a ring cutter. This includes rings made of ceramics, natural stone (e.g., jade or onyx), and tungsten carbide. These rings can be removed by cracking them into pieces in a controlled fashion using a vice-grip pliers.

A medium-sized vice-grip pliers is usually appropriate for most ring sizes. Open the jaws of the vice-grip pliers. Adjust the

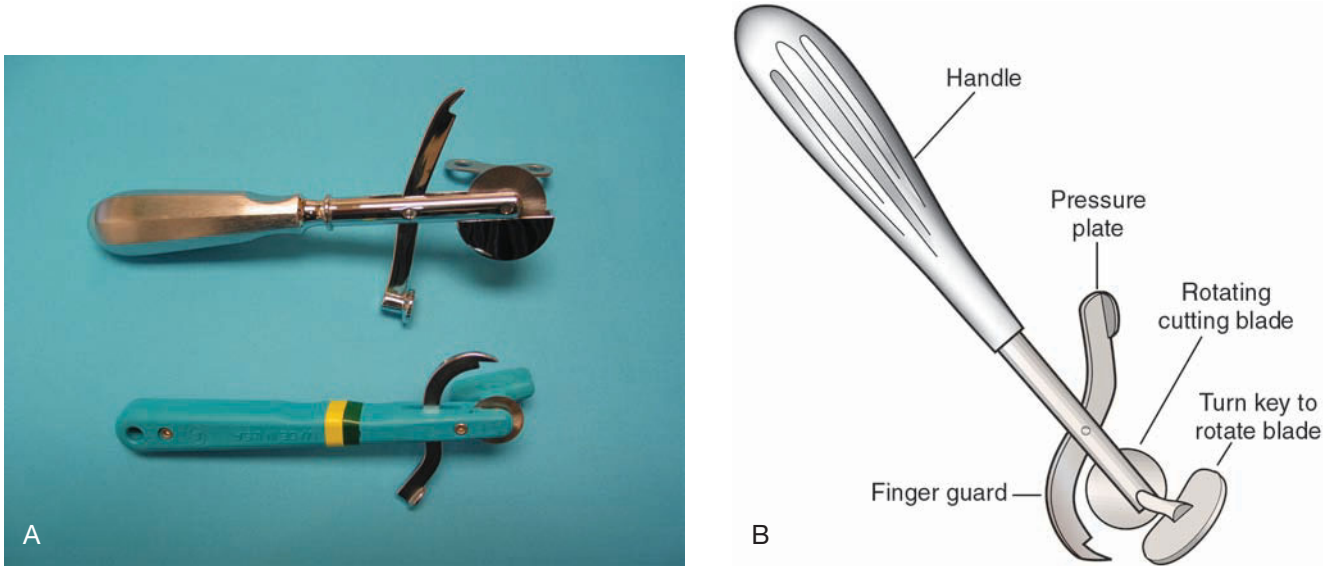


FIGURE 101-6. Manually operated ring cutters. **A.** Examples of manually operated ring cutters. **B.** The anatomy of a ring cutter.

tightening screw so that the closed jaws of the vice-grips fit over the ring (**Figure 101-10**). Close and clamp the vice grip so that the jaws close lightly on the ring. Release the jaws, turn the tightening screw one-quarter of a turn, and reclamp the jaws on the ring. Continue this process of releasing the jaws, turning the tightening screw one-quarter of a turn, and reclamping the jaws on different places of the ring each time until a crack is heard. Keep continuing this process of tightening the jaws and reclamping different areas of the ring until the ring breaks into pieces and falls off.

ALTERNATIVE TECHNIQUES

Patients may rarely present with other heavy circular objects on their digits such as steel rings, nuts, or washers that cannot be removed using a manually operated ring cutter. Powered cutting tools such as heavy-duty saws and bolt cutters may be needed to remove these objects. Battery-powered ring cutters may be ideal in these situations. Power saws and Dremel tools with carbon blades have been used to successfully remove hardened steel rings from a patient's fingers.[5] **If it becomes necessary to use a powered metal cutting device, additional care should be taken to protect the patient from secondary injury from the cutting element and the heat these powered devices may generate.**

ASSESSMENT

Thoroughly examine the finger for any injuries after the ring is removed. Reassess perfusion to the digit by noting the capillary refill time, the color, and the pulse oximeter reading on the affected digit compared to adjacent fingers.



FIGURE 101-7. The GEM Ring Cutting System (Mooney & Co., Ashland, OR). A battery-powered and motorized ring cutter.

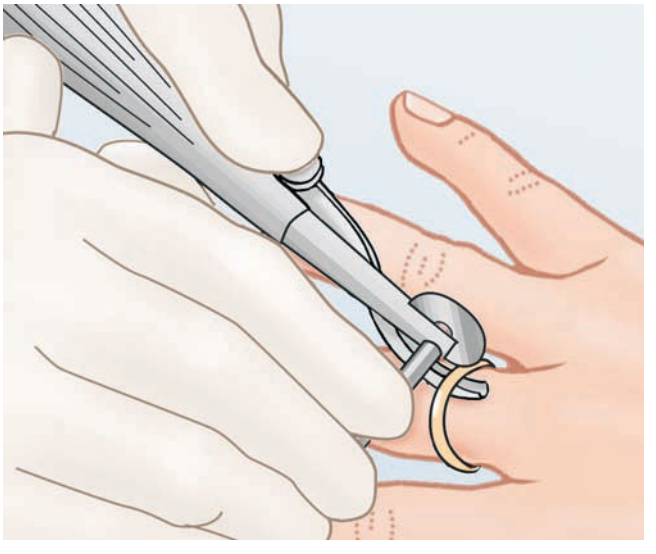


FIGURE 101-8. Ring removal using a manual ring cutter.



FIGURE 101-9. A pair of pliers is used to make the ring "oval" in shape. This may facilitate the use of a ring cutter.

AFTERCARE

No specific aftercare is required following the ring removal process. Elevation, nonsteroidal anti-inflammatory agents, and local wound care are all that is necessary. Consultation with a Hand Surgeon, Orthopedic Surgeon, Plastic Surgeon, or Podiatrist is recommended in severe cases that include embedded rings, infections, vascular compromise, and/or neurologic compromise. The aftercare is based on any lacerations and/or fractures of the digit. The patient's tetanus immune status should be ascertained and, if the skin is broken, the appropriate tetanus prophylaxis administered. Instruct the patient not to place any rings on the digit until the edema has completely resolved. Place the ring, and any pieces, in a specimen container and return it to the patient.

COMPLICATIONS

The direct complications of ring removal are minor compared to the complications that may occur from failure to remove a ring. Direct complications include secondary injury to soft tissues, vascular structures, and nerves and granuloma formation. This can be due to passing objects and instruments under an extremely tight ring or from improperly used instruments to remove the ring.

Ring cutters have their own specific issues. It may cut too slowly. Ensure that you are using the proper cutting technique. The cutting disk may be worn, dull, or the wrong cutting disk for the material.

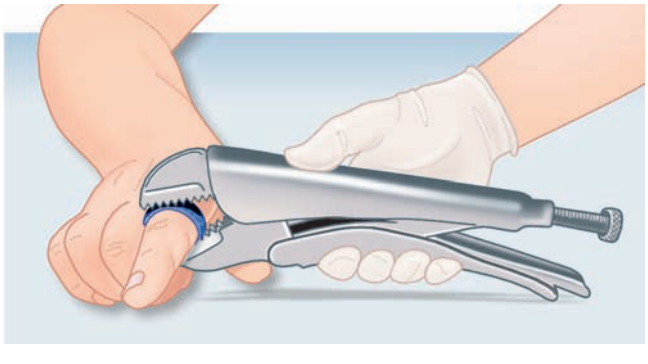


FIGURE 101-10. A vice-grip pliers can be used to remove hard or brittle rings.

Check that the proper cutting disk is on the ring cutter and that it is not dull or worn. Install fresh batteries or recharge them to maximize the power of the electric ring cutter. The ring, and the patient's finger, can become quite hot and burn the patient. Periodically check the progress and make sure that the ring has not been cut and you are now cutting the finger guard. Using a cutting disk that is dull, worn, or incorrect can generate significant heat. Correct these issues. Submerge the finger in ice water for a few minutes then resume cutting the ring.

SUMMARY

Ring removal is a relatively straightforward and simple procedure. In situations in which the ring is extremely difficult to remove, a variety of potential approaches may assure success. Use of the ring cutter is the most reliable and quickest technique. The decision to use a ring cutter should be based upon the urgency with which the ring must be removed and not upon the monetary or sentimental value of the ring.

102 Subungual Hematoma Evacuation

Steven H. Bowman

INTRODUCTION

The fingertips are sensitive, mobile, and prone to injury. Blunt trauma to the tip of the finger or toe may result in a variety of injuries including fractures, avulsions to the nail and nail apparatus, contusions, lacerations, and amputations. The most common injuries to the distal fingers and toes are crush injuries. The most common mechanisms of injury are closure of some type of door (car, house, etc.) on the finger, dropped objects on the fingers or toes, hand tools, and power tools.

Subungual hematomas often develop following blunt trauma to the distal finger or toe.[1–3] They result from the accumulation of blood between the nail and the nail bed. Treatment of a subungual hematoma is relatively straightforward, yet in some cases it is still controversial. It is important to understand the structure of the distal finger or toe, to determine whether simple drainage will be sufficient management, and to consider how initial management may affect outcome.

ANATOMY AND PATHOPHYSIOLOGY

The distal digits of the fingers and toes and the nail apparatus are complex structures (**Figure 102-1**). The perionychium is composed of the nail bed and the surrounding soft tissue. The hyponychium is the junction of the nail bed at the sterile matrix and the fingertip skin beneath the distal margin of the nail. The eponychium is the distal portion of the nail fold where it attaches to the proximal surface of the nail. The lunule is the white arc seen in the proximal portion of the nail. The nail bed consists of the germinal matrix on the proximal ventral floor of the nail fold and the sterile matrix, which extends from the lunule to the hyponychium. The germinal matrix is primarily responsible for the growth of the nail, with a significant contribution from the sterile matrix.[4,5] The nail bed must be smooth for normal nail growth. A nail matrix that has not been well approximated to minimize scar formation may develop a deformed nail.[1,3–8]

The nail bed receives its blood supply from the two terminal branches of the volar digital artery, which communicate to form

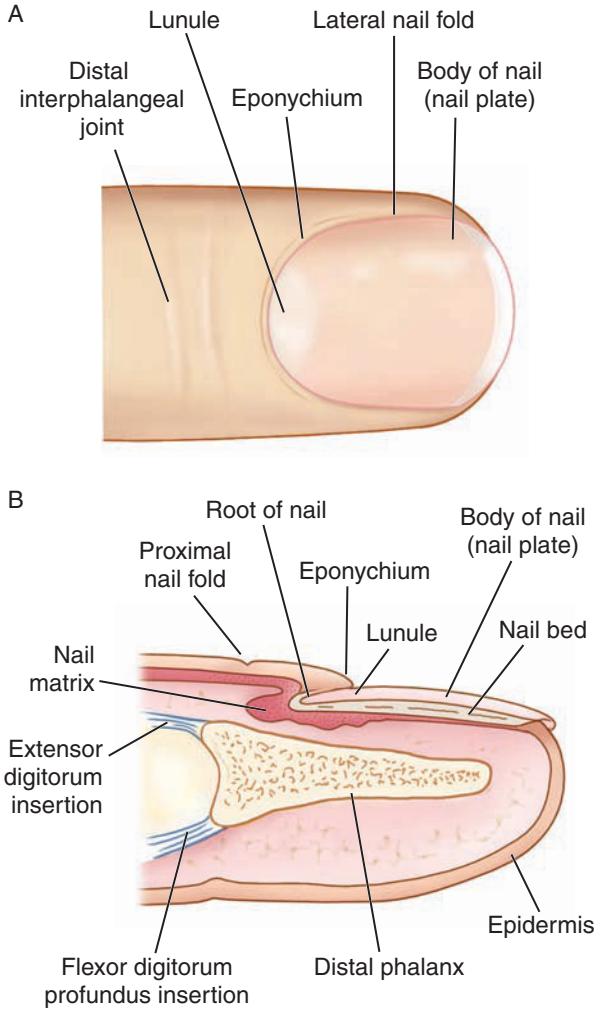


FIGURE 102-1. The anatomy of the distal fingertip and nail bed. **A.** Surface anatomy. **B.** Midsagittal view.

blood sinuses. Venous drainage begins at the proximal portion of the nail bed and the skin proximal to the nail fold.[4]

Force applied to the tip of the finger or toe disrupts the vascular structures in the nail bed. Trauma causes the capillaries of the nail bed to be compressed between the nail and the distal phalanx. Blood collects between the nail bed and the nail, forming a subungual hematoma (**Figure 102-2**). The patient's pain is directly related to the injury itself and the increased pressure from the hematoma. The hematoma appears as a black-and-blue or black-and-purple area under the nail that is extremely tender to palpation.

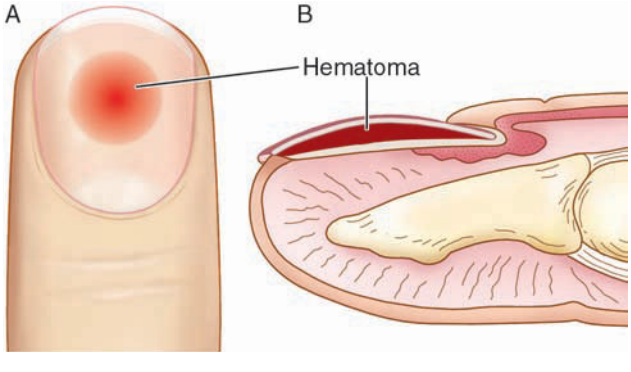


FIGURE 102-2. The subungual hematoma. **A.** Surface view. **B.** Sagittal view.

Nail bed injuries may be classified as simple lacerations, stellate lacerations, severe crush injuries, and avulsions.[1] It is important to understand that each of these types of nail bed injuries may result in a subungual hematoma.

The management of subungual hematomas is still somewhat controversial. The approach to management was initially very aggressive, since subungual hematomas are often seen with fractures of the distal phalanx, damage to the nail, and damage to the nail apparatus.[1,2,4–8] The surgical literature generally recommends removal of the nail, inspection of the nail bed, and repair of any nail bed injury if the subungual hematoma involves 25% or more of the nail surface.[1,2,4–9] This practice has been questioned recently by newer controlled studies that demonstrated excellent outcomes in patients with large (greater than 25%) subungual hematomas treated by trephination alone, regardless of the presence of fractures.[11,12] Larger hematomas involving over 50% of the nail surface may be treated successfully with trephination. Many authors, primarily Hand Surgeons, still advocate the removal of the nail plate to thoroughly inspect the nail bed and effect repair in all patients who present with a subungual hematoma. Although this approach is time-honored, more recent studies have demonstrated that it is not necessary if the patient's nail is still attached to the matrix, even in the presence of a distal phalanx fracture.[11,12]

INDICATIONS

Patients who present to the Emergency Department after sustaining an injury with a resultant subungual hematoma will generally complain of severe pain. Trephination, the process of making a small hole in the nail to allow the collected blood to escape, will provide significant relief for most patients.[2,9] **The trephination procedures described below should be utilized when patients present with a subungual hematoma and an intact (not fractured or avulsed) nail plate that is still attached to the matrix. If the nail plate is partially or completely avulsed from the matrix, simple evacuation of the hematoma may not constitute adequate therapy.**[9,10,11,13]

CONTRAINDICATIONS

Simple trephination is reserved for patients with intact nails. **Patients who present with nail plate fractures, avulsions of the nail plate, disruption of the nail margin, or partial amputations may require more extensive therapy with removal of the nail plate and repair of the nail bed.** A description of these techniques is provided in Chapters 96 and 104. Trephination using heat-based methods should be avoided in patients wearing artificial nails due to the potential for igniting the nail or nail adhesive.[13] **Subungual hematomas that extend proximal to the nail bed often represent proximal nail plate avulsions or injuries that require nail plate removal, nail plate repair or reinsertion, and nail bed repair.**

EQUIPMENT

Digital/Metacarpal Block

- Povidone iodine or chlorhexidine solution, or an isopropyl alcohol pad
- 3 mL syringe
- 25 or 27 gauge needle, 1 in. long
- Local anesthetic solution without epinephrine

Electrocautery

- Povidone iodine or chlorhexidine solution, or an isopropyl alcohol pad
- Battery-powered electrocautery device

Paper Clip Technique

- Povidone iodine or chlorhexidine solution, or an isopropyl alcohol pad
- Heat source (open flame)
- Paper clip
- Hemostat

Drill Technique

- Povidone iodine or chlorhexidine solution, or an isopropyl alcohol pad
- 18 gauge needle
- Cotton-tipped applicators

The PathFormer (Path Scientific, Carlisle, MA) is an FDA approved device for nail plate trephination. It allows for the precise control of the depth of penetration while making a 400 μm diameter hole in the nail plate. The device is a battery-powered drill that automatically retracts the drill bit after the nail plate is penetrated. Thus, the sensitive and vascular nail bed is not contacted or injured. Unfortunately, the PathFormer device is not often available in Emergency Departments.

PATIENT PREPARATION

Explain the procedure to the patient and emphasize that pain relief rapidly follows nail trephination. Obtain a consent to perform the procedure. Consider obtaining radiographs for significant traumatic injuries, suspected associated fractures, or any injury where the nail plate is damaged or avulsed. Place the patient in a sitting or semi-recumbent position on a gurney or multipositional procedure chair. Sit facing the patient. Place the hand with the injured digit palm side down on a flat surface such as a procedure table. Cleanse the injured digit of any dirt and debris. Apply povidone iodine or chlorhexidine solution over the nail plate and allow it to dry. An alcohol swab is an alternative to these solutions. **Always allow the alcohol to dry before touching the nail plate with a hot object so that the alcohol does not ignite.** A digital block is generally not needed if using heat-based methods to penetrate the nail plate.[2,5,9,13] The nail plate is not innervated and the hematoma prevents contact with the nail bed. A digital block may be required if the patient is excessively anxious, if additional injury is present, or if a drill technique is to be performed. Refer to Chapter 126 for the complete details regarding digital and metacarpal blocks. An alternative to the digital block is to soak the affected finger in ice water for a few minutes prior to the procedure. The techniques described below may be used on fingernails and toenails.

TECHNIQUES

ELECTROCAUTERY TECHNIQUE

Electrocautery is the preferred technique to drain a subungual hematoma. Battery-operated microcautery devices are generally available in the Emergency Department (**Figure 102-3**). Assure the patient that they will not be burned. Stabilize the injured digit proximally with the nondominant hand. Grasp the cautery unit like a pencil with the dominant hand. Press the button on the cautery unit to heat the tip. Release the button and allow the tip to cool for 1 to 2 seconds. This may prevent penetrating the nail plate too quickly and damaging the underlying nail bed. Place the hot tip on the nail plate, centered over the hematoma (**Figure 102-4**). **Tap the nail plate several times with the cautery pen tip. Do not constantly hold the hot tip against the nail plate.** The cautery tip will easily penetrate the nail plate. **Do not plunge as the nail bed can be injured in addition to causing additional pain to the patient.**

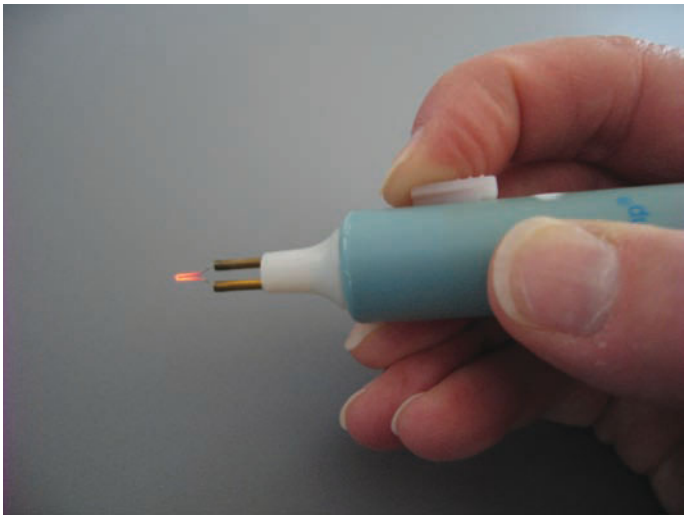


FIGURE 102-3. The battery-operated electrocautery device.

Darkened blood will flow out of the hole when the hematoma is entered. The nail will regain its normal color after the hematoma is drained. Apply slight digital pressure to the nail plate to ensure complete drainage of the hematoma. The patient will usually begin to feel pain relief at this point.

The tips of some microcautery devices are shaped in such a way that they will not make a hole that is wide enough to allow adequate drainage. Slightly rotate the cautery unit as it traverses the nail plate to ensure an adequate sized drainage hole of 3 to 4 mm. Some Emergency Physicians prefer to make an additional hole in the nail plate to ensure drainage if the first hole should become occluded.

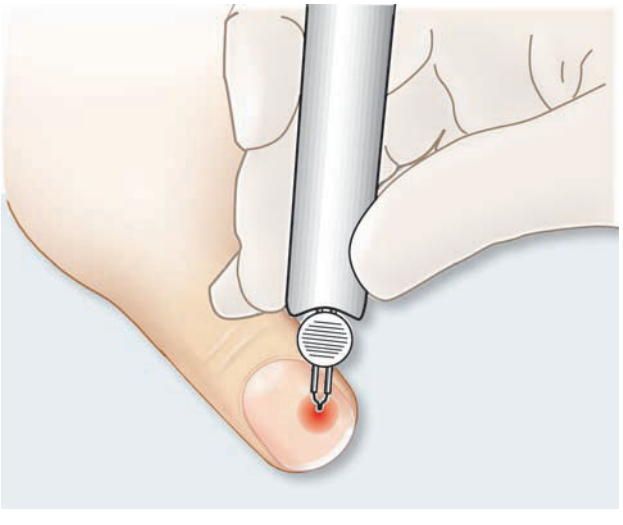


FIGURE 102-4. The electrocautery technique. The hot tip of the unit is centered over the subungual hematoma and allowed to penetrate the nail plate.

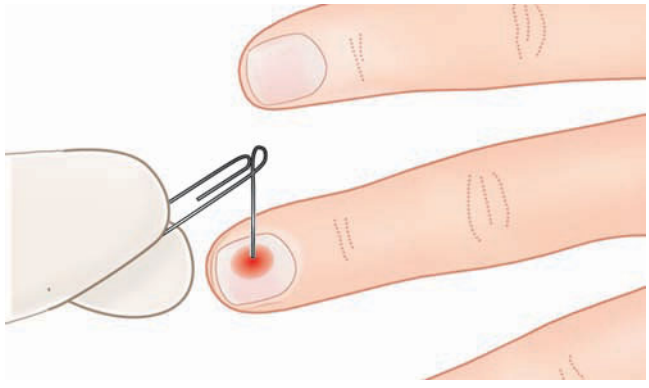


FIGURE 102-5. The paper clip technique. The hot tip of the paper clip is centered over the subungual hematoma and allowed to penetrate the nail plate.

As an alternative to the single large hole, place three to four smaller drainage holes in the nail plate.

PAPER CLIP TECHNIQUE

This technique is similar to that using the electrocautery unit. Unfold and heat the tip of a paper clip with a flame from a lighter or alcohol lamp. Place the heated tip of the paper clip against the nail plate, centered over the subungual hematoma (**Figure 102-5**). Apply slight downward pressure to allow the paper clip to perforate the nail plate. **Do not plunge as the nail bed can be injured in addition to causing additional pain to the patient.** A drop of blood will be seen as the paper clip enters the hematoma. Place at least one additional hole in the nail plate to ensure drainage if the first hole should become occluded.

The paper clip will not get as hot as a cautery device. More than one attempt may be necessary to penetrate a thick nail. Another disadvantage of this technique is the possibility of introducing carbonaceous material into the hole. The use of an open flame may be potentially dangerous or prohibited in the Emergency Department.

DRILL TECHNIQUE

This technique uses a needle as a small drill to penetrate the nail plate (**Figure 102-6**). Small electric nail drills are available that greatly simplify this procedure, though they may not be readily available in the Emergency Department. Drilling through the nail plate may require a digital block. This is particularly true if there is a fracture, another associated injury, or the nail plate is very thick. Grasp an 18-gauge needle by its hub with the dominant thumb and forefinger (**Figure 102-6A**). Place the tip of the needle over the nail plate, centered over the subungual hematoma. Spin the needle back and forth while applying gentle downward pressure. Small shavings will appear as the needle begins to drill through the nail plate. A loss of resistance will be felt as the hematoma is entered and darkened blood will flow from the hole. **Do not plunge as the nail bed can be injured in addition to causing additional pain to the patient.** Place at least one additional hole in the nail plate to ensure drainage if the first hole should become occluded.

The editor uses a modified version of this technique (Reichman, personal communication). A cotton-tipped applicator may be wedged into the needle hub to facilitate the drilling (**Figure 102-6B**). This method makes the drilling more efficient, as the cotton-tipped applicator is easier to hold and offers a mechanical advantage when it is twisted. The drill technique is very useful in the absence of a heat-generating device.

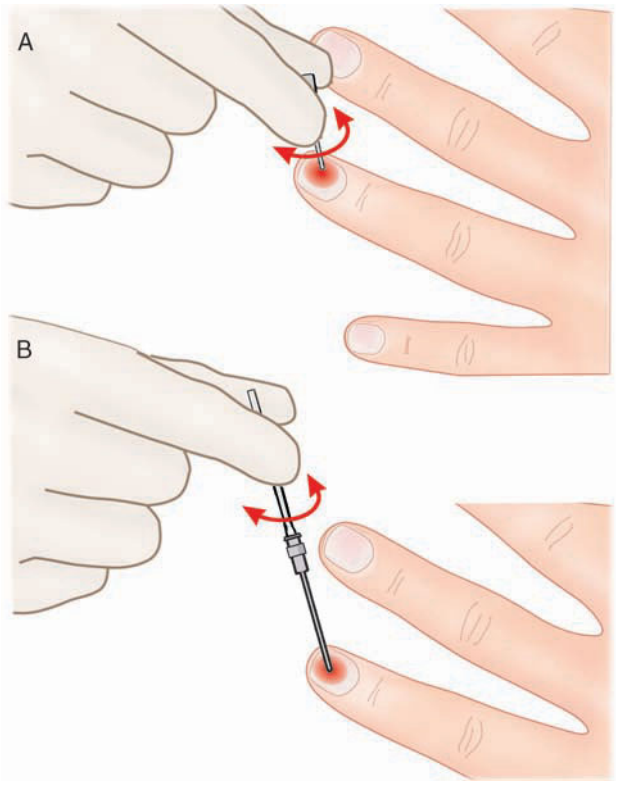


FIGURE 102-6. Drill techniques. **A.** A twisting motion of the 18 gauge needle is used to penetrate the nail plate. **B.** A cotton-tipped applicator has been inserted into the hub of the needle. A twisting motion is used to penetrate the nail plate.

ASSESSMENT

Gently compress the nail plate to evacuate the hematoma. Any underlying injury should be evaluated and managed.

AFTERCARE

The patient should keep the wound clean and monitor drainage. The nail plate may be covered with a nonadherent dressing. The hematoma may continue to drain for several hours or up to 1 to 2 days. If there is a reaccumulation, denoted by the reappearance of darkened blood beneath the nail, the nail can be soaked in warm water and pressure applied to express the hematoma. Inform the patient that the discoloration under the nail plate can persist for several weeks. Also inform them that the nail plate may fall off and it can take up to 3 months for another nail plate to completely form. A splint should be applied if a distal phalanx fracture is present. No studies have demonstrated that prophylactic antibiotics are beneficial in the management of a subungual hematoma.[9,14] The patient should immediately return to the Emergency Department or their primary physician for fever, increased pain, purulent drainage from the nail, or any redness or swelling of the digit.

COMPLICATIONS

Direct complications from nail trephination are rare.[11–13] Complications will more likely result from the original injury and include nail loss, nail deformity, cosmetic changes, and infection. Patients should be warned that as the nail grows out, loss of the nail is a possibility. The hematoma may reaccumulate if the hole in the nail is too small and becomes occluded. Reaccumulation can be

prevented by making a large hole or multiple holes in the nail plate. Plunging through the nail plate with a cautery unit or needle will cause the patient pain and injury to the nail bed that may be permanent and result in a deformed nail plate.

SUMMARY

Fingertip injuries are common. Patients will often present to the Emergency Department with a subungual hematoma and a complaint of pain. Rapid relief of pain and good outcomes can be obtained in the majority of cases by simply performing a nail trephination. It is important to distinguish when trephination alone will not be adequate therapy. Patients presenting with nail plate fractures, avulsions of the nail plate, or partial finger amputations will require removal of the nail plate and repair of the nail bed.

103 Subungual Foreign Body Removal

Steven H. Bowman

INTRODUCTION

Subungual foreign bodies are often difficult to treat. Foreign bodies such as wood or metal splinters, pencil lead, thorns, spines, or hair may become lodged beneath the fingernail.[1–3] Tradesmen such as carpenters, landscapers, auto mechanics, and individuals who work without hand protection with materials that produce small splinters are at risk for this type of injury. Subungual foreign bodies may also present less commonly under the toenails.

Patients generally present for medical intervention with pain after unsuccessfully attempting to remove the foreign body. Prior removal attempts often result in breakage of the foreign body or pushing it further beneath the nail; both of which complicate the next extraction attempt. Left untreated, retained subungual foreign bodies often become infected or cause tissue reactions and granuloma formation. These injuries may be treated rapidly with complete removal of the foreign body and without causing additional patient discomfort.

ANATOMY AND PATHOPHYSIOLOGY

The distal fingertip and nail apparatus are complex structures (**Figure 103-1**). The perionychium is composed of the nail bed and the surrounding soft tissue. The hyponychium is the junction of the nail bed at the sterile matrix and the fingertip skin beneath the distal margin of the nail plate. The eponychium is the distal portion of the nail fold where it attaches to the proximal surface of the nail plate. The lunule is the white arc seen on the proximal portion of the nail plate. The nail bed consists of the germinal matrix on the proximal ventral floor of the nail fold and the sterile matrix that extends from the lunule to the hyponychium. The germinal matrix is primarily responsible for the growth of the nail. The subungual space is the area immediately beneath the nail plate.

Foreign bodies may enter the subungual space at the distal fingertip beneath the nail, or may penetrate the nail plate directly (**Figure 103-2**). In either event, separation of the nail from the nail bed results in severe pain. Patients frequently attempt to remove the foreign body immediately because of this intense pain. An infection or foreign body reaction will often ensue if the foreign body is not removed in its entirety.

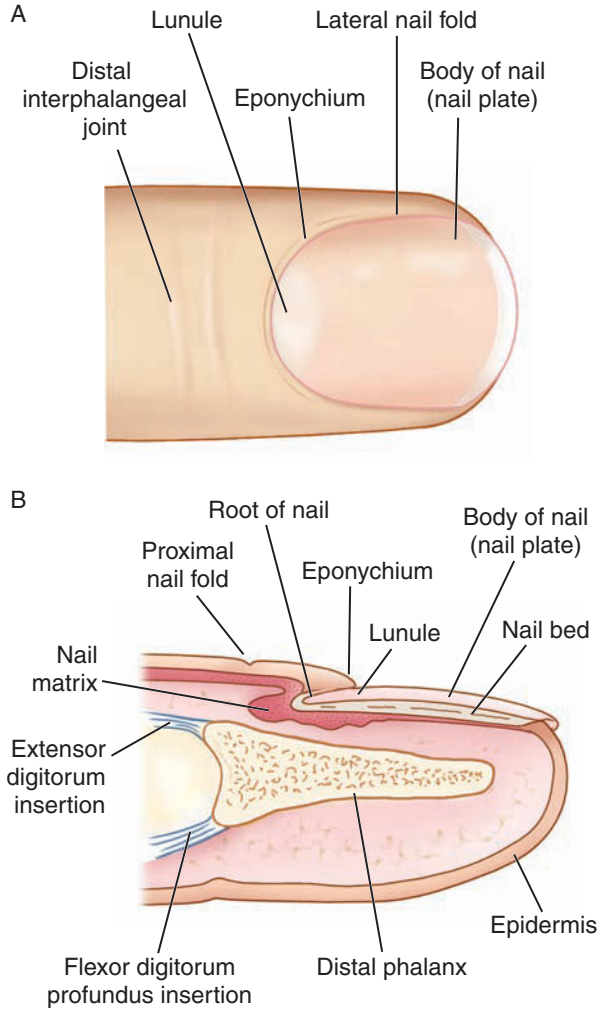


FIGURE 103-1. The anatomy of the distal fingertip and nail bed. **A.** Surface anatomy. **B.** Midsagittal view.

INDICATIONS

Subungual foreign bodies should be removed to prevent the complications of infection, foreign body reaction, and possible nail deformity. Deeply embedded foreign bodies, splintered foreign bodies, those that traverse the nail plate, or contaminated foreign bodies may require the removal of the nail plate to extract the foreign body. Refer to Chapter 104 regarding the details of removing the nail plate. Consult a Hand Surgeon if the foreign body cannot be removed, if the site is infected, if the foreign body is "chronic"

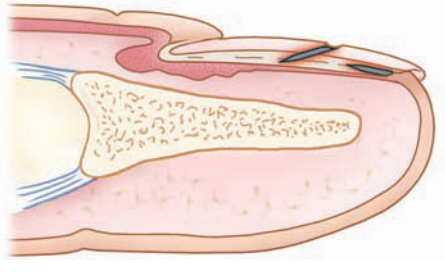


FIGURE 103-2. Subungual foreign bodies can enter from under the distal nail plate or through the nail plate.

and an osteomyelitis is present on radiographs, or if significant injury to the digit is present.

CONTRAINDICATIONS

There are no absolute contraindications to the removal of a subungual foreign body.

EQUIPMENT

General Supplies

- Povidone iodine or chlorhexidine solution
- Alcohol swabs
- Sterile saline solution
- Topical antibiotic ointment
- Nonadherent dressing (e.g., petrolatum gauze)
- 4 × 4 gauze squares
- Adhesive tape

Digital/Metacarpal Block

- 3 mL syringe
- 25 or 27 gauge needle, 1 in. long
- 3 to 5 mL local anesthetic solution without epinephrine

Scrape Technique

- Splinter forceps
- #11 or #15 scalpel blade on a handle

Wedge Technique

- Splinter forceps
- Tissue scissors or nail clippers

Needle Technique

- Needles, 19 and 25 or 27 gauges
- Splinter forceps
- Hemostat

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Obtain an informed consent for the procedure. Ascertain the patient's tetanus immune status and administer the appropriate tetanus prophylaxis. The Emergency Physician should attempt to gain the patient's cooperation. Place the patient sitting or in a semi-recumbent position with their hand on a bedside procedure table. Clean any dirt and debris from the affected finger. Apply povidone iodine or chlorhexidine solution and allow it to dry. Any manipulation of the nail bed will result in additional patient discomfort. Determine the need for a digital or metacarpal block depending on the type and extent of the foreign body and the removal technique. Please refer to Chapter 126 for the complete details regarding anesthesia of the finger or toe. Radiographs are not required unless a metallic foreign body cannot be visually located or the clinical suspicion exists for an osteomyelitis or a gas forming finger infection.

TECHNIQUES

Foreign bodies protruding through or from underneath the nail plate may be grasped with a forceps and removed. A scalpel blade or 18 gauge needle may be used to entrap a small protruding tip of the foreign body against the nail plate and draw it out. **Do not attempt to remove the foreign body through a puncture wound or small incision.** Enlarging the access site allows for easier removal, not breaking or fragmenting the foreign body, and complete removal. Superficially located subungual foreign bodies may be removed by one of the following techniques.

SCRAPE TECHNIQUE

This technique has been described anecdotally.[4,5] It appears promising as it does not require the administration of a digital block and causes less trauma to the nail and the nail bed compared to other techniques. This technique works well for subungual foreign bodies that either traverse the nail plate or are lodged beneath the distal or middle portion of the nail.

Support the patient's hand on a procedure table. Sit on a chair facing the patient. Place a #11 or #15 scalpel blade on the nail plate and directly over the foreign body (**Figure 103-3A**). Hold the blade perpendicular to the surface of the nail plate. Draw the scalpel blade from proximal to distal using short strokes and gentle pressure over the foreign body (**Figure 103-3A**). A small shaving of the nail plate is removed with each stroke of the scalpel blade. The finger may be soaked in lukewarm water for 15 to 20 minutes to soften the nail plate if it is thick and difficult to shave. Continue to remove successive slivers of the nail plate to eventually create a U-shaped defect and expose the foreign body (**Figure 103-3B**). Grasp the foreign body with a splinter forceps and remove it once a significant portion protrudes. The defect created in the nail plate will move distally and eventually be replaced as the nail plate continues to grow.

WEDGE TECHNIQUE

The wedge technique works well for subungual foreign bodies lodged beneath the distal portion of the nail plate.[1,6] Patients will require a digital or metacarpal block prior to attempting this technique since it involves manipulation of the nail bed.

Sit on a chair facing the patient. Cut a triangular wedge from the distal portion of the nail plate overlying the foreign body with a small pair of tissue scissors or nail clippers (**Figure 103-4A**).

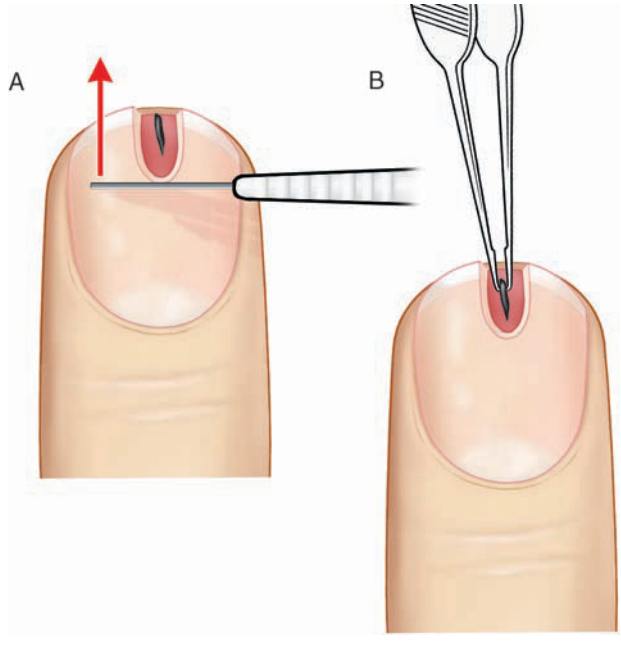


FIGURE 103-3. The scrape technique. **A.** With the scalpel blade held 90° to the nail bed, strokes are made in a proximal to distal direction. A U-shaped defect will be created to expose the foreign body. **B.** The foreign body is grasped and removed with a forceps.

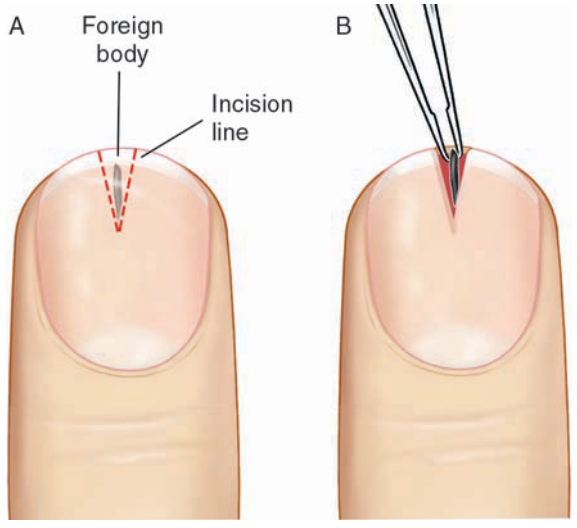


FIGURE 103-4. The wedge technique. **A.** A triangular incision is made in the nail plate overlying the foreign body. **B.** The cut section of the nail plate has been removed. The foreign body is grasped with a forceps and removed.

Prevent iatrogenic injury to the nail bed by ensuring that the tip of the scissors under the nail plate is aimed upward and against the nail plate. Remove the wedge of nail. This will provide enough exposure to grasp and remove the foreign body with splinter forceps (**Figure 103-4B**).

NEEDLE TECHNIQUES

The needle technique works well for subungual foreign bodies located beneath the distal portion of the nail plate.[1] Patients will require a digital or metacarpal block prior to attempting this technique. Insertion of a needle into the nail bed is extremely painful. The major drawback of this technique is the potential for leaving fragments of the foreign body beneath the nail plate.

Sit in a chair facing the patient. Introduce a 19-gauge needle beneath the nail plate and along the track of the foreign body (**Figure 103-5A**).[7] Use the tip of the needle to touch the foreign body. Lower the hub of the needle to raise its tip and trap the foreign body between it and the nail plate. Withdraw the needle while dragging the foreign body out along the nail plate. Alternatively, tease out and move the foreign body distally until it can be grasped with a splinter forceps.

Two alternate techniques have also been described for the needle extraction of a subungual foreign body.[7,8] The first is a modification of the needle technique.[7] Place a hook in the distal end of a 25 or 27 gauge needle with a hemostat or needle driver (**Figure 103-5B**). Pass the bent needle along the foreign body tract. Grasp the foreign body with the tip of the bent needle. Withdraw the needle to move the foreign body distally so that it may be grasped with a splinter forceps. A third technique involves the excision of a small portion of the nail plate overlying the foreign body with an 18 gauge needle.[8] This is similar to the shave technique with the exception of an 18 gauge needle being used instead of a scalpel blade.

ASSESSMENT

The subungual area should be inspected for any remaining fragments of the foreign body that may have broken off in the nail bed. **Any remaining fragments of the foreign body must be removed.** Refer the patient to a Hand Surgeon if the foreign body fragments cannot be removed.

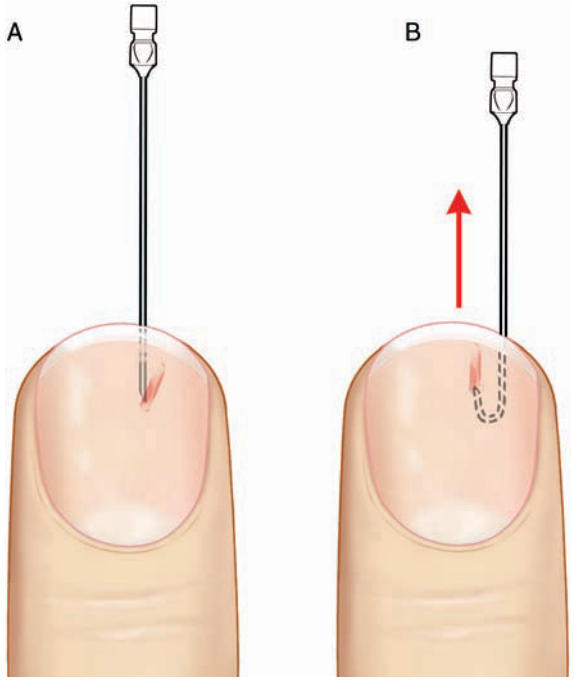


FIGURE 103-5. Needle techniques. **A.** A 19 gauge needle is inserted along the tract of the foreign body. The tip is used to tease the foreign body out of the tissues. **B.** The tip of a 25 or 27 gauge needle has been formed into a hook with the aid of a hemostat. The needle is inserted along the tract of the foreign body. The tip is used to grasp the foreign body and pull it out of the tissues.

AFTERCARE

In most cases, local wound care and the application of a topical antibiotic are all that is required. Irrigate the foreign body tract and excision site with sterile saline. Apply topical antibiotic ointment to the area. Apply a nonadherent dressing over the nail. Follow-up with a Hand Surgeon and systemic antibiotics may be necessary in severe cases, such as the presence of a nail deformity or chronic foreign bodies with an infection. Postprocedural pain can be managed with acetaminophen or nonsteroidal anti-inflammatory drugs. The use of prophylactic antibiotics is not recommended unless the foreign body was contaminated or had deeply penetrated into the soft tissue of the digit. Instruct the patient to return immediately to the Emergency Department if they develop any signs of an infection (i.e., purulent drainage, increased tenderness, redness or swelling of the digit, or fever).

COMPLICATIONS

There are a few potential complications from subungual foreign body removal. Damage to the nail bed can result in a residual nail deformity. Failure to completely remove a subungual foreign body may result in a nail deformity, an infection, or a foreign body reaction with granuloma formation. An infection can result from a contaminated foreign body, flora on the nail plate or skin driven into the soft tissues by the foreign body, or if aseptic technique is not followed.

SUMMARY

Patients with subungual foreign bodies often present in severe pain after prior unsuccessful attempts at removal or after complications develop. Though sometimes challenging, it is important that the

Emergency Physician completely remove the foreign material in the subungual space to prevent further complications. Providing adequate anesthesia and using the appropriate instruments and techniques allows the successful removal of most subungual foreign bodies in the Emergency Department.

104 Nail Bed Repair

Raemma Paredes Luck and Eric F. Reichman

INTRODUCTION

The fingertip, the most sensitive area of the hand, is often our first contact with the environment. It has important functional roles in grasping and pinching, in addition to its sensory and cosmetic functions.[1,2] The fingernail protects the fingertip and provides increased sensation to the volar pulp.[3] However, it also conceals the true extent of fingertip injuries. Hand injuries, with the fingertips most frequently involved, are second only to back injuries as the most common occupational injuries resulting in loss of work days.[4] Hence, it is important for the Emergency Physician to evaluate the full extent of the injury, to assess potential disabilities, and to recognize the need for prompt referral to a Hand Surgeon.

The fingernails are frequently injured due to their anatomic location and their functional role. Immediate primary repair is the ideal management when these injuries involve the nail bed and surrounding skin fold structures.[3,5] Careful repair is necessary to avoid functional impairment and cosmetic derangement of the nail plate.[6] The following discussion will refer primarily to the fingernail. The toenail has less importance, both cosmetically and functionally, as grasp and pinch are not needed. However, all the principles and recommendations made also apply to the toenail.[7]

ANATOMY AND PATHOPHYSIOLOGY

Knowledge of the anatomy of the nail unit enables the Emergency Physician to recognize the types of injuries and provide anticipatory guidance of the consequences of these injuries to the patients. The "perionychium" or the nail unit consists of the nail fold, the nail plate, nail bed, and the hyponychium (**Figure 104-1**).[1,2]

The nail plate enhances the sensibility of the fingertip by applying a counterforce to the pulp space nerve endings.[3] The digital tip and the nail plate also function in unison to smoothly coordinate normal pinch and grasp, which are important for picking up fine objects such as coins and pins.[3,8]

The nail plate is comprised of compacted, flattened, and elongated anucleated cells that originate from cornified epithelial cells.[9] There are three atomic sites where these cells exist.[5,8] The nail bed contains two of the sites: the sterile matrix and the germinal matrix.[8] The other location is the dorsal roof matrix (**Figure 104-1A**). Of these, the germinal matrix is the most important for normal nail growth.[5] The germinal matrix is responsible for approximately 90% of the nail plate by volume.[8] The sterile matrix is responsible for a small percent of the nail plate by volume and varies from individual to individual. This cell production accounts for the nail plate being thicker at its distal tip compared to its proximal origin.[8] The nail cells from the dorsal roof matrix are small in number and form a very thin layer on the surface of the nail plate. These cells are responsible for the shine of the nail. If the dorsal roof is destroyed, the nail will lose its shine and become dull.

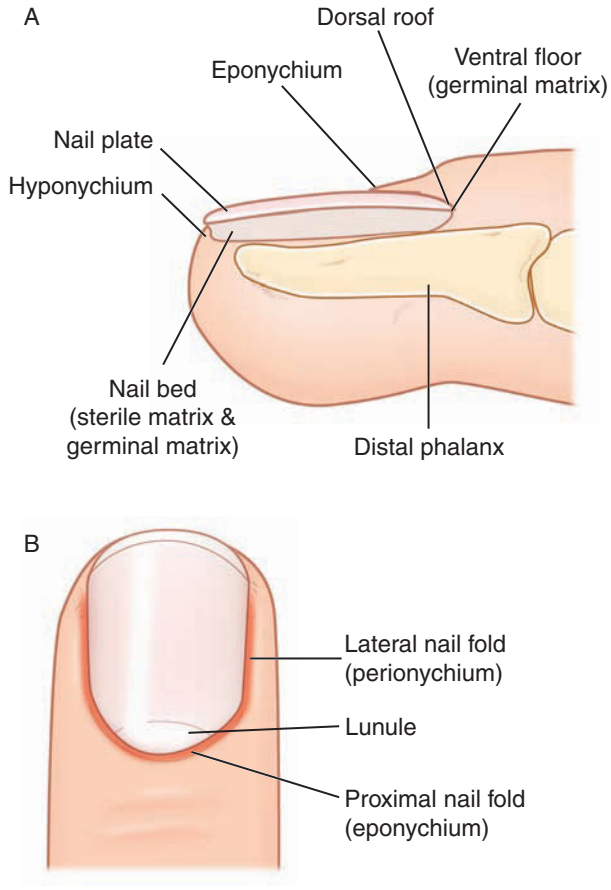


FIGURE 104-1. Anatomy of the fingernail. **A.** Lateral view. **B.** Top view. The colored area represents the perionychium.

Skin overlies the nail plate proximally and laterally (**Figure 104-1B**).[9] The proximal skin fold is referred to as the eponychium. The eponychium protects the germinal matrix located in the proximal nail bed and is the home of the dorsal roof matrix. The skin immediately over the dorsal roof is called the nail wall.[8] The lateral skin folds, the adjacent cutaneous areas, and the adjacent nail bed (germinal matrix and sterile matrix) are collectively referred to as the perionychium (**Figure 104-1B**).[6,8,9] The lunule is the pale arc just distal to the eponychium and roughly corresponds to the location of the germinal matrix.[1,2,8,9]

The nail bed is comprised of the germinal matrix proximally and the sterile matrix distally. The borders of the nail bed are the proximal nail fold, the lateral nail folds, and the hyponychium distally. The hyponychium is the thick layer of cells at the junction of the distal nail bed (sterile matrix) and the fingertip skin.[8] It is located just under the distal free margin of the nail plate (**Figure 104-1A**). The hyponychium serves as a barrier preventing the delicate nail bed from exposure to bacteria and fungi.[8]

The rate of nail growth varies from finger to finger, from individual to individual, and varies with age.[3,8] Nail growth is fastest between 4 and 30 years of age and after 80 years of age. Fingernails grow four times faster than the toenails.[1] A new nail takes a minimum of 4 months to grow, and even longer following an injury. Progression of the distal nail occurs at a rate of 0.1 mm/day or 0.5 to 1 mm/week.[3,9] This rate varies and is usually faster in fingers than in toes, and faster in the summer months.[3] The pressure of new cells being formed leads to the flattening and elongation of the older cells as well as their progression distally.[8]

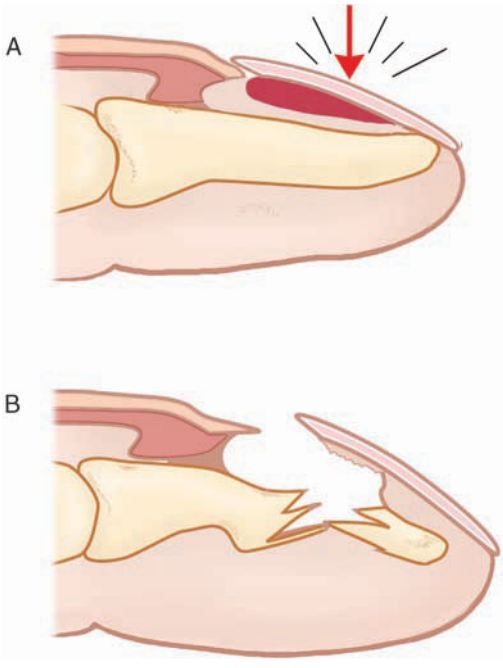


FIGURE 104-2. A crush injury to the distal fingertip. **A.** Proximal nail bed avulsion. **B.** A more severe crush injury can result in a proximal nail bed avulsion and fracture of the distal phalanx. Note that the distal nail plate remains attached to the sterile matrix in both of these injuries.

The sterile matrix is more adherent to the nail plate than to the adjacent germinal matrix. Therefore, avulsions involving nail bed tissue are more likely to occur at the sterile matrix.[8,10,11] Conversely, the nail plate is loosely held to the germinal matrix. This accounts for the peculiar injury of avulsions of the proximal nail plate from the proximal nail fold while the distal nail plate remains attached (**Figure 104-2**).

The digital artery supplies the volar radial and ulnar sides of the finger and consistently sends even smaller branches to the proximal nail fold and to the nail bed producing a rich capillary network.[1] The small veins of the nail bed, pulp, and lateral nail folds coalesce proximally to form a larger commissural vein that runs lateral to the distal phalanx and a terminal vein that runs dorsal to the distal phalanx. The digital nerve accompanies the digital artery and sends branches beyond the distal interphalangeal joint and into the nail fold, nail bed, and the finger pulp. The extensor tendon attaches itself to the distal phalanx just proximal to the germinal matrix.[8,11] The periosteum of the distal phalanx, in turn, closely adheres to the sterile matrix.[8]

With these anatomic considerations in mind, certain patterns emerge as a result of injury. Avulsions of the nail bed tend to occur in the sterile matrix rather than the less adherent germinal matrix. Another pattern of injury seen is the avulsion of the proximal nail plate from the proximal nail fold while the distal part remains attached to the nail bed (**Figure 104-2**). Because the sterile matrix closely adheres to the periosteum of the distal phalanx, fractures of the distal phalanx might injure the nail bed producing a subungual hematoma.[6] Due to the close proximity of the germinal matrix and the attachment of the extensor tendon, injuries to or repair of these structures might involve the other. A subungual hematoma is a collection of blood between the nail bed and the nail plate. Although a large subungual hematoma may require repair of the underlying nail bed, this is controversial.

Emergency Physicians must consider in each case whether there exists enough damage to require surgical nail bed repair. It is important to note that significant force is required to break, penetrate, or avulse the nail plate.[6] Therefore, the fragile nail bed is most likely disrupted if the nail plate is disrupted.

INDICATIONS

Injuries to the fingertip and nail, if not initially managed correctly, have long lasting functional as well as cosmetic consequences. The most important consideration is functional.[9] Normal nail growth after injury requires a smooth nail bed. Therefore, nail bed injuries must be meticulously repaired to prevent cosmetic deformities and functional impairment.[9–11] Scar tissue may form between the wound edges if the nail bed is not accurately approximated. This scar tissue will not form the intermediate nail cells responsible for nail adherence.[8] Furthermore, loss of the germinal matrix alone will result in permanent loss of the nail plate.[5,12] The skin folds surrounding the nail margins must also be preserved.[5,11] Failure to do so will result in the painful complication of adhesion formation between the skin fold and the nail bed.[5,11] Secondary repair of these spaces, or of the nail bed, requires more complex procedures and are usually associated with a poor outcome.[4,10] **Therefore, every effort should be made to primarily repair all significant nail bed injuries.**

CONTRAINDICATION

No absolute contraindications exist for primary nail bed repair. Any life-threatening injuries, limb-threatening injuries, and/or uncontrolled hemorrhage must be addressed prior to nail bed repair.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Restraining device(s), as necessary
- 10 mL syringe armed with a 27 gauge needle
- Local anesthetic solution without epinephrine, 1% lidocaine or 0.25% bupivacaine
- Digital tourniquet
- #15 scalpel blade on a handle
- Magnification device
- Sterile prefabricated nail, if available
- Nonadherent petrolatum gauze
- 5-0, 6-0, and 7-0 chromic gut (or polyglactin 910 or irradiated polyglactin 910) on a p-3 cutting needle
- 6-0 monofilament nylon sutures
- Needle driver
- Curved hemostat
- Fine scissors or periosteal elevator
- Forceps
- Sterile towels or drapes
- Sterile gloves
- Dry gauze/tube gauze
- Splinting material
- Battery-powered electrocautery device

The use of a digital tourniquet is essential to properly repair a nail bed. Its use provides a bloodless field, which allows for a more meticulous and precise wound approximation. Numerous options are available to use as a tourniquet in the Emergency Department. Home-grown options include the use of a sterile Penrose drain,

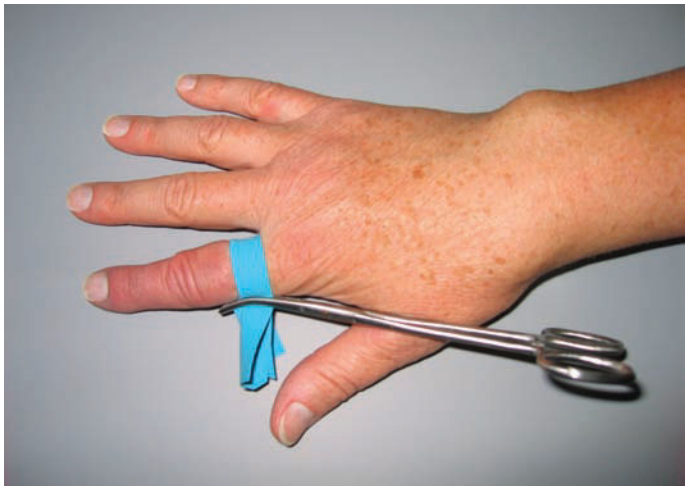


FIGURE 104-3. A sterile Penrose drain or IV tourniquet used as a digital tourniquet.



FIGURE 104-5. The Tourni-cot digital tourniquet.

rubber IV tourniquet, or sterile glove. A sterile Penrose drain or IV tourniquet secured with a hemostat is often used as these items are readily available (**Figure 104-3**). A sterile glove may be used as a tourniquet (**Figure 104-4**). Apply a sterile glove onto the patient's hand that is snug or a size one-half smaller than their actual glove size. Cut just the tip off of the glove over the affected finger(s). Roll the cut finger back and onto the proximal phalanx to form the tourniquet (**Figure 104-4**).

Several commercially produced digital tourniquets are often available in the Emergency Department. The Tourni-cot (Mar Med Co., Grand Rapids, MI) is a sterile, single use, disposable, rubber ring that slides over the fingertip and rolled backward until it rests over the proximal phalanx (**Figure 104-5**). These come in several sizes to fit the appropriate finger size. The advantage of the Tourni-cot is that it exsanguinates the digit as it is applied. The T-Ring (Precision Medical Devices LLC, San Clemente, CA) is a "one size fits all" digital tourniquet (**Figure 104-6**). It is a sterile, single use, disposable, rubber diaphragm with a central hole. It slides over the fingertip and is pushed backward until it rests over the proximal phalanx. The T-Ring also exsanguinates the digit as it is applied.

PATIENT PREPARATION

The first step in the evaluation of fingertip injuries is obtaining a thorough history. The mechanism of injury can provide some clues to the type and extent of injuries as well as amount of contamination to be expected. Other pertinent information includes age, hand dominance, occupation or hobbies, comorbidities, and tetanus vaccination status. All significant injuries to the fingertip should be evaluated radiographically for fractures. The management of fingertip injuries may differ in the presence of a fracture. Thoroughly evaluate and document a complete neurovascular examination, tendon function and intactness, and ligamentous stability of the joints. Ascertain the patient's tetanus immune status and administer prophylaxis if required.

It is important to explain both the risks of doing the procedure and of not doing the procedure. Document this conversation and obtain an informed consent. Place the patient on a gurney with the hand on a bedside procedure table in a well-lit area. Be prepared to use age-appropriate sedation or to apply appropriate restraints for children.[11] Procedural sedation may be necessary in patients who are agitated, uncooperative, or require extensive repair. Apply a type



FIGURE 104-4. A sterile glove used as a digital tourniquet.

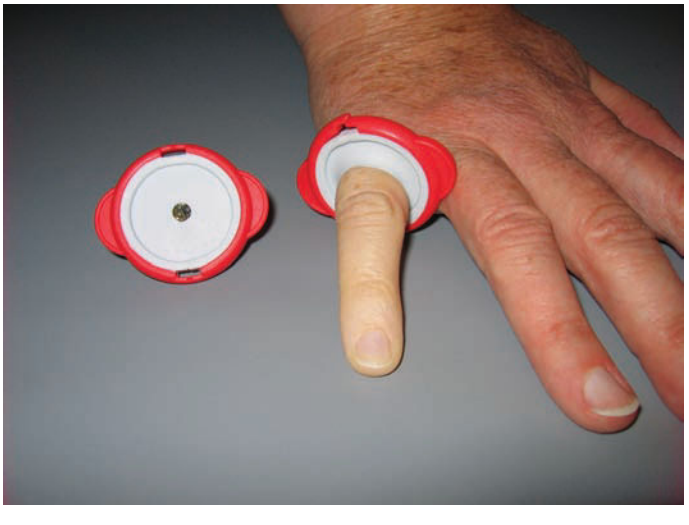


FIGURE 104-6. The T-Ring digital tourniquet.

of magnification device if available. This may consist of a head-strap device, a swing arm device, magnification glasses, or loupe magnification glasses.

Anesthetize the injured digit(s). Anesthesia may be achieved with a digital block or a metacarpal block when only a single digit is involved.[6] Lidocaine (1% or 2%) can provide pain relief of up to 3 hours. For longer analgesia, use 0.5% bupivacaine. Although recent studies have shown that the practice of using lidocaine with epinephrine for digital blocks is safe, this is still controversial and many do not advocate its use.[13–15] Multiple metacarpal blocks or an axillary nerve block may be performed if multiple digits are involved.[6] Please refer to Chapter 126 for the details regarding regional nerve blocks.

Thoroughly clean the hand of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry.[16] Irrigate the wound with sterile saline. If the nail plate has been avulsed, irrigate it with a dilute povidone iodine or chlorhexidine solution followed by a gentle rinse with sterile saline. **It is important not to scrub the undersurface of the avulsed nail plate because adherent squamous tissue may be destroyed.**[6]

A bloodless field is desired and, in many cases, necessary. Apply a digital tourniquet as described in the "Equipment" section above.[6] If available, a pneumatic tourniquet may be placed on the arm instead of using the digital tourniquet. The pneumatic tourniquet is especially helpful when the patient has fractures or lacerations of the proximal digit that preclude the use of a digital tourniquet. Avoid using a blood pressure cuff, as these tend to deflate during use. **As with all tourniquets, limit the amount of time in which the tourniquet is in place.** Create a sterile field by applying sterile towels.

TECHNIQUES

Adhering to certain principles will improve the outcome when repairing nail beds. A smooth and flat nail bed is necessary to the normal growth of the nail and should be the primary goal in any repair. Avoid or severely limit the amount of debridement.[5] The germinal matrix must be meticulously repaired and the proximal nail fold, the eponychium, preserved or that space is obliterated within a few days and result in adhesions or abnormal nail growth.[5] Thoroughly clean and replace the nail plate whenever possible. This will preserve the nail folds surrounding the nail bed, allow the nail plate to serve as a splint for fractures, and act as a protective cover for the healing nail bed.[6] Treatment goals also include preservation of length and sensation of the fingertip, early mobilization, prevention of joint contractures, and attention to cosmesis.[4,17]

The technique of nail bed repair depends upon the type of injury as well as which structures are involved. Various classification schemes, such as the nature of injury or anatomic location, have been developed to categorize fingertip injuries and guide treatment. Nail bed injuries are classified as simple lacerations, crushing lacerations, avulsion-lacerations, lacerations with associated fractures, lacerations with loss of skin and pulp, and fingertip amputations.[2,12]

NAIL PLATE REMOVAL

A significant force is required to break the nail plate. **The nail plate should be removed to visualize the underlying nail bed if the nail plate is damaged or avulsed, or the lateral skin folds lacerated as an associated nail bed injury is highly likely.** Removal of the nail plate is unnecessary in minor injuries where the nail plate is not damaged and still attached to the nail folds.

Remove the nail plate to repair nail bed injuries or to inspect the nail bed for potential injuries (**Figure 104-7**). Insert the closed tips of a fine scissors between the nail bed and the nail plate. A periosteal elevator, if available, can be substituted for the scissors. Hold the scissors parallel to the long axis of the finger. Slightly angle the tips of the scissors toward the nail plate to prevent any damage to the nail bed.[11] Advance the tips of the scissors 1 to 2 mm. Open the blades of the scissors to separate the nail bed from the nail plate. Close the blades of the scissors. Continue to advance the tips of the scissors in 1 to 2 mm increments and separate the nail bed from the nail plate. Stop advancing the scissors when the tips of the blades are at the level of the eponychium. Firmly grasp the nail plate with a hemostat. Pull the nail plate parallel to the long axis of the finger to completely remove it from the finger.

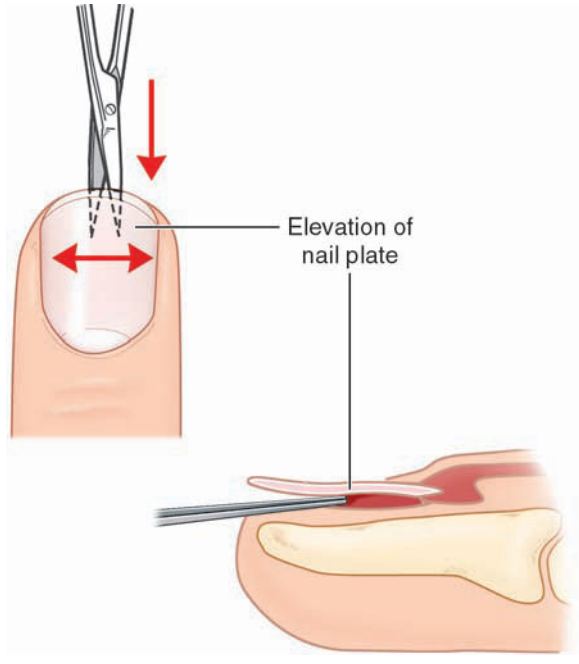


FIGURE 104-7. Removal of the nail plate. Dissect along the plane between the nail plate and the nail bed using a pair of fine scissors or periosteal elevator.

Making two linear incisions with a scalpel at 90° from the eponychial edge will allow greater exposure to the germinal matrix for repair (**Figure 104-8**).[7] This allows the eponychium to be folded or sutured back and therefore increase exposure of the germinal matrix.[2,17]

SIMPLE LACERATIONS

Simple lacerations are caused by localized blows to the nail plate. After removing the nail plate and exposing the nail bed, repair the laceration meticulously using 6-0 or 7-0 chromic gut or irradiated polyglactin 910 sutures.[2,6,17] **Minimize debridement as much as possible to avoid scarring that will result in nonadherence or**

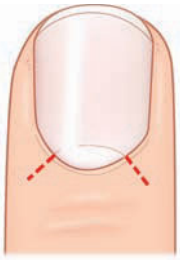


FIGURE 104-8. Incisions can be made at 90° to the corners of the eponychium for better exposure of the germinal matrix.

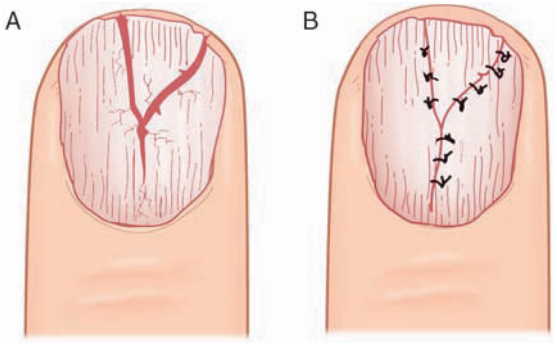


FIGURE 104-9. Crushing lacerations to the nail bed. **A.** Stellate or complex lacerations of the nail bed can occur after a crush injury. **B.** Approximation of the nail bed with fine absorbable sutures.

splitting of the nail plate. Repair any skin lacerations adjacent to the nail bed using 6-0 or 5-0 monofilament nylon sutures.[5] Nail fold lacerations may require repair in layers in order to preserve these spaces.[9]

CRUSHING LACERATIONS

The second type of injury is a crush injury with resultant lacerations. Crushing injuries may produce stellate lacerations and fragmentation of the nail bed (**Figure 104-9A**). Attempt to meticulously repair the fragmented nail bed using 6-0 or 7-0 chromic gut or irradiated polyglactin 910 sutures to achieve precise approximation and the smoothest result possible (**Figure 104-9B**).[6]

AVULSION-LACERATIONS

The third type of nail bed injury is the avulsion-laceration (**Figure 104-10A**). These injuries are more complex than the previously described injuries. Distal nail bed avulsions simply require petrolatum gauze to be placed over the injury followed by sterile gauze. Suture the petrolatum gauze and sterile gauze in place using 5-0 or 6-0 nylon suture for 10 days to allow the wound to heal by second intention (**Figure 104-10B**).[5,17] Avulsion-laceration injuries may require consultation with a Hand Surgeon depending on the amount of tissue involved and whether the germinal matrix is involved.[6,11,12] More severely damaged nail beds with a large amount of avulsed tissue usually require dermal grafts or split-thickness matrix grafts.[6]

Small fragments of avulsed nail bed may remain attached to the nail plate. These may be simply treated by carefully replacing the nail plate in its anatomic position.[18] Larger segments of avulsed nail bed that remain attached to the nail plate should be repaired (**Figures 104-11A & B**). Gently shave away the nail bed from the nail plate with a #15 scalpel blade (**Figure 104-11C**). Replace the avulsed nail bed and suture it in place with 5-0 or 6-0 chromic gut or irradiated polyglactin 910 sutures (**Figure 104-11D**).[10,18] Apply a petrolatum gauze dressing and replace the nail plate.

A special type of avulsion injury occurs when there is a crush injury to the distal fingernail. This results in an avulsion of the proximal nail plate with or without involvement of the germinal matrix (**Figure 104-2**). The proximal nail plate is less adherent to the nail bed and can be pulled out from under the eponychium (**Figure 104-2**). Remove the nail plate if the proximal nail plate is avulsed without involvement of the germinal matrix. Clean the nail plate and nail bed with sterile saline. Replace and secure the nail plate.

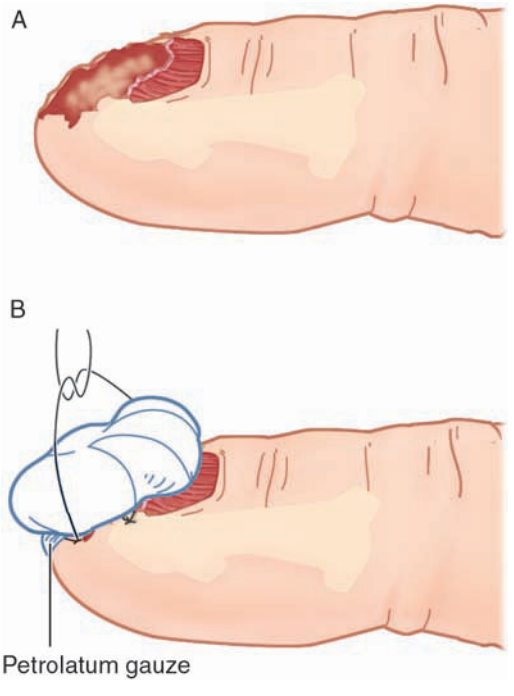


FIGURE 104-10. Avulsion-laceration of the nail bed. **A.** The dorsal aspect of the fingertip is avulsed with the nail plate. **B.** Petrolatum gauze is placed over the injury. This is subsequently covered with sterile gauze and sutured into place for 10 days.

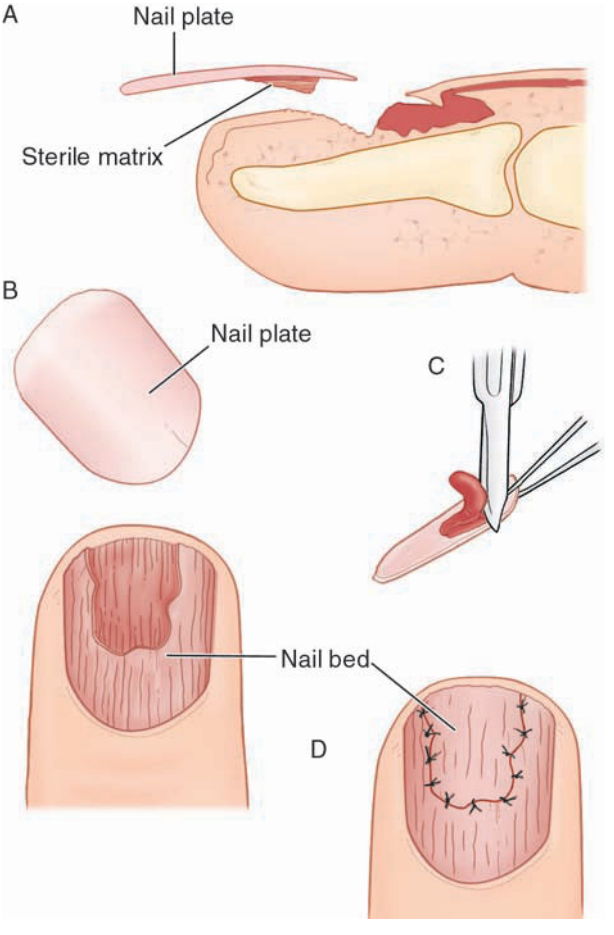


FIGURE 104-11. Large avulsion of the nail bed that is adherent to the nail plate. **A.** Lateral view of injury. **B.** Top view of injury. **C.** Gently shave away the avulsed segment. **D.** Repair the nail bed using the avulsed segment.

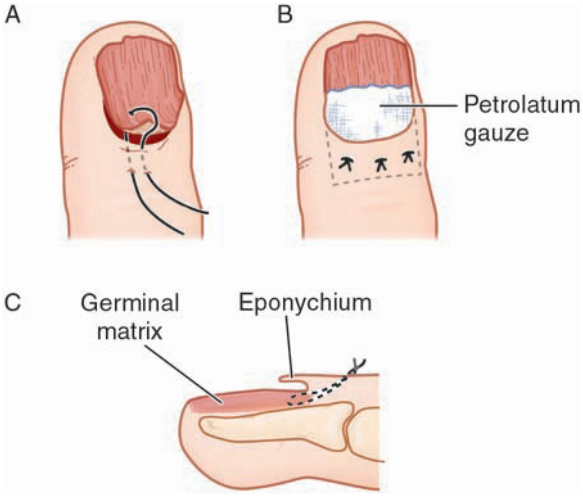


FIGURE 104-12. Repair of the germinal matrix after an avulsion. **A.** A series of horizontal mattress sutures are placed. **B.** The nail bed is returned to its proper location and the sutures tied. **C.** Lateral view of the repair.

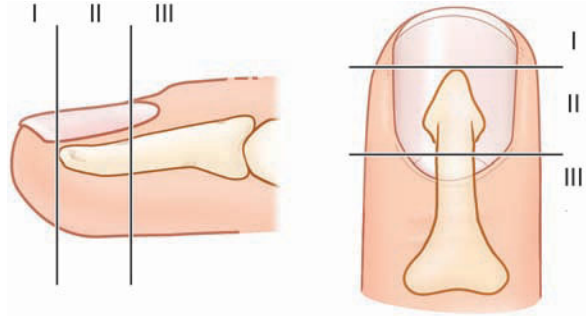


FIGURE 104-13. Classification of fingertip injuries. Zone I is distal to the bony phalanx. Zone II is distal to the lunule and over the bony phalanx. Zone III is proximal to the distal end of the lunule.

More often with these crush injuries the germinal matrix is avulsed as well. In these cases, the germinal matrix should be replaced with a series, usually three, of 6-0 nylon simple interrupted or horizontal mattress sutures (**Figure 104-12**).[5,6,10] Place all three sutures before returning the nail bed to its proper location. Making two linear incisions with a scalpel at 90° from the eponychial edge will allow exposure to the germinal matrix for repair (**Figure 104-8**).[7] This allows the eponychium to be folded or sutured back and therefore increase exposure of the germinal matrix. Place a piece of petrolatum gauze between the eponychium and the germinal matrix after the repair (**Figure 104-12B**). Larger germinal matrix avulsions require consultation with a Hand Surgeon for grafting.[2,6,11,17]

LACERATIONS WITH ASSOCIATED FRACTURES

The fourth type of nail bed injury is lacerations associated with fracture(s). Approximately 50% of nail bed injuries have an associated phalangeal tuft fracture.[19] The nail bed laceration should be repaired as previously described and the fracture addressed as a separate entity.[5] It is important to remember that the sterile matrix is closely adherent to the dorsal periosteum of the distal phalanx. Therefore, fractures require precise anatomic reduction in order for normal nail bed healing and nail plate growth to take place.[6,10,12] Replacing the nail plate and splinting the finger after repairing the nail bed laceration is often enough to reduce these fractures. Occasionally, fixation may be employed by a Hand Surgeon using Kirschner wires to prevent rotation of the bony fragments.[2,6]

LACERATIONS WITH SKIN LOSS AND FINGERTIP AMPUTATIONS

The final two types of injury are lacerations with loss of skin and pulp, and fingertip amputations. They can be further classified according to zones based upon the anatomic level of amputation (**Figure 104-13**).[3] Zone I injuries occur distal to the bony phalanx. These do not result in the loss of function and rarely result in a cosmetic deformity. Management consists of cleansing, placing topical antibiotic ointment over the injured area, and then applying a layer of petrolatum gauze. This should be followed by a sterile dressing and a splint. Zone II injuries occur distal to the lunule and over the bony phalanx. These injuries often have exposed bone. Zone III injuries occur proximal to the distal end of the lunule. Zone II and Zone III injuries should be managed in consultation with a Hand Surgeon. Either type of injury may require reconstruction with a pedicle flap and/or skin grafting.[3]

TREPHINATION FOR A SUBUNGUAL HEMATOMA

A subungual hematoma is a collection of blood under the nail plate caused by blunt trauma to the fingertip. The nail bed is usually crushed or lacerated with resultant extravasation of blood into the plane between the nail plate and the nail bed.[11] As pressure builds up, compression of nail bed nerves occurs and often causes significant pain. Usually this pain is what causes the patient to seek medical attention. The management of subungual hematomas is discussed separately because these injuries are typically minor and treated by simple trephination. A complete discussion of the management of subungual hematomas can be found in Chapter 102.

It is generally accepted that subungual hematomas <50% of the nail plate may be managed conservatively by simple trephination (puncture) of the nail plate.[2,5,6,11,17,20,21] This allows for drainage of blood and immediate pain relief. No anesthesia is usually necessary for this procedure. Ideally, this is accomplished with the use of an electrocautery device creating a 3 to 4 mm hole in the nail plate overlying the hematoma. The nail plate should be clean and dry for this procedure. If an electrocautery device is not available, a heated paperclip may be used.[5] Refer to Chapter 102 for more complete details of the procedure.

Some controversy exists over the management of subungual hematomas >50% of the nail plate. The concern is that a larger hematoma may hide an occult laceration that requires repair in order to avoid the complication of step-off with subsequent ridging as the new nail grows back. Some authors feel that it is impossible to accurately assess the amount of damage beneath a subungual hematoma unless the nail plate is removed to directly inspect the nail bed.[6,21] These authors noted that subungual hematomas that have separated greater than 50% usually have lacerations that require repair. Another study found that a subungual hematoma with more than 50% separation had a 60% incidence of having a nail bed laceration that required repair and up to a 95% incidence when there was an associated phalanx fracture.[21] In contrast to these studies, a prospective study found no complications at 6 months follow-up for subungual hematomas treated by electrocautery trephination alone.[2,20] This was regardless of the size of the subungual hematoma or the presence of a fracture. These authors feel that removing the nail plate and attempting repair may actually cause further trauma to the nail bed.[20]

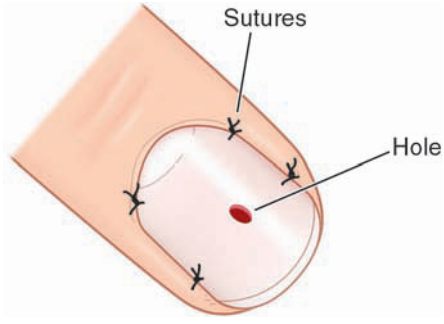


FIGURE 104-14. A hole is placed in the nail plate before it is sutured in place.

It was previously recommended that radiographs be obtained to rule out a fracture for all hematomas larger than 50% of the nail plate. A newer study found no correlation between the size of the hematoma and the presence of fractures.[20] If a fracture is suspected, have a low threshold to obtain plain radiographs prior to evacuating the hematoma.

In summary, most subungual hematomas may be treated by simple nail trephination using an electrocautery device. This procedure will lead to beneficial drainage only if done before 36 to 48 hours from the time of the injury.[11] The clinical benefit of nail bed repair with larger subungual hematomas is controversial. **It may be prudent to maintain a lower threshold for nail bed repair with a larger subungual hematoma, particularly if an ideal cosmetic outcome is desired.**

AFTERCARE

Whenever possible, the nail plate should be replaced after repairing any of the above-mentioned injuries. The nail plate covers the sensitive nail bed and protects it from injury, maintains the proximal nail fold (eponychium) to allow for growth of a new nail, and splints the nail bed. In order to accomplish the best outcome, place a hole in the center of the nail plate to allow for fluid drainage.[11] Make one or two holes in the lateral aspects of the nail plate. Suture the nail plate in place using 5-0 nylon sutures through the lateral skin folds (**Figure 104-14**).[6,10,11] These sutures should remain in place for 7 days. An alternative to suturing the nail plate in position is to use tissue adhesive. After replacing the nail plate, apply tissue adhesive along the eponychium and lateral nail folds at the area where they overlap the nail plate. An artificial nail may be used if the original nail plate is not available. The potential problem with sterile prefabricated nails is that there exists an increased risk for infection and a risk of erosion into the nail bed or nail folds.[6] The editor recommends petrolatum gauze be used to maintain the nail fold structures when the original nail plate is not available or significantly damaged (**Figure 104-15**).

After repair of the nail bed, the digit(s) involved will need to be bandaged in order to protect it from infection, moisture, and trauma. The application of becaplermin, recombinant human platelet-derived growth factor, has shown to improve outcomes.[22] This substance is not routinely used in the Emergency Department and should be applied after consultation with a Hand Surgeon. Place petrolatum gauze over the nail bed to avoid adherence from secretions. Apply a tube gauze dressing followed by a digital aluminum splint.[3] Movement of the distal interphalangeal joint should be restricted for 7 to 10 days with a splint.[6] For infants and young children, the entire hand should be dressed. If petrolatum gauze was used to keep the proximal nail fold (eponychium) open, it should be removed in 5 to 10 days.[6] Petrolatum gauze used to keep open the lateral nail folds (perionychium) should remain in place for 10 days.[5] Any sutures placed in the skin structures or nail folds should be removed in 7 to 10 days.[5]

Prophylactic antibiotics are not routinely required. They are recommended for large avulsions, amputations, and associated fractures when there is contamination with organic material.[6] Topical antibiotics may be applied to Zone I fingertip amputations. All injuries require a wound check in 24 to 72 hours.[3,5,6] The patient's tetanus immune status should be determined and prophylaxis administered if required. The hand should be elevated whenever possible. Narcotic analgesics may be prescribed as needed for pain control.

It is important to explain to the patient that regeneration of a new nail may take up to 6 to 12 months.[6] Warn the patient that as the new nail forms, it may look irregular and snag on cloth or string objects.[6] The patient should trim and file the leading edge of the new nail once it extends past the hyponychium in order to avoid snagging.

COMPLICATIONS

The complications associated with failure to repair or improper repair of a nail bed can be either functional, cosmetic, or both. The more serious complications are those which impair function or cause pain. There are basically seven complications that may arise. These exclude the infectious complications (abscess formation, cellulitis, and lymphangitis) that are inherent to all wounds. The occurrence of osteomyelitis from these injuries is rare, even with open fractures. The seven complications are loss of the nail, a split nail, a nonadherent nail, an ingrown nail, a malaligned nail, wide nails, and narrow nails.[12]

The complete loss of a nail could result in significant functional impairment to the fingertip as well as an abnormal looking fingertip. Complete nail loss occurs when there is complete disruption of the germinal matrix, either by significant avulsion of the matrix or amputation. Remember that if the germinal or roof matrices are not

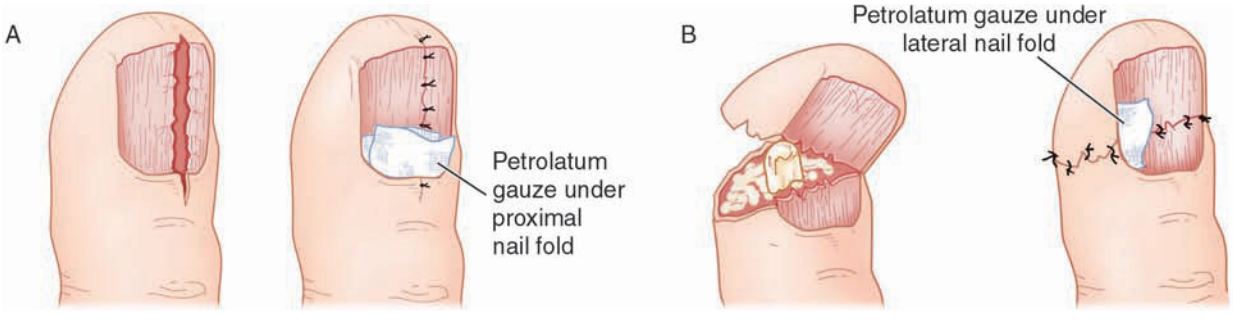


FIGURE 104-15. Petrolatum gauze may be placed between the dorsal roof and germinal matrix (**A**) or between the lateral skin fold and nail bed (**B**) to preserve the skin fold spaces.

repaired, the pouch deep to the proximal skin fold (eponychium) is obliterated within a few days.[20]

A split nail occurs when the germinal matrix is improperly approximated.[5,6,12] A wide scar will result that will not form a new nail. Subsequently, a split nail develops. This can be avoided by the careful approximation of the nail bed with sutures.

A nonadherent nail occurs when the nail bed is not repaired and granulation tissue forms secondarily. The nail plate will not adhere at the site of the granulation tissue as well as distal to the granulation tissue.[12] The nail can snag and be exposed to repeated tears once the nail plate loses adhesion to the nail bed.

The nail plate may ingrow if the lateral skin folds or sulci are not maintained and kept open.[12] Adhesions that form between the skin and nail bed can be very painful when the new nail tries to grow through that space.[5] Ingrown nails also have the long-term problem of a higher rate of infections (paronychia). This can be avoided by the replacement of the nail plate or the placement of petrolatum gauze to elevate the lateral nail fold from the nail bed.

The nail plate will grow in a malaligned direction if the matrix is displaced or repaired in such a manner that it is improperly aligned.[12] Functional impairment and cosmetic deformity may ensue depending upon the degree of this misdirected growth.

Wide nails often result from a crush injury with a tuft fracture.[12] Separated bony fragments leave the nail bed flatter and wider. Narrow nails occur when a central avulsion-laceration is not repaired. Scar tissue forms in the center and allows the intact lateral portions to contract toward each other.[12] The new nail subsequently becomes narrow and thick.

Tubular gauze dressings are commonly applied after the repair of a nail bed. When improperly placed, tubular gauze dressings can result in significant injury.[23,24] This includes digital ischemia that may be permanent and require an amputation. Tubular gauze dressings should not be placed by healthcare personnel not trained in their proper application.

SUMMARY

Nail bed injuries are common and may result in a cosmetically deformed or functionally impaired fingertip. Complications may occur even with precise repair. The treatment of choice is immediate primary repair of the nail bed and surrounding structures. Remember to minimize any debridement and to replace the nail plate whenever possible. Injuries with associated fractures and simple subungual hematomas are managed separately from the nail bed injury. Always be thorough and meticulous when repairing nail bed injuries to provide the best possible outcome. Finally, know when to consult with a Hand Surgeon.

105 Ganglion Cyst Aspiration and Injection

Thomas P. Graham

INTRODUCTION

Ganglion cysts, also known as synovial cysts or ganglia, are the most common soft tissue tumors of the wrist and hand.[1] They are a common reason for patients to present to the Emergency Department. The chief complaint is usually a mild pain or ache, exacerbated by movement, and localized to a 1 to 2 cm mass on the wrist or hand. Patients may also present with concerns about a painless "lump." Acute trauma prior to presentation is uncommon, though patients often give a history of repetitive motion at the site. The mass usually increases in size progressively over time or, occasionally, may grow rapidly over a short period. Patients presenting to the Emergency Department with ganglia may have already attempted one of several popular home remedies, including homeopathic medications or striking the cyst firmly with a large book or hammer.

Ganglion cyst aspiration is a relatively simple procedure that may be performed by the Emergency Physician. The practice of cyst aspiration has been challenged because of the high recurrence rate after the procedure.[2,3] Recurrence rates of up to and even greater than 50% have been described.[4,5] However, the procedure usually alleviates presenting symptoms, is occasionally curative, and is more cost-effective than referring all patients for surgical treatment.[6]

ANATOMY AND PATHOPHYSIOLOGY

Ganglia are synovial cysts that originate from a joint capsule or tendon sheath. They have no malignant potential. It is unclear whether ganglia are formed by herniation of the tendon sheath, myxomatous degeneration of connective tissue, or some other mechanism. Contained within the cyst is a viscous, jelly-like fluid. Ganglia often connect with the underlying synovial cavity or tendon sheath by a stalk. Hyaluronic acid makes up all or part of the mucoid fluid.[7]

Ganglia are usually encountered on the dorsum of the wrist, in particular over the scapholunate ligament (**Figure 105-1**). They may also be found on the palmar surface of the wrist, the lateral surface of the wrist, or on the hand itself. Ganglia of the foot and ankle are less commonly seen.[8] Ganglia are less commonly encountered in other areas such as the shoulder, hip, elbow, knee (including the anterior cruciate ligament), the lumbar spine, temporomandibular joint, and even the odontoid process of the cervical spine.[9–11]

Ganglia present as fixed or slightly movable masses that are usually solitary. Frequently characterized as smooth and "rubbery," cysts may become more noticeable with wrist flexion. They vary in size from barely palpable to 3 cm in diameter (smaller than 1.5 cm being the norm). Tenderness is sometimes but not invariably present. Ganglion cysts will transilluminate, as they are fluid-filled. They may "disappear" over time by spontaneously rupturing or resorption.

Diagnosing a ganglion cyst is usually not difficult. However, ganglia of the foot and those occurring in other uncommon locations may be difficult to palpate despite causing significant discomfort. The differential diagnosis of ganglia includes joint capsulitis, neuromas, and other soft tissue neoplasms such as sarcomas and chondrosarcomas. Ultrasonography can be employed to aid in the diagnosis, particularly of occult ganglia or ganglia presenting atypically.[12] MRI is frequently used to confirm the diagnosis and plan its



FIGURE 105-1. Oblique view of the wrist demonstrating a ganglion cyst overlying the scapholunate joint.

operative removal. Plain radiographs and laboratory tests are not helpful in the work-up.

INDICATIONS

The most common indication for ganglion aspiration is worsening pain and swelling, in particular when normal range of motion is restricted or occupational disability is present. Failure of conservative measures such as rest, splinting, and the use of nonsteroidal anti-inflammatory medications to resolve symptoms may also prompt ganglion aspiration in the Emergency Department.

CONTRAINDICATIONS

There are few contraindications to ganglion cyst aspiration. Introducing a needle through an area of cellulitis should be avoided. However, cellulitis overlying a ganglion is uncommon and should raise suspicion for an alternate diagnosis such as a skin abscess. The procedure can be safely deferred, with the patient being given a referral to a Hand Surgeon, if the diagnosis of a ganglion is uncertain.

The location of a ganglion is generally not a contraindication to aspiration. However, the procedure should be deferred if there is a concern that the aspirating needle could damage an adjacent structure and cause neurologic or vascular injury. Aspiration of lower extremity ganglia may be performed in a similar fashion to hand and wrist lesions, with similar results.[8,13] Some literature suggests that volar wrist ganglion cysts recur at an even higher rate than those of the dorsal wrist and lower extremity; leading some authors to recommend surgical excision, and not aspiration, as the primary therapy for this subset of ganglia.[14]

EQUIPMENT

- Sterile gloves
- Povidone iodine solution or chlorhexidine solution
- Local anesthetic solution without epinephrine
- 25 or 27 gauge needle on a 3 mL syringe for local anesthesia
- 16 or 18 gauge needle on a 5 or 10 mL syringe for aspiration
- 10 to 15 mg methylprednisolone acetate (20 mg/mL) or prednisolone tebutate (20 mg/mL)

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Obtain an informed consent, either signed or verbal, with adequate documentation to support the latter method. If available, ultrasonography can be used to confirm the diagnosis and to facilitate needle entry into the cyst. When ganglia are located near neurovascular structures, ultrasound can help to avoid these structures.[15] Place the patient on a gurney with the hand on a bedside procedure table. Clean the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. It is recommended to provide local anesthesia for patient comfort, although the cyst can be aspirated and/or injected without anesthesia. Place a subcutaneous wheal of local anesthetic solution immediately over or adjacent to the periphery of the ganglion.

TECHNIQUE

GANGLION ASPIRATION

Manipulate the wrist (or other affected extremity) to expose more of the cyst and facilitate needle entry into the cavity. Insert a 16 or 18 gauge needle on a 5 or 10 mL syringe through the anesthetized tissue and into the ganglion cyst cavity (**Figure 105-2**). Apply negative pressure to the syringe to aspirate the cyst contents once the tip of the needle is within the cyst cavity. The contents may be difficult to aspirate, as the mucinous contents of the cyst are quite viscous. The cyst can be manipulated and compressed to express more of the contents into the syringe once the very viscous, clear or yellow material begins to flow into the syringe. Generally, 1 to 2 mL of fluid can be aspirated from a typical ganglion. Withdraw the needle when fluid can no longer be aspirated. Apply a simple dressing. A pressure dressing may also be temporarily applied, taking care not to compromise neurologic or vascular function.

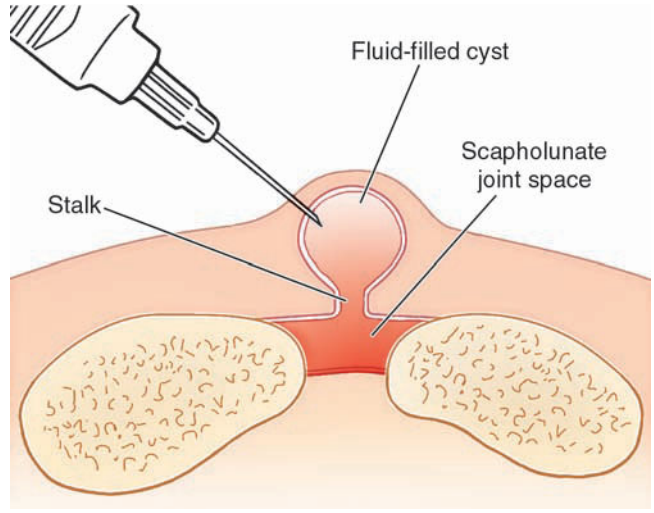


FIGURE 105-2. Cross section through the scapholunate joint demonstrating a ganglion cyst. The needle is inserted into the cyst cavity to aspirate its contents.

GLUCOCORTICOID INJECTION

The injection of glucocorticoids into a ganglion cyst immediately after aspiration is commonly recommended. One small study showed glucocorticoid injections decreased recurrence rates compared to aspiration alone.[16] The literature has not yet shown a clear benefit.[17] If a steroid injection is desired, securely hold the aspirating needle in place after the cyst contents have been aspirated into the syringe. Remove the syringe. Without moving the needle, attach a second syringe containing 10 to 15 mg of the glucocorticoid solution onto the needle. Aspirate to confirm the tip of the needle is not within a vascular structure. Inject the glucocorticoid solution into the cyst cavity. Withdraw the needle and apply a simple dressing.

ALTERNATIVE TECHNIQUES

Other variations of ganglion cyst aspiration and injection have been described in the literature. The injection of hyaluronidase into the cyst, with or without corticosteroids, has shown favorable results.[18,19] Puncturing the ganglion wall at multiple separate locations has not been proven to decrease the recurrence rate when compared to aspiration at a single point alone.[20] Injection of hypertonic saline and other sclerosants (e.g., 1 mL of 3% sodium tetradecyl sulfate) has been suggested. Further study is necessary before these techniques can be recommended for widespread use in the Emergency Department.

ASSESSMENT

Patients usually report total or near-total relief of their symptoms immediately after aspiration. Obtaining highly viscous, clear or yellow fluid from the cyst virtually confirms the diagnosis.

Obtaining purulent fluid suggests a skin abscess and not a ganglion cyst. Failure to obtain fluid does not rule out the diagnosis of a ganglion, but should prompt an evaluation for alternative diagnoses.

AFTERCARE

Patients should be reassured that ganglia are not malignant tumors. Immobilization of the affected limb may be performed temporarily for patient comfort. However, splinting limits the ability of patients to function normally and does not appear to affect recurrence rates.[21] Aftercare instructions should direct patients to return to the Emergency Department for any significant increase in pain, erythema at the site or up the extremity, swelling beyond the ganglion's original size, purulent discharge, continued bleeding, or the development of a fever. Patients should also be directed to elevate the extremity, avoid strenuous activity of the affected limb, and rewrap the pressure dressing (if one is applied) to make it snug but not uncomfortable. Acetaminophen or nonsteroidal anti-inflammatory medications may be recommended for relief of mild postprocedure pain. Narcotic analgesics are not required nor recommended. Oral corticosteroids have not been demonstrated to play a role in ganglion therapy.

All patients with ganglion cysts aspirated in the Emergency Department should be informed of the potential for recurrence and the possibility of definitive ganglion treatment by surgical excision. Referral to a Hand Surgeon should be provided, if desired by the patient. Although reports of postsurgical recurrence rates vary widely, currently the most effective therapy for ganglion cysts is believed to be open excision. During this procedure, a Hand Surgeon removes the cyst and, if possible, the stalk or pedicle that connects it to the normal synovium. Arthroscopic removal of wrist ganglia has also been described and performed successfully.[22]

COMPLICATIONS

Complications of ganglion cyst aspiration are uncommon. They include bleeding and infection. Bleeding is self-limited and easily controlled with manual pressure. The use of sterile technique will minimize any infectious complications (abscess, cellulitis, or septic arthritis). Rare complications of corticosteroid injection include localized depigmentation that is due to injection outside of the cyst capsule or leakage out of the cyst capsule through the needle tract.[23] Subcutaneous infiltration of glucocorticoids can also result in fat atrophy, skin atrophy, and skin dimpling from fat atrophy.

SUMMARY

Ganglion cysts are common growths of the wrist and hand. They frequently enlarge to cause pain, sometimes to the point of disability. Contraindications to the aspiration of a ganglion cyst in the Emergency Department are few. The procedure is often warranted due to debilitating pain, deformity, or inability on the patient's part to promptly seek the care of a surgical specialist. The procedure is simple, quick, and only slightly uncomfortable if performed correctly. Although the injection of steroids into the cyst is commonly advocated to prevent recurrence, the efficacy of this procedure has not been conclusively demonstrated. Ganglia recurrence is very common after aspiration and may occur even after surgical excision. This fact must be clearly relayed to the patient. All patients should be offered referral to a Hand Surgeon on a nonemergent basis to discuss further intervention.

106 Subcutaneous Abscess Incision and Drainage

Samuel J. Gutman and Michael B. Secter

INTRODUCTION

Subcutaneous abscesses are commonly seen in the Emergency Department. Approximately 1% to 2.5% of patients present with this chief complaint.[1–3] Abscesses occur in numerous anatomical areas with varied etiology and bacteriology. An abscess is a tender and fluctuant mass located in the dermal or subdermal tissue. It usually demonstrates the classic inflammatory responses of rubor, tumor, dolor, and calor. Although the abscess is usually tender, the surrounding and underlying tissue should not be tender.[4,5] There is usually minimal surrounding erythema in a mature abscess.

Incision and drainage is the definitive treatment of a soft tissue abscess.[6] This procedure results in significant improvement in symptoms and a rapid resolution of the infection in uncomplicated cases.[7] However, premature incision before localization of pus will not be curative and may be deleterious. In cases of immature abscesses or cellulitis, oral antibiotics and warm compresses may be of value in helping the infection to coalesce. These methods are not a substitute for incision and drainage and should not be continued for more than 24 to 36 hours without a reassessment of the patient. With the emergence of methicillin-resistant *Staphylococcus aureus* (MRSA), the role for ancillary antibiotic use has come into question.

ANATOMY AND PATHOPHYSIOLOGY

PATHOGENESIS

An abscess is a localized collection of pus caused by suppuration buried in a tissue, organ, or confined space.[8] Intact skin is very resistant to bacterial invasion. Localized pyogenic infections are usually initiated by a breakdown in the normal epithelial defense mechanisms in the normal host. Plugging of the ducts of a superficial exocrine gland, such as apocrine and sebaceous glands or a congenital cyst or sinus, may initiate the process. Occlusion prevents desquamation and provides a moist environment for organisms to proliferate. The combination of a high concentration of organisms, the presence of nutrients, and sufficient damage to the corneal skin layer to allow organisms to penetrate the skin defenses results in abscess formation.[1,9]

Subcutaneous abscesses typically begin as a cellulitis with organisms that cause necrosis, liquefaction, and accumulation of leukocytes and debris. Early stages appear as an area of hyperemia and tender inflammation that later becomes fluctuant as an exudate of leukocytes, necrotic material, and cellular debris accumulates. This is followed by loculation and walling off of the pus. This progresses and the area of liquefaction increases until it "points" and eventually ruptures through the area of least resistance.[5]

The body area involved depends upon host factors such as drug use, employment-related exposures, or minor trauma.[9,10] Areas with a compromised blood supply are more prone to infection as normal host cell-mediated immunity is not as available.[9] The frequency of abscess occurrence in different body areas includes the buttocks and perirectal area in 25% of cases, the head and neck in 20%, the extremities in 18%, the axilla in 16%, and the inguinal area in 15%.[1]

BACTERIOLOGY

The majority of abscesses are polymicrobial with the isolated organisms usually representing the normal resident flora associated with

the body area on which the abscess is found.[1,11] Nonresident bacteria are found in abscesses that occur as a result of direct inoculation of extraneous organisms such as those following human bite wounds, intravenous drug use, or bacterial seeding of embedded foreign bodies.[12] In normal hosts, aerobic *Staphylococcus* and group A *Streptococcus* are the most common organisms isolated from abscesses of the head, neck, extremities, and trunk.[11,13] Anaerobes are found in all areas of the body but predominate in abscesses of the buttocks and perirectal regions.[11,13]

Staphylococcus aureus occurs in 24% to 60% of abscesses and in pure cultures is the only organism in 21% to 72% of cases.[1,13–16] Community-acquired MRSA (CA-MRSA) is presently considered to be the most common identifiable pathogen causing abscess at major centers.[17] CA-MRSA is defined as infection with MRSA acquired in the community lacking the traditional risk factors of hospital-acquired MRSA including a recent stay in a long-term care facility or in a day care setting, recent healthcare contacts or surgery, an indwelling device, dialysis, immunosuppression, chronic illness, or recent antibiotic use.[18,19] Many cohorts of patients who are at a higher risk of acquiring MRSA infections include those with recent household or daycare contacts, children, men who have sex with men, those in the military, incarcerated patients, athletes (especially those in contact sports or who share equipment), Native Americans, Pacific Islanders, patients with previous MRSA infections, and intravenous drug users.[18–21] While it is important to consider MRSA in patients with aforementioned risk factors it is essential not to exclude MRSA in the absence of them.[17] Patients presenting with a complaint of a "spider bite" should be investigated for MRSA.[18,19,22] In a recent observational study of urban patients, MRSA was isolated from abscesses in 51% of patients.[23] An American study of 11 academic centers found MRSA incidence rates as high as 74% in patients presenting with abscesses.[17] As much as 77% of MRSA-related illness, especially presenting in the Emergency Department, are skin and soft tissue infections (SSTI).[24]

CA-MRSA carries the *mec*A gene, which is thought to impart the antimicrobial resistance. This is carried on the Staphylococcal Cassette Chromosome Type-IV, which is distinct from other forms of MRSA.[18,19] CA-MRSA also produces an exotoxin called Panton-Valentine Leukocidin (PVL) that predisposes patients to cutaneous infections.[18,19] PVL has been identified in up to 98% of CA-MRSA cases.[17]

Up to 17% of abscesses are sterile.[1,7,13] Nearly 40% of these are secondary to intravenous drug use and most likely result from injection of necrotizing chemical irritants.[3] Viruses (e.g., herpes), autoimmune mechanisms, or systemic illnesses including metastatic tumors, benign tumors, and granulomatous disease may also cause sterile abscesses.[4,25] These atypical etiologies may present with the absence of local inflammatory signs and symptoms and only with an exacerbation of the underlying disease process.

SPECIFIC CLINICAL ENTITIES

Furuncles, or boils, are acute circumscribed abscesses of the skin and subcutaneous tissue that most commonly occur on the face, neck, buttocks, thigh, perineum, breast, or axilla. Carbuncles are aggregates of interconnected furuncles that frequently occur on the back of the neck where the thick skin causes lateral extension of the infection rather than pointing toward the skin surface. These occur with a higher frequency in diabetics. They can be large and cause systemic signs, symptoms, and complications. Carbuncles often require surgical consultation and treatment in the Operating Room.

Hidradenitis suppurativa is a chronic relapsing inflammatory disease process affecting the apocrine glands primarily in the axilla, the inguinal region, or both.[26] Initially, this process will appear like a typical abscess and is only identifiable in its chronic scarring phase when there are multiple lesions with tender areas of induration and inflammation in various stages of healing. The chronic process leads to draining fistulous tracts that require ongoing surgical management. Emergency Department management involves the usual incision and drainage procedure of any area of fluctuance. Patients should be informed that the intervention is not curative and that the problem is chronic. Arrange a referral to a General Surgeon, Dermatologist, or Plastic Surgeon for long-term follow-up.

Up to 80% of breast abscesses occur in nonlactating women.[4] Peripheral and superficial lesions are similar to abscesses elsewhere on the body and respond to conservative incision and drainage with an incision that radiates out (centripetally) from the nipple.[27] Deeper and periareolar abscesses are often complex and require surgical referral and general anesthesia to properly treat. Postpartum mastitis is common and precipitated by milk stasis and bacterial invasion through a cracked nipple. The offending organism is commonly *Staphylococcus aureus* or *Streptococcus* species. Treatment includes the application of heat, oral antibiotics, and continued breast emptying with a breast pump or feeding of the baby. The mastitis may evolve into an abscess and is often associated with systemic symptoms. Appropriate antibiotic therapy and follow-up in 24 to 48 hours is required.

Sebaceous cysts are a common cause of a subcutaneous abscess. They can persist for long periods as nontender subcutaneous swellings before becoming infected. They appear like most other abscesses. Sebaceous cysts can be identified by a small punctate sinus tract near the center of the fluctuant area. The initial treatment is incision and drainage. The contents are usually thick cheesy material that needs to be manually expressed. A sebaceous cyst has a definite shiny white capsule that must be excised, preferably at the time of incision and drainage or at the first follow-up visit, to prevent recurrence. The area is then treated as any other healing abscess cavity.

The recurrence of an abscess that has been previously drained should suggest the possibility of underlying osteomyelitis, a retained foreign body, or the presence of unusual organisms such as mycobacteria or fungi. Recurrent abscesses should prompt further investigation including an assessment of the patient's immune status.

SPECIAL CONSIDERATIONS

The precise risk for endocarditis associated with subcutaneous abscesses is unknown. Up to 5% of patients with abscesses have bacteremia at the time of presentation.[4,16] Incision and drainage of cutaneous abscesses can result in transient bacteremia with the organism causing the abscess.[7,14,28] More recently, the clinical relevance of this bacteremia has become controversial.[16] **At this time, only patients considered to be at high risk for endocarditis are recommended to receive antimicrobial prophylaxis before incision and drainage (Table 106-1).**[29] Bacterial endocarditis prophylaxis should be directed at the most likely pathogen causing the infection. An antistaphylococcal penicillin or a first-generation cephalosporin is an appropriate choice for most soft tissue infections (**Table 106-2**). Clindamycin is an acceptable alternative for patients allergic to penicillin. Patients with immunodeficiency and localized soft tissue abscesses may be at higher risk for developing septicemia secondary to bacteremia induced by incision and drainage, but it is unclear if they are at higher risk of complications and death.[30,31] These patients may benefit from prophylactic antibiotics prior to incision and drainage, but only indirect evidence and no controlled studies are available.[32] **High-risk patients with known**

TABLE 106-1 Cardiac Conditions at Risk for Endocarditis that Require Antibiotic Prophylaxis for Incision and Drainage[29]

Prosthetic cardiac valves—including bioprosthetic and homograft valves
Previous bacterial endocarditis
Unrepaired cyanotic congenital heart disease (CHD)—including palliative shunts and conduits
Repaired CHD with prosthetic material or device—within 6 months after the procedure (regardless of method of placement)
Repaired CHD with residual defects at or adjacent to site of prosthetic patch or device
Cardiac transplant with cardiac valvulopathy
Except for the conditions listed above antibiotic prophylaxis is no longer recommended for any other form of CHD

or suspected MRSA infection should receive IV Vancomycin or Clindamycin when undergoing incision and drainage.[29]

PATIENT ASSESSMENT

Prior to the treatment of an abscess, a focused history should be taken assessing for trauma, intravenous drug use, history of fever, and past medical history. Specifically inquire about diabetes, renal failure, steroid use or other immune suppression, peripheral vascular disease, and valvular heart disease. It is important to note any of the aforementioned risk factors for CA-MRSA as this may alter management of certain patient populations. Past anesthetic history and the potential for aspiration should be assessed if procedural sedation is to be considered.[33] Medications and allergies should be queried. The patient's tetanus status must be confirmed and booster doses provided as required.

A brief physical examination documenting function and intact distal neurovascular status of extremities involved is required. Evidence of pain on passive or active movement of fingers may suggest a deep space infection.[4] A high index of suspicion is required, especially in injection drug users (IDU), to identify those seemingly simple cutaneous infections that unpredictably evolve into extensive necrotizing soft tissue infections.[34] General assessment of the airway and cardiopulmonary system, vital signs, and mental status is indicated if procedural sedation is to be employed.[33]

Routine laboratory studies are not indicated in otherwise healthy individuals. In immunocompromised patients, a CBC looking for leukopenia or toxic granulations should be considered. Diabetics should have electrolytes, BUN, creatinine, and glucose assessed. Elevated potassium in diabetics may indicate myonecrosis.[35] Consider a urinalysis for myoglobinuria.

Culturing the purulent material from a drained abscess was previously considered to be of little value. Controversy exists today as to the value of culture in abscess management. While many experts suggest that it is of little value because it has no bearing on acute management (curative I & D), others suggest that it is vital to help determine antimicrobial susceptibility and outbreak patterns.[22] **Cultures should be obtained as they may alter later management in cases with recurrent or refractory infections, those patients who are seriously ill or immunocompromised, patients on an antimicrobial with variable activity, those who have failed surgical treatment, and any patient being admitted to the hospital.[22,36]** Gram stain and cultures for both aerobic and anaerobic bacteria may be helpful in those patients who are febrile, systemically unwell, immunocompromised, or who present atypically. Consider obtaining radiographs of the affected areas if there is a history of trauma, drug use, or concern regarding deep infection. Foreign bodies and fractures may not be easily identifiable because of the edema and tenderness caused by the infection. Gas or osteolytic lesions on plain radiographs may indicate severe deeper infection, the need for urgent surgical consultation, and prompt antibiotic therapy.[37]

ULTRASONOGRAPHIC EVALUATION

Bedside ultrasound use in the Emergency Department is of great value to the Emergency Physician in evaluating skin and soft tissue infections. This modality can be used to differentiate a cellulitis from an abscess in difficult cases. Ultrasound is portable, inexpensive, comfortable for patients, and provides no radiation

TABLE 106-2 Prophylactic Antibiotic Regimens for Procedures[29]

Clinical situation	Agent	Dose*	Timing
Standard general prophylaxis	Amoxicillin	Adults: 2.0 g Child: 50 mg/kg	PO, 30–60 min prior to the procedure
Unable to take oral medications	Ampicillin	Adults: 2.0 g Child: 50 mg/kg	IV or IM, 30 min prior to the procedure
Unable to take oral medications	Cefazolin or Ceftriaxone**	Adults: 1.0 g Child 50 mg/kg	IV or IM, 30–60 min before procedure
Allergic to penicillin or ampicillin	Cephalexin**	Adults: 2.0 g Child: 50 mg/kg	PO, 30–60 min prior to procedure
Allergic to penicillin or ampicillin	Clindamycin	Adults: 600 mg Child: 20 mg/kg	PO, 30–60 min prior to procedure
Allergic to penicillin or ampicillin	Azithromycin or Clarithromycin	Adults: 500 mg Child: 15 mg/kg	PO, 30–60 min prior to procedure
Allergic to penicillin and unable to take oral medications	Cefazolin or Ceftriaxone**	Adults: 1.0 g Child: 25 mg/kg	IV or IM, 30–60 min prior to procedure
Allergic to penicillin and unable to take oral medications	Clindamycin	Adults: 600 mg Child: 20 mg/kg	IV or IM, 30-60 min prior to procedure
Known or suspected MRSA	Vancomycin	Adults: 1 g Child 20 mg/kg	IV, 30 min prior to procedure

*Total child dose should not exceed adult dose.

**Cephalosporins should not be used in patients with immediate-type hypersensitivity reactions (urticaria, angioedema, or anaphylaxis) to penicillin.

exposure. It is fast and easy to gain proficiency for specific applications.[38] Ultrasound is indicated for ambiguous physical findings such as widespread cellulitis, localizing an incision site, and for ruling out dangerous masses such as a pseudoaneurysm that masquerade as an abscess.[39] Ultrasonography is helpful in identifying small or early abscesses, deep abscesses, abscesses under previous scars, and for localizing adjacent major vessels or nerves.[39] Recent studies have found that ultrasound has a sensitivity of 98% and specificity of 88% in detecting an abscess.[38] One study of presumed cellulitis in the Emergency Department found that ultrasound changed the case management in 71 of 126 patients (56%), as swelling thought to be due to cellulitis can hide an abscess.[40] In the pediatric population, ultrasound is useful in evaluating a cellulitis and determining if an incision and drainage is necessary.[41] Finally, ultrasound can be used to guide an aspiration to confirm the presence of an abscess and to obtain material for culture and gram stain.[42]

Before ultrasonographic examination, it is important that the Emergency Physician has an appreciation of the anatomical structures of the area. The location and sonographic appearance of arteries, veins, nerves, and tendons should be known before the incision and drainage procedure. Generally, a 5 to 7.5 MHz linear array transducer is used. Some find a standoff pad or gel-filled glove to be useful for superficial structures.[39] Once the probe has been electronically focused to an ideal depth, scan the area of infection in two orthogonal planes.[39,40] Lower frequency transducers are useful for deeper abscesses, while higher frequency probes are more effective for superficial abscesses. **It is important to use probe covers as well as proper cleaning and disinfecting supplies in order to avoid cross contamination.**

Differentiation between a cellulitis and an abscess on ultrasound is based on several findings. Cellulitis shows diffuse hyperechogenicity and thickening of the skin and subcutaneous fat. The presence of echo-poor strands between hyperechoic fatty lobules in the subcutaneous tissue is known as cobblestoning and is indicative of cellulitis.[38,39,42] (**Figure 106-1**). An abscess has a wider array of presentations on ultrasound. Most frequently, an abscess is a spherical or elliptical shaped anechoic or echo-poor region with sharper echogenic borders.[39,43] (**Figure 106-2**). Within the echo-poor area there may be gas, lobulations, septations, and echogenic debris. There are some cases where the abscess can appear to be isoechoic and even hyperechoic. In these cases, there may be a role for ultrasound-guided aspiration.[43] If unsure if an abscess is present on ultrasound, gentle digital palpation or pressure may induce motion of the purulent material within the abscess.[43] Posterior acoustic enhancement can be seen in the presence of an abscess.[39] This technique can help rule out similarly presenting hematomas, necrotic tumors, vascular lesions, or schwannomas.[42] There is an emerging role for Doppler ultrasound in abscess evaluation. The findings of increased vasculature, peripheral blushing and hyperemia, and increased large vessel flow around the abscess are common (**Figure 106-3**).[44]



FIGURE 106-1. Ultrasound image of a breast showing cobblestoning of the subcutaneous tissue indicative of edema secondary to cellulitis with echogenic material surrounded by echo-poor areas consistent with early abscess formation.

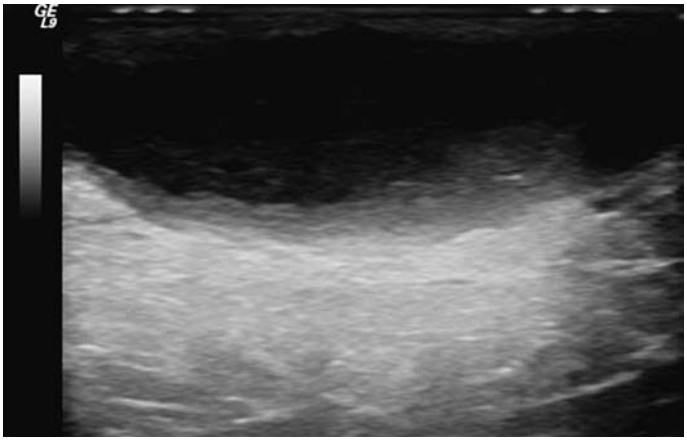


FIGURE 106-2. Ultrasound image showing a large hypoechoic area representing a large superficial abscess.

INDICATIONS

The presence of a fluctuant mass in an area of induration, erythema, and tenderness is clinical evidence that an abscess requires incision and drainage. Antimicrobial treatment without incision and

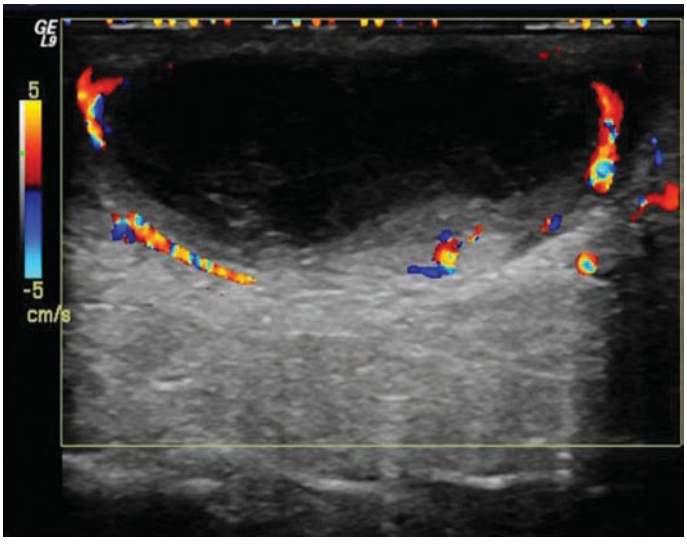


FIGURE 106-3. Color Doppler ultrasound image showing peripheral hyperemia around a large abscess cavity.

drainage can lead to treatment failures in patients with abscesses.[45] Examination alone may not definitively indicate an abscess, especially if it is deep. This can be further confirmed by bedside ultrasound, with or without needle aspiration.[4] Obtaining purulent material on aspiration identifies an abscess and is an indication for incision and drainage.[4] If no pus is aspirated, oral antibiotics, warm compresses, and follow-up in 24 hours must be arranged for a reassessment.

CONTRAINDICATIONS

The only absolute contraindication to the incision and drainage of an abscess in the Emergency Department is the possible association with a mycotic aneurysm.[10,35] Commonly, abscesses overlie large vessels including those in the anterior triangle of the neck, the supraclavicular fossa, the deep space of the axilla, the antecubital fossa, the groin, and the popliteal space.[46] In these locations, or if the abscess is pulsatile, fine needle aspiration for blood, diagnostic imaging, and/or angiography is indicated prior to incision and drainage.

Relative contraindications to incision and drainage include an inability to achieve adequate anesthesia. An abscess associated with a deep foreign body that requires additional real-time imaging such as a fluoroscopy or ultrasound may require surgical referral.[47] Proximity of an abscess to important neurologic, tendinous, or vascular structures may require specialty consultation and magnification in the operating room. Deep space infections or involvement of any joint requires admission for parenteral antibiotic therapy and possible operative debridement. Patients presenting with soft tissue infections exhibiting pain out of proportion to physical examination findings or deep anesthesia of the involved or distal area should raise the possibility of deeper infections such as necrotizing fasciitis or myonecrosis.[37] Perirectal and periurethral abscesses are often larger and deeper than they appear and may be complicated by sinus tracts that require exploration under general anesthesia. Manipulation of abscesses in the "danger triangle" of the face (corners of the mouth to glabella) can lead to septic thrombosis of the cavernous sinus. Periorbital or orbital abscesses require ophthalmologic assessment and treatment.

EQUIPMENT

Anesthesia

- 18 and 27 gauge needles, 1½ in. long
- 10 mL syringes
- Povidone iodine or chlorhexidine solution
- Local anesthetic solution with epinephrine
- Local anesthetic solution without epinephrine if abscess is near an end arteriolar system
- Ethyl chloride spray
- Ice pack

Procedure

- #11 and #15 scalpel blades on a handle
- Two hemostats, in two sizes for breaking up loculations and probing the cavity
- Scissors
- Normal saline
- 10 or 20 mL syringe with a 20 or 22 gauge angiocatheter
- Suction source, tubing, and catheter for larger abscesses
- 4 × 4 gauze squares
- Iodoform gauze packing
- Adhesive tape
- Culture swabs and vials
- Ultrasound machine with a 5 to 7.5 MHz probe
- Ultrasound probe covers
- Ultrasound gel
- Standoff pad
- Ultrasound probe cleaning and disinfecting solutions

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Patients should be warned of potential cosmetic complications prior to proceeding. Obtain an informed consent to perform the procedure. If endocarditis prophylaxis is indicated, oral regimens should be given 1 hour prior to the procedure and parenteral regimens within 30 minutes of the procedure (**Table 106-1**). Clean the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the skin and allow it to dry. Apply drapes to delineate a sterile field. Many Emergency Physicians regard this last step optional. The procedure of cutting into a contaminated abscess is considered to be clean and not sterile.

ANESTHESIA

It is usually possible to achieve adequate anesthesia for the skin incision but any additional manipulation may be painful. Local anesthetic infiltration is often less effective than in other procedures. The pH of infected tissue is often low and retards the diffusion of the local anesthetic solution into nerve axons.[48] A regional field block can be instituted by injecting a ring of 1% lidocaine or 0.5% bupivacaine subcutaneously approximately 1 cm away from the perimeter of the erythematous border of the abscess. The onset of anesthesia occurs after about 5 minutes. A small amount of local anesthetic solution can be injected intradermally into the roof of the abscess in a linear fashion along the line of the planned incision (**Figure 106-4A**).[4] Be careful during this portion of the procedure as the abscess may be under pressure. The inadvertent injection of local anesthetic solution into the abscess cavity may cause fluid to be forcibly ejected toward the Emergency Physician. **Appropriate universal precautions should be employed including a face mask and eye protection.**

In superficial abscesses or furuncles, which are unlikely to require significant exploration, topical ethyl chloride spray can be used to provide anesthesia. Invert the bottle and compress the spray nozzle to begin the flow of fluid. Direct the spray toward the planned site of incision. The pain relief from ethyl chloride is variable and fleeting. It is also highly flammable.[5] The application of an ice pack over the planned incision site secured with an elastic bandage for 15 minutes can also be effective. This may be especially useful for children, those with severe needle phobias, or in cases of a true anesthetic allergy.

Nitrous oxide is safe and was previously thought to be effective as an adjunct to the incision and drainage of abscesses.[49] More recently, it has been shown to cause no significant reduction in pain and to only be marginally effective as an anxiolytic.[50] Procedural sedation with agents such as ketofol (ketamine and propofol in a 50:50 mixture in a dose of approximately 1 mL/kg IV in adults) can be useful in deep abscesses that require extensive probing.[51] It is difficult to obtain adequate pain control in these cases, even with a well-performed field block.

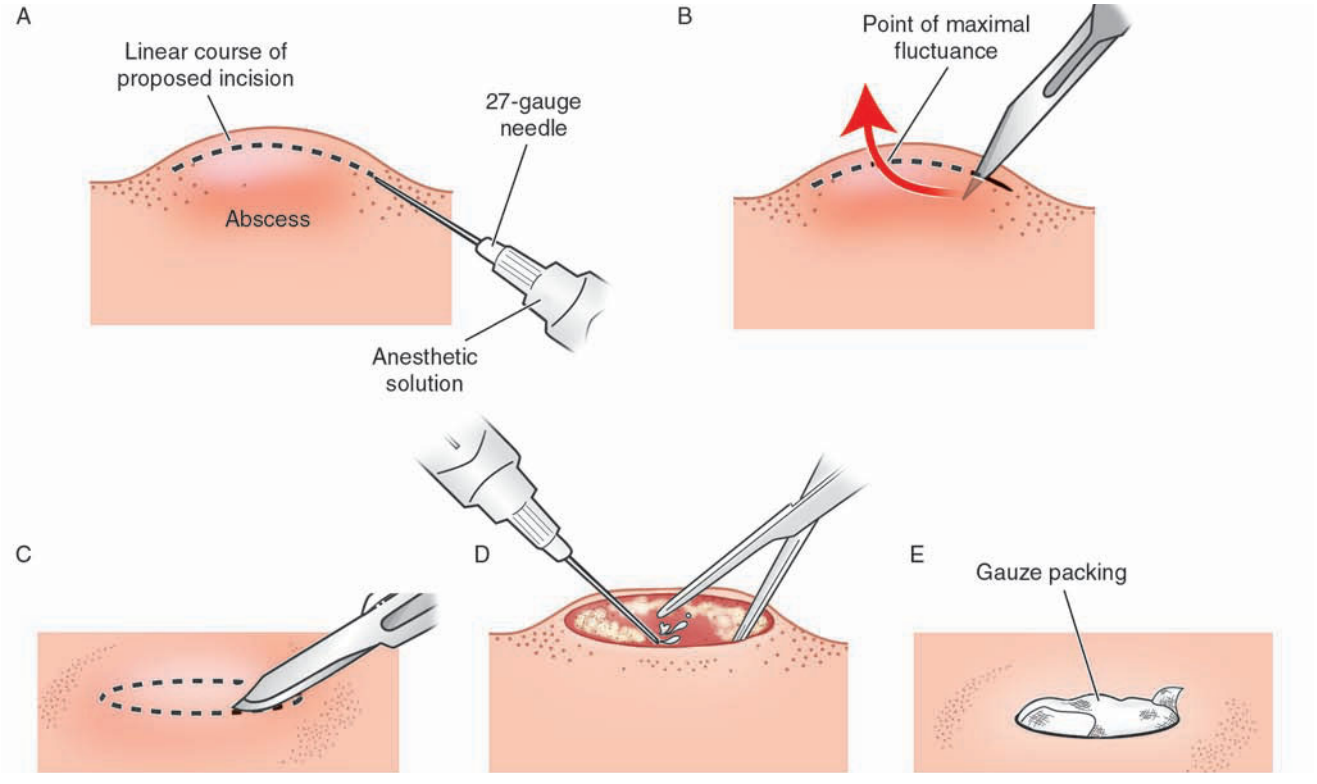


FIGURE 106-4. Incision and drainage of a subcutaneous abscess. **A.** Infiltration of local anesthetic solution over the abscess. **B.** A straight incision to drain the abscess. **C.** An elliptical incision to drain the abscess. **D.** The wound is irrigated with sterile saline. Any pockets of pus are opened by blunt dissection with the hemostat. **E.** The wound is packed open.

TECHNIQUES

ASPIRATION

Aspiration is performed as a diagnostic procedure in cases of soft tissue infections where the presence of an abscess is unclear, a mycotic aneurysm must be ruled out, or samples for Gram stain and culture are required. **Aspiration is not a therapeutic procedure in and of itself.** Anesthetize the skin. If ultrasound is available, locate the abscess cavity and try to determine the shortest needle path. Insert an 18 gauge needle attached to a 10 mL syringe into the skin. On ultrasound, the needle should appear as a bright, hyperechoic line with posterior reverberation artifact.[42] As the needle penetrates deeper, it should become increasingly oblique. Apply negative pressure to the syringe. Advance the needle into the area where pus or blood is presumed to be loculated. The procedure should be terminated and incision and drainage should be performed immediately if pus is obtained on aspiration. Anaerobic and aerobic culture bottles should be inoculated directly from the syringe if cultures are indicated. Simple swabbing of the purulent material after incision and drainage is inadequate for growth of anaerobic organisms. If blood is aspirated, terminate the procedure and apply firm pressure to the area to prevent a hematoma from forming. Angiography with surgical consultation should immediately follow. If no pus or blood is aspirated, redirect the needle in several directions to confirm the absence of an abscess. Discharge the patient with oral antibiotics, warm compresses, and follow-up in 24 hours for a reassessment.

INCISION AND DRAINAGE

Make an incision spanning the entire area of fluctuance and parallel to the relaxed skin tension lines to reduce scarring.[35] A straight incision with a #11 scalpel blade is usually performed (**Figure 106-4B**). An elliptical incision with a #15 scalpel blade is an alternative and often results in a similar appearing final scar (**Figure 106-4C**). The purpose of the elliptical incision is to remove a full thickness wedge of tissue so that the wound will remain open. This type of incision should not be made in cosmetically sensitive areas (e.g., face, neck, or breasts) or in areas with minimal subcutaneous tissue (e.g., hands and feet). **It is important to ensure a large enough incision to promote adequate drainage with the exception of cosmetically sensitive areas where a stab incision may be initially attempted to limit scar formation.**[5]

Debride any necrotic or devitalized tissue. Probe the cavity by inserting a hemostat. Gently spread the jaws open to break up any loculations and to release any further pockets of purulent material (**Figure 106-4D**).[6] Rotate the hemostat around the entire abscess to break any loculations. A scalpel should not be used for the blunt dissection of an abscess cavity as it may cause additional tissue damage and bacteremia.[14] Remove the tough shiny capsule by grasping the edges with a hemostat and applying firm traction if the abscess is due to an infected sebaceous cyst. The capsule can often be removed intact.

Irrigate the abscess cavity with an 18 gauge angiocatheter attached to a 10 mL syringe containing sterile saline (**Figure 106-4D**). This will flush away all loosened purulent and necrotic material. Loosely pack iodoform gauze into the abscess cavity (**Figure 106-4E**). Leave 1 to 2 cm of gauze exiting from the cavity to prevent the incision from sealing over and ensure an adequate drainage tract for the cavity. The value of antiseptic impregnated gauze over plain gauze is uncertain. Do not over pack the abscess cavity as this may interfere with the inflammatory hyperemia necessary for healing or retard drainage and reproduce "abscess-like" conditions.[6] Apply an absorbent dressing of 4 × 4 gauze over the

wound. Splinting and elevation of the affected area may be beneficial in select patients (e.g., young patients and confused patients).

AFTERCARE

The majority of available evidence suggests that incision and drainage of subcutaneous abscesses alone is adequate treatment and additional antimicrobial therapy is unnecessary in healthy patients with no major comorbidities. Many recent studies involving abscesses, including those caused by MRSA, have demonstrated that patients have similar outcomes regardless of whether or not appropriate antibiotics were used after an abscess incision and drainage.[17,24,52–54] A pediatric study demonstrated 94% resolution with incision and drainage alone in patients with abscesses smaller than 5 cm in diameter.[52] Some conflicting evidence from a retrospective cohort found ancillary antimicrobial treatment active against MRSA had a resolution of 95% while those patients not receiving antimicrobial treatment had a resolution of only 87%.[55]

Consider empiric antimicrobial therapy active against MRSA in cases involving multiple lesions, cutaneous gangrene, immunocompromised patients, extensive surrounding cellulitis, systemic toxicity, unusual pathogens, and in patients requiring hospitalization.[36,56] Further, recommendations from the Center for Disease Control suggest antibiotics after incision and drainage in those with rapid progression, comorbidities such as diabetes mellitus, HIV, neoplastic disease, those patients at extremes of age, abscesses in locations that are difficult to drain or have a risk of septic phlebitis associated with it, and lack of response to incision and drainage alone.[19] Pediatric patients with abscesses greater than 5 cm should also receive empiric antimicrobial therapy.[52]

An oral antibiotic such as cephalexin can be a good first choice for healthy individuals in areas where the prevalence of MRSA is extremely low.[19] **Knowledge of local MRSA prevalence and antimicrobial susceptibility patterns are paramount when selecting the appropriate antibiotic.**[19,36] If more than 10% to 15% of community *Staphylococcus aureus* isolates are MRSA, empiric treatment with agents that show activity against MRSA is warranted.[57] Current guidelines for outpatient therapy suggest using trimethoprim-sulfamethoxazole, Clindamycin, Doxycycline, Minocycline, or Linezolid. Rifampin can be added to many of these antimicrobials, but should not be used alone. IV therapy for patients with significant comorbidities and signs of systemic infection should include either Vancomycin, Daptomycin, Linezolid, or Tigecycline.[22,56] Trimethoprim-sulfamethoxazole, Clindamycin, and Doxycycline (if over the age of 7 years) are recommended in healthy children.[58] More serious infections should be approached with IV Vancomycin or Clindamycin, with the addition of nafcillin or gentamicin, and admission to the hospital.[58] The addition of an agent active against Group A Streptococcus is also recommended in cases with a severe surrounding cellulitis.[19] Current literature and consideration of the local antibiotic resistance patterns should guide antimicrobial selection.[19,56,59]

Follow-up in 24 to 48 hours to remove the packing and assess the response to therapy should be arranged. Pain can be adequately controlled with the use of acetaminophen or nonsteroidal anti-inflammatory drugs. Narcotic analgesics are rarely required. Instruct the patient to immediately return to the Emergency Department if they develop fever, chills, increased pain, increased swelling, or increased redness to the surrounding skin. Repack the cavity approximately every 48 hours until granulation tissue is developing throughout the wound and the drainage tract is well established if a large amount of drainage continues.[15,60] At that time, the remaining packing is removed and the patient is instructed to soak the area in warm water three to four times per day.[3] Healing occurs in 5 to 9 days in most cases.[4,6,15] The patient may be discharged from medical care when all signs of infection (i.e., erythema, drainage, pain, and induration) have resolved.

FUTURE ADVANCES IN ABSCESS MANAGEMENT

It is currently standard practice to pack an abscess cavity after an incision and drainage. Packing is used for hemostasis, to keep the abscess cavity from closing prematurely, and to debride the abscess cavity. Packing an abscess cavity can be painful and requires multiple follow-up visits. These visits are at an additional cost to the patient. A small, prospective study of noncomplicated abscesses found not packing an abscess cavity resulted in less pain, less analgesic use, and no increased morbidity.[62] Further studies are required before any definitive recommendation can be made regarding to pack or not to pack an abscess cavity.

Abscesses are currently allowed to heal by granulation. This process can take weeks and results in large scars. Primary suture closure after incision and drainage has been used around the world except in the United States.[63,64] This treatment can reduce scarring, reduce pain, and promote faster healing. Most of the studies involve a small number of patients, administered preprocedural antibiotics, and were performed in the Operating Room. Further studies are required before this change in practice can be recommended for the Emergency Department management of abscesses.

DECOLONIZATION AND PREVENTION

The role of decolonization regimes after incision and drainage does not have established effectiveness.[19] However, a decolonization regimen may play a role in those patients with recurrent infections, those not responding to therapy, or in patients with a closely associated cohort at risk (e.g., infirmed family, sports teams, or the institutionalized).[36] A recent randomized controlled trial of 2% chlorhexidine gluconate wash, 2% mupirocin intranasal ointment and oral rifampin, and doxycycline for 7 days found that after 3 months, 74% of patients were free of MRSA colonization.[61] This number dropped to 54% at 8 months post-treatment.[61] Colonization rates vary by geography and colonization is considered a risk factor for MRSA infection. However, decolonization is not routinely recommended due to limited supporting evidence, poor patient compliance, and the risk of increasing antibiotic resistance.[22]

Patient education is the most effective way to reduce the spread of infection and recurrent infections from MRSA.[19,22] Maintaining a clean and dry wound, frequent handwashing and bathing, avoiding sharing any personal items at all (athletic or otherwise), laundering clothing that has come into contact with the wound, avoiding skin to skin contact and disinfecting equipment and other surfaces are essential recommendations that should be made to outpatients with MRSA skin and soft tissue infections.[19]

COMPLICATIONS

Complications resulting from the incision and drainage of an abscess are uncommon. In most cases, some scarring will result from deliberate open packing and secondary intention granulation of the wound. Infectious complications, including inciting bacterial endocarditis as discussed earlier, are possible. **Endocarditis can be avoided with appropriate screening of patients and the administration of prophylactic antibiotic therapy in patients at risk.** Precipitation of septicemia because of transient bacteremia in an immunodeficient patient must be considered prior to the procedure. Incision and drainage of a mycotic aneurysm should not occur if an appropriate assessment is completed prior to making the incision.

SUMMARY

Simple incision and drainage under local or regional anesthesia in the Emergency Department can effectively treat most subcutaneous abscesses. Adjunctive procedural sedation may be required to adequately probe a deep cavity. A directed history and physical examination will identify those who may require additional lab work, imaging, specialty consultation, and follow-up. The majority of patients will not require antibiotics, although there may be a role for ancillary treatment in selected patients with MRSA infections. Attention must be paid to requirements for endocarditis prophylaxis and consideration given to the possibility of inducing bacteremia in any given patient.

107 Paronychia or Eponychia Incision and Drainage

Lisa R. Palivos

INTRODUCTION

A paronychia is an infection or abscess of the tissues around the base and along the sides of the nail plate. It is the most common infection in the hand.[1] A paronychia can be located on the fingers or the toes. It occurs in all age groups. It can cause significant pain and discomfort leading to a visit to the Emergency Department.

A paronychia initially presents with redness, swelling, and tenderness along the edges of the nail plate. This can progress to an abscess that requires drainage. An infection that extends to the overlying proximal cuticle is termed an eponychia. This chapter discusses the treatments, which vary with the extent and the location of the infection.

ANATOMY AND PATHOPHYSIOLOGY

The dorsal aspect of the distal digit consists of the nail plate, the nail bed (matrix), and the perionychium (**Figure 107-1**). The nail bed is situated beneath the nail plate and is responsible for growth of the nail. The perionychium consists of the soft tissue surrounding the nail plate (eponychium and lateral nail folds).

A paronychia is usually the result of frequent trauma, tight fitting apparel (e.g., gloves, pantyhose, and shoes), aggressive manicures, the use of artificial nails, hangnails or ingrown nails, or nail biting.[2] A disruption of the seal between the nail plate and nail fold allows bacteria to enter, leading to pus formation in the eponychial space (**Figure 107-1**). It begins as a swelling and erythema in the dorsolateral corner of the nail fold that can progress to an abscess. A paronychia can grow and spread to adjacent structures and result in a felon, an osteomyelitis, or a tenosynovitis. Many paronychias are polymicrobial, containing both aerobic and anaerobic organisms.[14] The most common organism to cause a paronychia is *Staphylococcus aureus*.[3] In children and nail biters, paronychias are often caused by anaerobes secondary to finger sucking or nail biting.[4] Gram-negative organisms should be considered in immunocompromised hosts. Chronic paronychias are the result of separation of the nail from the nail plate, which leaves a space for bacteria and fungi to collect.[12] These infections are usually caused by *Candida albicans*.[5]

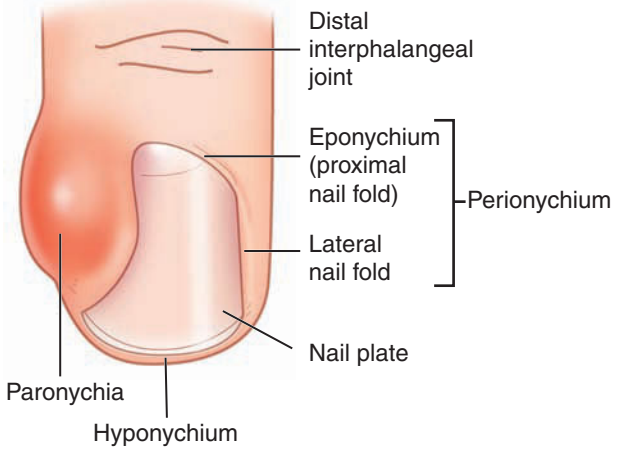


FIGURE 107-1. The distal finger illustrating a paronychia and the surface anatomy.

INDICATIONS

An early paronychia with signs of cellulitis may be treated nonsurgically. This requires frequent warm soaks (e.g., water, vinegar, or Burow's solution), immobilization, elevation, topical antibiotics (e.g., bacitracin or Mupirocin) with or without topical corticosteroids, and follow-up in 24 hours.[2,6,11,12] Paronychia resistant to these measures should be treated with oral antibiotics to cover *Staphylococcus*, plus anaerobic coverage if nail biting or finger sucking were causative agents.[12] Amoxicillin/clavulanate, clindamycin, and trimethoprim-sulfamethoxazole are commonly used antibiotics. Take into account the prevalence of methicillin-resistant *Staphylococcus aureus* in your community when deciding upon the choice of antibiotic.

A progression of the infection results in fluctuance and the formation of an abscess. The digital pressure test may be used to diagnose the presence of an abscess when the exam is otherwise equivocal. Instruct the patient to oppose the thumb and affected finger and apply light pressure to the distal volar aspect of the affected digit. If an abscess is present, the skin under the nail plate will blanch.[10] The presence of an abscess, fluctuance, or pus beneath the nail plate requires an incision and drainage procedure. This procedure will relieve the patient's pain, promote healing, and prevent complications from local extension into surrounding bone and soft tissues.

CONTRAINDICATIONS

A herpetic whitlow is a herpes simplex virus infection of the distal phalanx that can be confused with an early paronychia or felon. The presence of multiple clear vesicles that coalesce suggests a herpetic whitlow. The herpetic whitlow is a nonsurgical and self-limited infection. Treatment consists of a dry dressing to the affected finger in order to prevent autoinoculation and transmission of the infection, oral antiviral agents, and analgesics. Incision and drainage is not recommended, will prolong the recovery, and lead to secondary bacterial infection.[7] A chronic paronychia should be referred to a Hand Surgeon or Dermatologist for treatment.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves
- #11 scalpel blade or an 18 gauge needle
- Local anesthetic solution without epinephrine
- 18 and 27gauge needles
- 5 to 10 mL syringe
- Ethyl chloride spray
- Forceps

- Mosquito hemostat
- Ribbon-gauze packing, ½ in. wide
- Petrolatum gauze, ½ in. wide
- Scissors
- 4 × 4 gauze squares
- 18 gauge angiocatheter
- 20 mL syringe
- Sterile saline
- Adhesive tape

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain an informed consent for the procedure. Assess and update the patient's tetanus immune status if indicated. Place the patient on a gurney with the extremity on a bedside procedure table in a well-lit room. Soak the digit in warm water for 5 minutes to soften the skin. Perform a digital nerve block if the patient is apprehensive, has significant tenderness, or if it is not a simple paronychia or eponychia. Refer to Chapter 126 for the complete details regarding digital anesthesia techniques. Alternatively, apply ethyl chloride spray to the area until the skin turns frosty and pale. Apply povidone iodine or chlorhexidine solution circumferentially to the distal digit and allow it to dry. The digit can be secured to a sterile tongue depressor for better control, especially in uncooperative children.

TECHNIQUES

SIMPLE PARONYCHIA OR EPONYCHIA

There is no need for a skin incision in an uncomplicated paronychia or eponychia. Simply lifting the eponychium off the nail plate at the point of maximal tenderness and/or fluctuance is usually curative. Slide the tip of a #11 scalpel blade (or an 18 gauge needle) under the paronychia, or eponychia, at the site of maximal fluctuance (**Figure 107-2**). Advance the scalpel blade to lift the soft tissue from the nail plate until there is an efflux of purulent fluid. Apply digital pressure to the area to express the pus. Gently place a hemostat under the soft tissue to break any loculations. Irrigate the pocket with an angiocatheter on a syringe containing sterile saline.

Packing a paronychia is controversial and physician-dependent. Place a small piece of ribbon gauze or petrolatum gauze under the elevated soft tissue followed by a simple dressing. If packing is not performed, apply an antibiotic ointment followed by a simple dressing or bandage. Oral antibiotics are not recommended for an uncomplicated paronychia or eponychia.

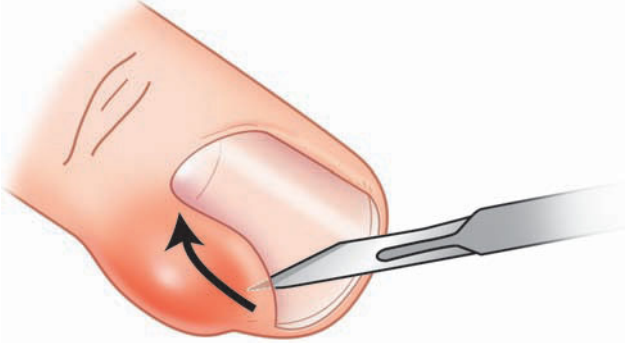


FIGURE 107-2. Drainage of a simple paronychia or eponychia. The eponychial fold is elevated from the nail plate with a #11 scalpel blade. Note that the blade is parallel to the nail plate, thereby avoiding injury to the nail matrix and not incising the skin.

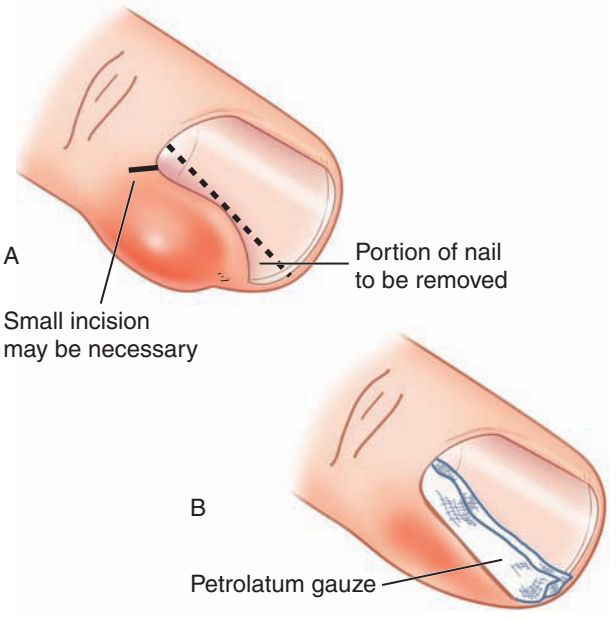


FIGURE 107-3. Removal of the lateral nail plate is required when pus extends laterally below the nail plate. **A.** The dotted line over the nail represents the incision required to remove the nail plate. An additional incision may be required on the eponychium. **B.** The lateral portion of the nail plate has been removed and petrolatum-gauze packing has been inserted to keep the nail fold elevated from the nail bed.

PARONYCHIA WITH EXTENSION UNDER THE LATERAL NAIL PLATE

A more extensive incision and drainage is required when pus accumulates laterally and beneath the nail plate. Remove the lateral nail plate to allow adequate drainage (**Figure 107-3A**). Use scissors to cut the nail plate longitudinally. Aim the point of the scissors upward and against the undersurface of the nail plate to prevent injuring the nail bed. Remove the lateral nail plate with a hemostat. A small (2 to 3 mm) incision may be required in the corner of the nail fold to remove the nail plate (**Figure 107-3A**). This will result in the egress of pus. Irrigate the area with saline. Insert a small piece of petrolatum gauze under the nail fold (**Figure 107-3B**). This will prevent the nail fold from fusing to the nail bed.

PARONYCHIA WITH EXTENSION UNDER THE PROXIMAL NAIL PLATE

A paronychia with extension under the proximal nail plate also requires the removal of a portion of the nail plate (**Figure 107-4**). Make two 3 to 4 mm long incisions at the corners of the nail folds (**Figure 107-4A**). Cut the proximal one-third of the nail plate with scissors (**Figure 107-4B**). Aim the point of the scissors upward and against the undersurface of the nail plate to prevent injuring the nail bed. Grasp and remove the proximal segment of the nail plate with a hemostat. This will result in the egress of pus. Irrigate the area with saline. Insert a piece of petrolatum gauze under the nail fold to prevent it from fusing to the nail bed (**Figure 107-4C**).

Removal of the entire nail is rarely necessary except in the case of an extensive subungual abscess. An alternative to nail removal

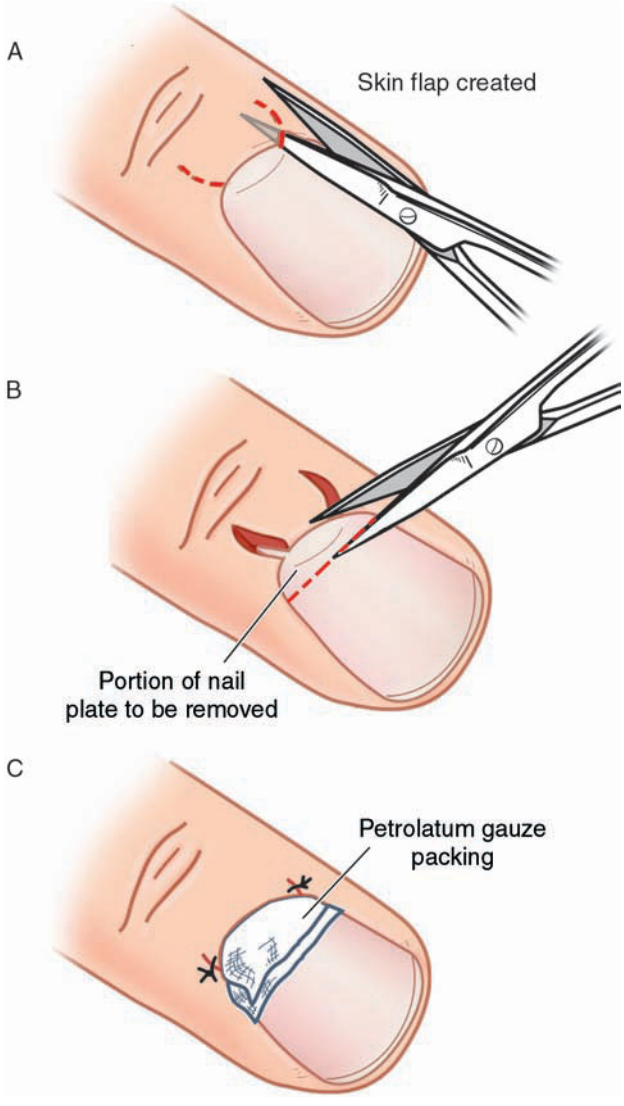


FIGURE 107-4. Removal of the proximal nail plate is required when pus extends proximally below the nail plate. **A.** Two incisions are required through the eponychium, represented by dotted lines. **B.** The dotted line over the nail plate represents the incision required to remove the nail plate. **C.** The proximal portion of the nail plate has been removed and petrolatum-gauze packing has been inserted to keep the nail fold elevated from the nail bed.

is trephination with a heated paper clip or a microcautery unit.[8] A large opening or multiple holes are required with this technique in order to eliminate the pus. Refer to Chapter 102 for the complete details regarding trephination.

CHRONIC PARONYCHIA

A chronic paronychia occurs from recurrent episodes of inflammation or from neglected infections. It is much more difficult to treat and eradicate than an acute infection. A chronic paronychia is seen frequently in immunosuppressed patients, such as those with diabetes or cancer. These effects are due to the disease process, such as in diabetes, or due to effects of treatment, as seen with certain HIV drugs and chemotherapeutic agents.[12] A chronic paronychia is also common in people who wash their hands often, such as dishwashers and healthcare providers. It can also be due to frequent contact with chemicals, finger biting or sucking, and cuticle trimming. The most frequently isolated organism is *C. albicans*, which commonly coexists with *S. aureus*.[5,6] Initial treatment typically includes avoiding the noxious exposure, topical emollients, and antifungals.[13] Definitive treatment for a chronic paronychia is eponychial marsupialization. This involves removal of a crescent-shaped piece of skin proximal to the nail fold and parallel to the eponychium, extending from the radial to ulnar borders. In addition to marsupialization, complete or partial nail removal may be necessary if nail ridging is present.[9] A chronic paronychia may be confused with another condition that looks similar and mimics a chronic paronychia such as cysts, foreign body reactions, malignancies, psoriasis, and verrucae. Refer all chronic paronychia to a Hand Surgeon due to the higher rate of recurrence, the complexity in management, and where follow-up care can be more consistent.

AFTERCARE

Immobilize and elevate the digit. Instruct the patient to avoid nail biting or sucking. Any discomfort can be treated with acetaminophen or nonsteroidal anti-inflammatory medications. Follow-up care in 24 hours is important as complications can occur despite proper Emergency Department management. Packing of a simple paronychia should be removed in 24 hours. Warm soaks can begin immediately if packing is not placed. Otherwise, warm soaks should be delayed until the packing is removed in 24 hours. There is no evidence that oral antibiotics improve outcome after the incision and drainage of a simple and uncomplicated paronychia. Oral antibiotics are not necessary unless the nail bed is involved, there is apparent cellulitis of the surrounding tissue, or if there are systemic signs of infections such as lymphangitis and fever.[6] Patients should return to the Emergency Department if they develop a fever, reaccumulation of pus, redness extending up the finger and hand, or increased tenderness to the digit.

Most simple paronychias resolve within a few days. If they persist longer or recur, consult a Hand Surgeon for more aggressive management, such as eponychial marsupialization and nail plate removal.

Paronychia or eponychia that extend under the nail plate require follow-up in 24 hours. The packing must be maintained between the nail fold and the nail bed for at least 5 to 7 days. The nail fold will fuse to the nail bed if the packing is removed too soon and a new nail plate will not form. These infections require a 5 to 7 day course of oral antistaphylococcal antibiotics. Nonsteroidal anti-inflammatory medications supplemented with occasional narcotic analgesics will provide adequate pain control for these patients.

COMPLICATIONS

Complications, even in a properly drained paronychia, include a felon, osteomyelitis of the distal phalanx, and a tenosynovitis. Superinfection with *C. albicans* or other fungi can also occur. These complications can be due to the paronychia itself or from an inadequate incision and drainage procedure.

Complications from the incision and drainage procedure are rare if it is properly performed. Care must be taken if the lateral or proximal nail plate is removed to avoid damaging the underlying matrix so that a nail deformity does not result. Fusion of the nail fold to the nail bed will result in a new nail not being formed. Inadequate drainage can result in the infection spreading to adjacent bone and soft tissues. Incision of the skin instead of elevating it off the nail plate can result in prolonged healing.

SUMMARY

A paronychia is one of the most common hand infections. The treatment depends on the extent and location of the infection. The incision and drainage procedure is quick, simple, and easy to perform.

Simple paronychias require elevation of the nail fold with no incision. A more extensive incision and drainage is required along with nail excision when pus accumulates below the nail plate. Follow-up is critical as complications may occur, even when the Emergency Department treatment is optimal.

108 Felon Incision and Drainage

Lisa R. Palivos

INTRODUCTION

A felon is a subcutaneous infection or abscess in the pulp space on the volar surface of the distal phalanx. It is usually caused by penetrating trauma, an abrasion, spread from adjacent tissues (e.g., eponychium, osteomyelitis, or paronychia), or a minor cut with invasion of bacteria. A felon can also develop in the presence of a foreign body, such as a wood splinter or a thorn.[1] It can be iatrogenic from multiple fingersticks for glucose determination.[2] The offending organism is usually *Staphylococcus aureus*. Mixed infections and gram-negative infections may occur in the immunocompromised patient. A felon can less commonly occur on the toes. The information in this chapter can be applied to a felon of the finger or the toe.

ANATOMY AND PATHOPHYSIOLOGY

Felons initially present with a gradual onset of pain and erythema of the distal volar finger. Intense throbbing pain, warmth, and swelling develop with the formation of an abscess as the infection progresses. **The proper treatment for a felon is incision and drainage.** There are multiple techniques to incise and drain a felon. The patient requires digital elevation, immobilization, oral antistaphylococcal antibiotics, oral analgesics, and close follow-up to prevent complications following the incision and drainage.[3–7]

The distal finger consists of a closed compartment that is bound by the nail plate dorsally, by the skin ventrally and distally, and by the flexion crease proximally (**Figure 108-1**). This pulp region is divided by multiple (up to 15 or 20) vertical fibrous septa.[8] These septa extend from the volar surface of the fat pad to the periosteum of the distal phalanx. They divide and compartmentalize the pulp area. When an abscess occurs, it is confined by the septa. They also limit the proximal spread of an infection. Unfortunately, they also inhibit the abscess from reaching the surface and inhibit drainage after the incision and drainage procedure. Blood is supplied by branches of the digital arteries that run parallel and lateral to the phalanx and terminate in the pulp region. The terminal branches of the digital nerves lie palmer and superficial to the arteries. The flexor digitorum profundus tendon inserts on the volar surface of the proximal distal phalanx.

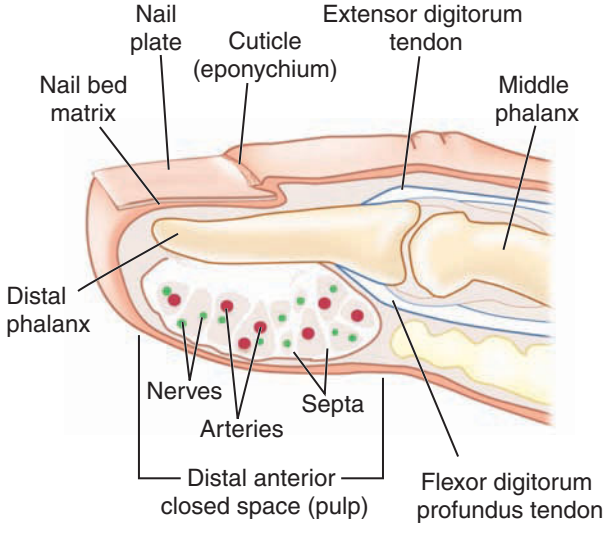


FIGURE 108-1. Midsagittal section demonstrating the anatomy of the distal finger.

INDICATIONS

All felons that are fluctuant should be incised and drained. Volar digital pads that are tense, tender, painful, and suspected of containing a felon should be incised and drained regardless if fluctuance is palpated or not.

CONTRAINDICATIONS

Felons that are not yet fluctuant, as in an early infection, may be treated with warm soaks, elevation, oral antibiotics, and follow-up in 24 hours.[6,7] A herpetic whitlow can sometimes be confused with a felon.[5,9] A herpetic whitlow can be clinically distinguished by the presence of multiple vesicles and a history of recurrence or simultaneous genital or oral lesions. Treatment of a herpetic whitlow is nonsurgical and consists of a protective dry dressing, oral antiviral agents, and analgesics. Incision and drainage of a herpetic whitlow may spread the virus and predispose the patient to secondary bacterial infection.[9]

Consult a Hand Surgeon for complicated felons. This includes a felon that is associated with lymphangitis, osteomyelitis, a tenosynovitis, an infection that has spread proximal to the distal interphalangeal joint, or if the patient is immunocompromised. These patients require hospital admission, intravenous antibiotics, and possible incision and drainage in the Operating Room.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves
- #11 scalpel blade on a handle
- Local anesthetic solution without epinephrine
- 18 and 27 gauge needles
- 5 or 10 mL syringe
- 20 mL syringe
- Ethyl chloride spray
- Sterile saline
- 18 gauge angiocatheter
- Mosquito hemostat
- Ribbon gauze, ½ in. wide
- Bandage material
- Digital splint (plaster, preformed, or tongue depressor)
- Sling
- Digital tourniquet, optional
- Aerobic and anaerobic culture bottles, optional

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain an informed consent for the procedure. Assess and update the patient's tetanus immune status if indicated.

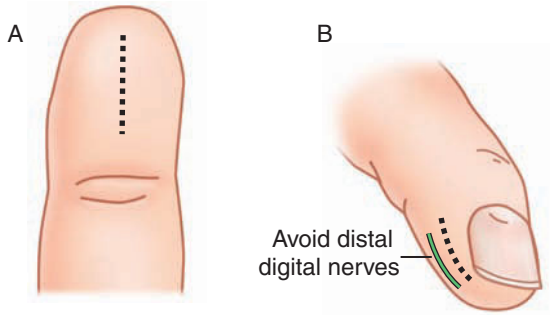


FIGURE 108-2. Recommended incisions for the incision and drainage of a felon. A felon should be incised and drained in the area of maximal fluctuance. **A.** The longitudinal fat pad incision over the area of maximum fluctuance. **B.** The unilateral longitudinal incision is high, lateral, and just below the level of the nail.

Some physicians prefer to obtain anteroposterior and lateral radiographs of the digit to rule out an osteomyelitis or foreign body prior to performing the procedure. A positive radiograph for osteomyelitis will alter the time course for antibiotic therapy and require follow-up with a Hand Surgeon.

Place the patient on a gurney with the extremity on a bedside procedure table in a well-lit room. Soak the digit in warm water for 5 minutes to soften the skin. Perform a digital nerve block if the patient is apprehensive, has significant tenderness, or if it is not a simple felon. Refer to Chapter 126 for the complete details regarding digital anesthesia techniques. Alternatively, apply ethyl chloride spray to the area until the skin turns frosty and pale. Apply povidone iodine or chlorhexidine solution circumferentially to the distal digit and allow it to dry. Apply sterile drapes to delineate a sterile field. The digit can be secured to a sterile tongue depressor for better control, especially in uncooperative children. The application of a digital tourniquet to create a bloodless field is optional.

TECHNIQUES

Multiple incisions can be employed. Make an incision in the area of greatest fluctuance or tenderness with a #11 scalpel blade.[3–6] Make a longitudinal incision if the maximal tenderness is in the center of the pulp of the distal fingertip (**Figure 108-2A**). **The incision should not come within 4 mm of or cross the crease of the distal interphalangeal joint as this can lead to injury of the flexor digitorum longus tendon or the joint, flexor tenosynovitis, and flexion contractures.**[7] Make the incision along the lateral surface of the finger if the felon has maximal tenderness on the radial or ulnar aspect of the finger (**Figure 108-2B**). Purulent and/or bloody pink fluid will exit from the incision. While not required, consider obtaining aerobic and anaerobic cultures of the purulent material. Gently probe the loculations with a mosquito hemostat. Irrigate the wound with an 18 gauge angiocatheter on a 5 or 10 mL syringe containing sterile saline. Place a piece of ribbon gauze into the wound. Apply a dry bulky dressing.

ALTERNATIVE TECHNIQUES

Alternative incisions have been advocated but are not recommended because they have higher complication rates (Figure 108-3). These incisions can result in neurovascular injury, painful scars, and altered fingertip sensation. The hockey stick incision can result in digital nerve injury and produce numbness to the fingertip (**Figure 108-3A**).[5] The through-and-through or bilateral longitudinal incision can result in bilateral digital nerve injury and complete anesthesia of the fingertip (**Figure 108-3B**).[6] The transverse palmar incision may transect the digital neurovascular bundles (**Figure 108-3C**). The fishmouth or horseshoe incision is very extensive, can take a long time to heal, produces a large scar, and an unstable pulp (**Figure 108-3D**).[5]

AFTERCARE

Splint the involved digit. Provide the patient a sling to keep the hand elevated. Since the incidence of community-acquired methicillin-resistant *Staphylococcus aureus* (CA-MRSA) skin and soft tissue infections presenting to the Emergency Department are increasing, an oral antibiotic effective against CA-MRSA is recommended.[10,11] Depending on local resistance patterns, sulfamethoxazole-trimethoprim, doxycycline, or clindamycin are appropriate choices for a 7 to 10 day course. Nonsteroidal anti-inflammatory medications supplemented with narcotic analgesics will control any postprocedural pain. Instruct the patient to soak the digit in warm water several times a day to speed healing. Patients should immediately return to the Emergency Department if they experience fever, increased pain, difficulty using the finger, redness of the finger or hand or arm, or a discharge from the wound.

The patient should be reevaluated in 24 to 48 hours for removal of the gauze and inspection of the digit. Remove the gauze during the follow-up visit. Perform a digital or metacarpal block for patient comfort. Irrigate the wound with sterile saline and break up any further loculations, if needed. Replace the gauze for another 24 to 48 hours if there is continued drainage.

COMPLICATIONS

Untreated or mistreated felons may cause skin necrosis, osteitis or osteomyelitis of the distal phalanx, septic arthritis of the distal interphalangeal joint, extension of the infection into the palm and adjacent fingers, suppurative tenosynovitis, and lymphangitis.[12] Flexor tenosynovitis can occur if the incision is extended too far proximally and too deep. Improperly placed incisions can result in injury

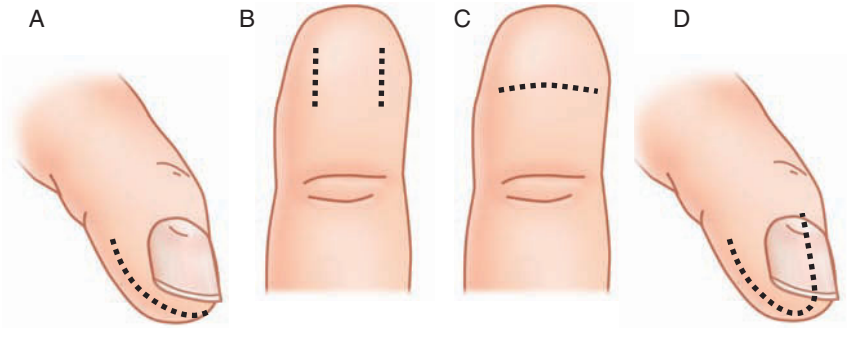


FIGURE 108-3. Incisions not recommended for the drainage of a felon. **A.** The hockey stick incision. **B.** The through-and-through or bilateral longitudinal incision. **C.** The transverse palmar incision. **D.** The fishmouth incision.

to the flexor digitorum profundus tendon or the distal interphalangeal joint, mobility of the pad of the finger, neurologic compromise, and/or vascular compromise. The lack of improvement within 24 to 48 hours requires consultation with a Hand Surgeon.

SUMMARY

Felons require incision and drainage. The procedure is quick, simple, and easy to perform. The incision should be made at the point of maximal fluctuance while avoiding injury to the digital arteries, digital nerves, the flexor digitorum profundus tendon, and the distal interphalangeal joint. Close follow-up is mandatory to prevent any complications. Consult a Hand Surgeon for any complications associated with the felon.

109 Pilonidal Abscess or Cyst Incision and Drainage

Lauren M. Smith

INTRODUCTION

Controversy surrounds pilonidal disease, from who first described it, to the etiology, and how to manage it surgically. Some believe that pilonidal disease was first described in 1880 by Hodges.[1] However, others say it was first described in 1833 by Mayo.[2] Hodges used the term "pilonidal sinus" to describe a chronic infection that contained hair and was usually found between the buttocks. The word "pilonidal" comes from "pilus" or hair and "nidus" or nest. It literally means "nest of hair." The condition did not receive much attention until it became a significant problem in the armed services around the time of World War II. In 1940, in the United States Navy, the number of sick days caused by pilonidal disease and its complications exceeded those of either syphilis or hernias.[3] This condition was coined as "jeep disease" by Buie in 1944 because of the high occurrence rate in those that drove or were frequent passengers in military vehicles.[4]

Pilonidal sinus disease primarily affects Caucasian males. Blacks are infrequently affected and the condition is rare in Asians and Indians. Males are affected three to four times more frequently than females. The affected females tend to be younger than males.[19] The condition is prevalent from the onset of puberty to young adulthood and is rare after the age of 40. The peak age of incidence is 21 years. The increased incidence in adolescents and young adults is attributed to hormonal effects of increased hair on the torso, increased activity of sebaceous and sweat glands, fat deposition on the buttocks, and deepening of the gluteal cleft. Other risk factors may include hirsutism, obesity, and poor personal hygiene. Repeated trauma to the area may also contribute to the formation of pilonidal disease. There is an increased prevalence in drivers and others with occupations requiring long periods of sitting.[6,7]

Patients with pilonidal sinus disease may present with three different clinical pictures: asymptomatic disease, an acute abscess, or chronic disease. Asymptomatic disease patients have a painless sinus pit at the top of the natal cleft. Patients with chronic disease may have mild discomfort and a chronically draining sinus in the upper gluteal region. Approximately 50% of patients with symptomatic pilonidal disease will present acutely with severe pain and frequently swelling that is indicative of a pilonidal abscess that necessitates incision and drainage.[8,9] Inspection will reveal one or more midline sinus tract openings, often with protruding tufts of hair. The area will be tender, erythematous, and indurated when an abscess is present. Fluctuance and swelling may not be readily appreciated. The sinuses may be quite extensive depending upon the chronicity of the disease process prior to presentation.

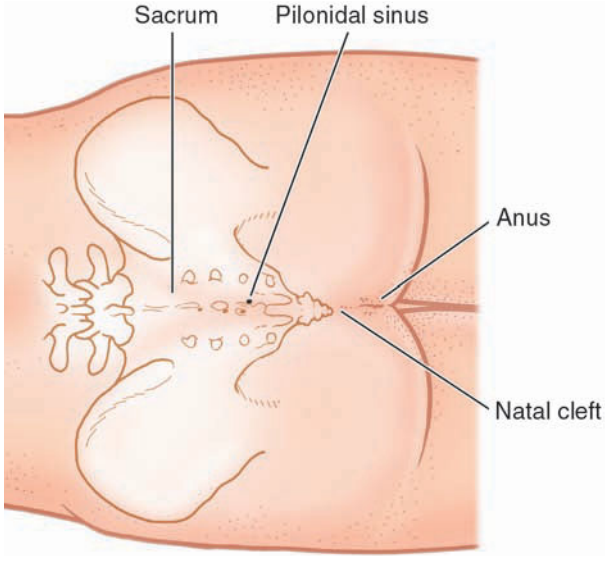


FIGURE 109-1. Pilonidal sinuses occur in the midline, approximately 4 to 5 cm above the anus and in the natal cleft.

ANATOMY AND PATHOPHYSIOLOGY

A pilonidal sinus consists of a characteristic midline opening, or series of openings, in the upper aspect of the gluteal cleft and approximately 4 to 5 cm from the anus (**Figure 109-1**). The skin enters the sinus giving the opening a smooth edge. This primary tract leads into a subcutaneous cavity that contains granulation tissue and often a nest of hairs (**Figure 109-2**). The hairs may be seen projecting through the skin opening. Many sinuses have lateral or secondary openings (fistulas) extending from the pilonidal abscess (**Figure 109-2**).

There have been various opinions as to the etiology of the condition since the first description of the disease. In the first half of the twentieth century, it was generally attributed to a congenital lesion. Some authors believed that the pilonidal sinus originated from a remnant of the medullary canal that subsequently became infected. However, pilonidal disease can form in other areas of the body that lack hair, as some barbers have experienced in interdigital spaces.[10,11] Currently, it is widely accepted that pilonidal disease is acquired.[5] Some of the contributing factors to this belief are the

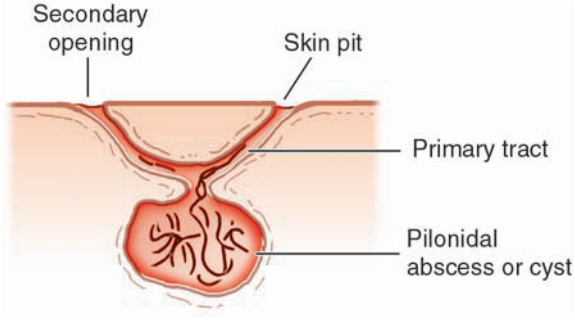


FIGURE 109-2. Cross section through a pilonidal abscess and sinus. A primary tract and skin pit leads to the subcutaneous abscess. There may be secondary or lateral openings (fistulas).

rate of recurrence after excision, occurrence at other sites than the gluteal cleft, and the frequency seen among certain populations (i.e., barbers, armed forces, etc.).[10,11]

Loose hairs from the adjacent gluteal region are thought to form a bristly tuft and penetrate into the skin, perhaps in an area of skin irregularity. This process may be aided by pressure on the region in persons with occupations that require long hours of driving or sitting. The hairs may also be pulled in by a suction effect between the moving buttocks. The hair penetrates the skin and causes a foreign body reaction and secondary inflammation with the potential for infection and abscess formation. The sinuses spread cranially and laterally. They rarely approach the anus and generally remain superficial to the presacral fascia.[9,10,12]

INDICATIONS

Incision and drainage is indicated whenever a patient presents with a pilonidal abscess. Antibiotics alone are ineffective in treating a pilonidal abscess. Rarely, systemic signs and symptoms may ensue. There are reported cases of necrotizing fasciitis from neglected pilonidal sinus disease. Thus, it is preferable to treat pilonidal abscesses expeditiously with an incision and drainage procedure.

CONTRAINDICATIONS

The great majority of pilonidal abscesses may be drained in the Emergency Department. Patients occasionally present with fever, systemic signs and symptoms, and/or toxicity. They should be admitted to the hospital for parenteral antibiotics, incision and drainage, and observation. This is particularly true if the patient has diabetes or is immunocompromised. Consult a Surgeon to manage these patients. Extensive abscesses should be incised and drained in the Operating Room under general anesthesia. Patients who are asymptomatic do not require an incision and drainage and can be referred to a Surgeon for removal. The procedure should be conducted under general anesthesia in the Operating Room if adequate anesthesia cannot be obtained and pain limits the procedure.

EQUIPMENT

- Gown, face mask, and gloves
- Benzoin solution
- Povidone iodine or chlorhexidine solution
- Skin razor
- 10 mL syringe
- 25 or 27 gauge needle, 2 in. long
- Local anesthetic solution with epinephrine, lidocaine, or bupivacaine
- #11 scalpel blade on a handle
- #15 scalpel blade on a handle
- Curved hemostat
- 4 × 4 gauze squares
- Ribbon gauze, plain or iodoform
- Adhesive tape

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The postprocedure care should be explained as well. Document the discussion of the risks and benefits of the procedure. Obtain a signed informed consent for the procedure.

The best visualization of the sacral region, particularly in obese patients, occurs with the use of a proctoscopic examination table, if available (**Figure 109-3A**). Place the patient prone on a gurney or on the proctoscopy table. Alternatively, place the patient in the lateral knee-chest position to expose the affected area (**Figure 109-3B**). Apply benzoin solution to the buttocks and allow it to dry. Apply adhesive tape to the buttocks and tape them open (**Figure 109-4**). Clean any dirt and debris from the skin overlying the abscess or cyst. Apply povidone iodine or chlorhexidine solution and allow it to dry. Shave the surrounding area, if the patient is hirsute, to aid in the application of the dressing after the procedure. Some authors advocate shaving the sacral region to prevent recurrence as well, although this has not been proven to be effective. A gown, face mask, and gloves (nonsterile) are recommended to be worn for this procedure.

ANESTHESIA

Local anesthesia should be administered, recognizing that it is often difficult to obtain complete anesthesia by direct infiltration of an abscess. Local anesthetics are weak acids and are less effective in the acidic environment of an abscess. The skin over the abscess

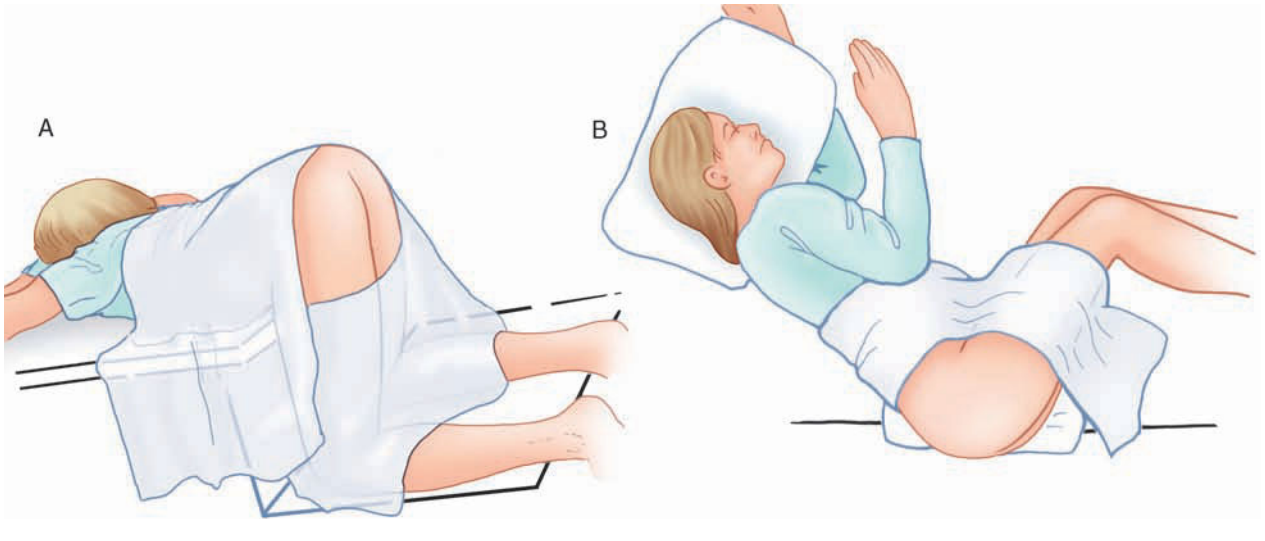


FIGURE 109-3. Patient placement. **A.** Prone on a proctoscopy table. The patient may also be placed prone on a gurney. **B.** The lateral knee-chest position.

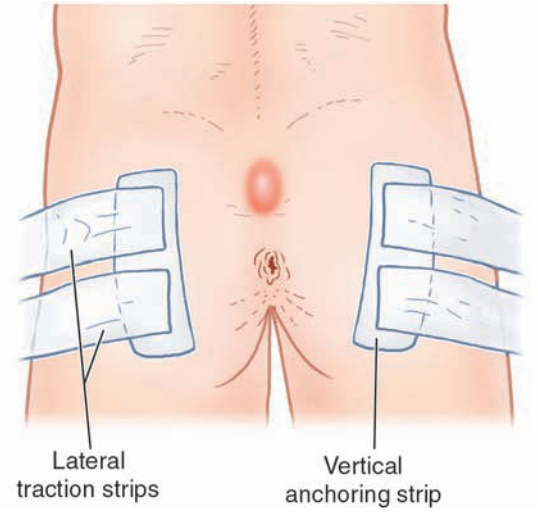


FIGURE 109-4. Exposure of the abscess.

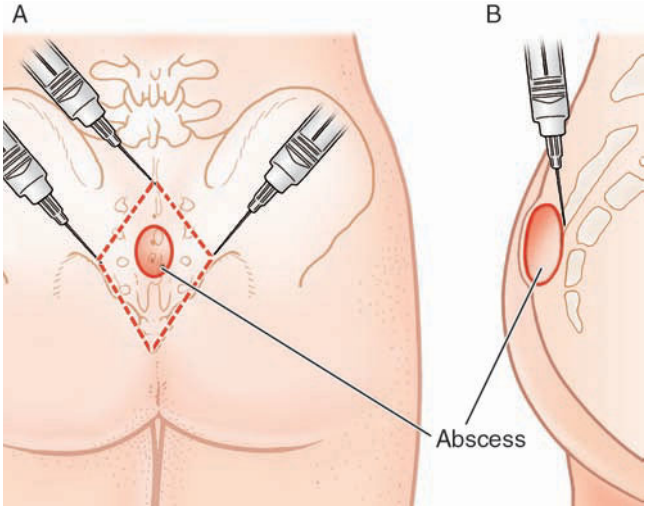


FIGURE 109-6. Field block anesthesia for a pilonidal abscess. **A.** Local anesthetic solution is infiltrated subcutaneously on all four sides of the abscess. **B.** The local anesthetic solution is infiltrated deep to the abscess cavity in a fan-like pattern.

cavity usually becomes insensate, but anesthesia of the abscess cavity itself is not possible. The pain caused by injection of the local anesthetic solution is related to the rate that it is injected and the force necessary to inject it. **Inject the local anesthetic solution slowly through a small-bore needle (25 or 27 gauge) as the needle is withdrawn through the dermis.** The needle bore will create a passage through the subcutaneous tissue as it is inserted that enables the local anesthetic solution to be infiltrated slowly and with less discomfort.

Hold the syringe horizontal in reference to the skin surface. Inject 3 to 4 mL of local anesthetic solution intradermally over the dome of the abscess (**Figure 109-5**). The skin will blanch if the injection is given properly. **Do not inject the local anesthetic solution into the abscess cavity.** The increased pressure within the cavity will cause more discomfort to the patient and may cause the local anesthetic solution or the abscess contents to be forcefully expelled if there is an opening in the skin.

Additional anesthesia is accomplished by performing a field block (**Figure 109-6**).[13] Inject local anesthetic solution subcutaneously around the periphery of the abscess (**Figure 109-6A**). Inject local anesthetic solution deep to the abscess in a fan-like pattern (**Figure 109-6B**).

Systemic analgesia (i.e., procedural sedation) is usually required since it is quite difficult to obtain adequate anesthesia of an abscess locally. Refer to Chapter 129 for the complete details of procedural sedation. Patient-administered nitrous oxide, with or without supplemental narcotic analgesics, is an alternative to procedural sedation. Refer to Chapter 128 for the complete details of nitrous oxide anesthesia. Obtain an additional signed informed consent for the procedural sedation or the nitrous oxide administration. **The procedure should be conducted under general anesthesia in the Operating Room if adequate anesthesia cannot be obtained and pain limits the procedure.**

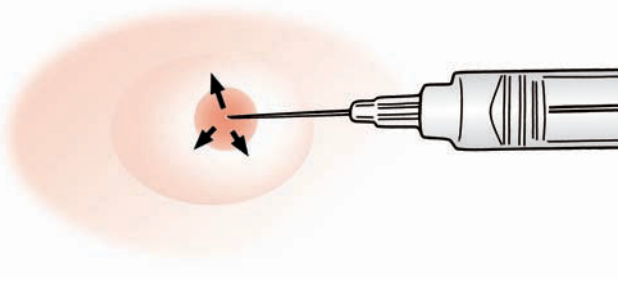


FIGURE 109-5. Subcutaneous infiltration of local anesthetic solution. The needle and syringe are held parallel to the skin. The needle is inserted into the subcutaneous tissue overlying the pilonidal abscess. Infiltrate the local anesthetic solution as the needle is withdrawn. The skin should blanch (shaded area) if injected properly.

TECHNIQUE

Incise the skin over the area of maximum fluctuance with a scalpel blade. A 10% recurrence rate after drainage of chronic abscesses through a vertical incision lateral to the midline has been reported.[14] This may be due to better healing of wounds that are off the midline. Thus, some authors and Colorectal Surgeons recommend that the incision for an acute abscess be off the midline if the abscess can be drained adequately through the incision (**Figure 109-7A**). Extend the incision the length of the abscess to allow for proper drainage. A full-thickness, thin ellipse of skin can be removed to prevent premature closure of the skin edges. Approximately 40% of pilonidal abscesses will be cured from simple incision and drainage alone.[15] It is not necessary to perform more radical excision procedures in the Emergency Department.

It is important that loculations be lysed and the area thoroughly drained to minimize recurrence. Several methods can be used to lyse adhesions within the cavity. A gloved finger may be used to bluntly break up the adhesions. Hemostats can be inserted and spread within the abscess cavity. A useful technique employs a 4×4 gauze square clamped in a hemostat and swirled inside the abscess cavity to break adhesions and remove debris (**Figure 109-7B**). This technique aids in removing hair and the infected lining of the cyst. Irrigate the abscess cavity with normal saline.

Loosely pack the cavity with ribbon gauze. Packing the cavity too tightly may cause ischemia to the surrounding tissue, delays healing, and is uncomfortable for the patient. The purpose of the packing is to keep the skin edges from adhering before the cavity closes. Cover the incision with a simple bandage composed of gauze and adhesive tape. A thick layer of absorbent gauze will soak up any continued drainage.

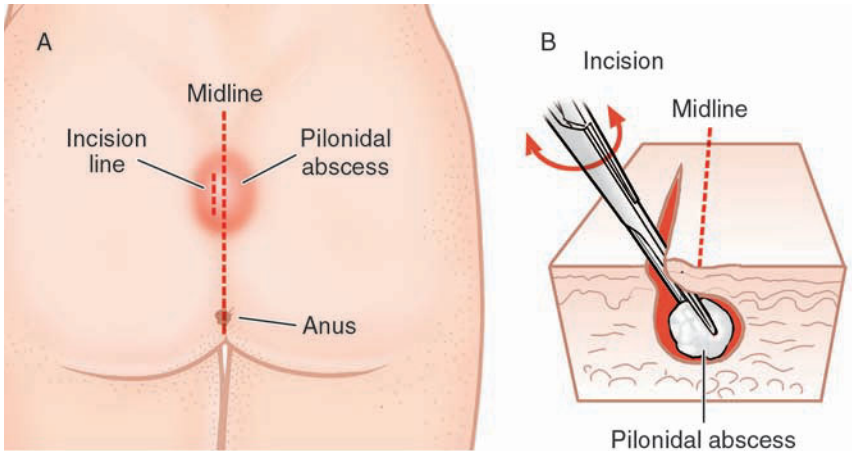


FIGURE 109-7. Incision and drainage of a pilonidal abscess. **A.** An incision is made lateral to the midline and overlying the abscess cavity. **B.** A hemostat with gauze clamped in the jaws is inserted into the abscess cavity and rotated to break loculations and remove debris.

AFTERCARE

Antibiotics are generally unnecessary to treat a simple abscess when there is no cellulitis surrounding the wound.[16] No data could be found on the optimal duration of antibiotic treatment if the overlying skin is cellulitic. The conventional 7 to 10 day course of antibiotics is probably adequate. Likewise, no studies could be found regarding treating patients with diabetes, cardiac valve disease, those who have hardware in their body, or those who are immunocompromised and have a pilonidal abscess. These patients are at risk for infectious complications and it is advised that they be treated with oral antibiotics.

There is a disparity in the literature regarding the bacteriology of pilonidal abscesses. *Staphylococcus aureus* is the most commonly found bacteria and, surprisingly, *Escherichia coli* is rarely found.[17] A report in children recovered primarily anaerobes from pilonidal cysts.[18] *Escherichia coli* was the most common aerobe cultured from this series. **In light of these conflicting results, and in the event that antibiotics are deemed necessary, coverage for skin flora as well as aerobes and gram-negative organisms would be advised.** A combination of a first-generation cephalosporin or penicillinase-resistant penicillin along with metronidazole or clindamycin is recommended. **Keep in mind the ever increasing rates of community-acquired methicillin-resistant *Staphylococcus aureus* (CA-MRSA) infections.** Consider prescribing clindamycin, doxycycline, or trimethoprim-sulfamethoxazole if CA-MRSA is a potential pathogen.[19]

Instruct the patient to change the gauze dressing as often as necessary to keep the outside of the dressing dry. The patient should return for follow-up in 48 hours for a wound check and removal of the packing. If the wound is large, or there is not a clear open tract for continued drainage, reinsert new packing upon follow-up. Incisions that remain open do not require repacking. Advise the patient to have the packing changed every 24 to 48 hours, depending upon the amount of drainage. Decrease the amount of packing each time to allow the wound to heal from the base outward. The patient should thoroughly wash the wound with soap and water in the shower or take a sitz bath each time the packing is removed. It is helpful to let the stream of shower water run inside the wound to aid in wound irrigation. After showering, the patient should dry the area thoroughly. Discontinue the packing once the wound is well granulated and there is no concern that the skin edges will adhere to each other. The patient must continue to clean the wound thoroughly every day until it is fully healed. Healing may take several weeks depending upon the size of the abscess cavity. Instruct the patient that they must return to the Emergency Department if they develop a fever, increased pain, or increased redness of the skin surrounding the abscess. Patients often have pain in the first 2 to 3 days after the incision and drainage. This can be controlled with nonsteroidal anti-inflammatory drugs and supplemented with occasional narcotic analgesics.

Inform the patient that incision and drainage in the acute care setting is not definitive treatment and that the condition may recur. Arrange for follow-up with a Surgeon who can provide wound care as well as definitive therapy if surgery is required. Definitive treatment of a chronic pilonidal abscess or sinus still remains controversial among Colorectal Surgeons. Options include wide excision with primary closure, wide excision with secondary closure, or marsupialization.[2]

Educate the patient about their role in the prevention of a recurrence. Recurrence may be prevented with meticulous hygiene and periodic shaving of the area.[10,13] Instruct the patient on the methods for meticulous hygiene in the area, even after the wound has healed. Repeated trauma to the area should be avoided. This includes exercises such as sit-ups and leg lifts, and prolonged periods of sitting.

COMPLICATIONS

Pilonidal disease may return, even with radical and extensive surgical excision procedures. **Thus, recurrence is to be expected and the patient alerted of this possibility.** Rarely, pilonidal lesions progress to necrotizing fasciitis. Proceed cautiously with patients who are diabetic or otherwise immunocompromised as they are at risk for widespread infections. Those with systemic signs and symptoms are best admitted for treatment. Necrotizing fasciitis is a surgical emergency and requires extensive operative debridement, systemic antibiotics, and intensive supportive care.

Rarely, a nonhealing pilonidal infection may be a pilonidal sinus malignancy.[20] Squamous cell carcinoma has been described to arise from chronic sinus tracts. This emphasizes the importance of follow-up for all patients with pilonidal sinus disease.

Other complications include infection and tissue injury. The incision and drainage procedure can result in a subsequent cellulitis, endocarditis, fasciitis, meningitis, myositis, sacrococcygeal osteomyelitis, or septicemia. The sharp and blunt dissection can injure underlying or adjacent structures including blood vessels, the coccyx, muscles, nerves, and tendons.

SUMMARY

Pilonidal disease is common in the young adult population and more prevalent in males. It is now widely accepted as being an acquired condition caused by hair that penetrates an irregular area of skin in

the sacral area. Pits occur in the skin that in turn lead to cysts in the subcutaneous tissue. Patients may present with asymptomatic pits noted incidentally, as chronically draining sinuses, or an acute painful abscess. No treatment is necessary for asymptomatic patients. Nontender sinuses may be referred for surgical treatment. Abscesses should be drained expeditiously under adequate analgesia and anesthesia. Antibiotics are not indicated unless the patient has surrounding cellulitis or is immunocompromised. Recurrences are common and patients must be referred for follow-up with a Surgeon who can provide wound care as well as surgical treatment for chronic cases.

110 Perianal Abscess Incision and Drainage

Maggie Ferng and Ryan C. Headley

INTRODUCTION

Anorectal infections are common problems presenting to the Emergency Department. Understanding anorectal anatomy is essential to make a diagnosis, institute proper treatment, and anticipate complications. Failure to diagnose and treat an extensive abscess may be life threatening. It is imperative to obtain a surgical consultation if one is unsure of the extent of an abscess.

Anorectal infections occur mostly in the third or fourth decade of life. Perianal abscesses are two to three times more common in men than women.[1] Male predominance is even more pronounced in the pediatric population.[2] In one series, all patients under 2 years of age were males, while 60% of the children greater than 2 years were males.[2] The increased incidence of perianal infection in males may be related to androgen conversion in the anal glands.[3] In infants, deep anal crypts are associated with perianal abscesses.[4]

Abscesses may completely resolve after a proper incision and drainage procedure. However, 50% recur or develop a chronic epithelialized tract or fistula-in-ano. Abscesses and fistulas are different sequelae of the same process.[5]

ANATOMY AND PATHOPHYSIOLOGY

Knowledge of the anatomy of the region is important to understand the pathophysiology of anorectal infections (**Figures 110-1 & 110-2**). Columnar epithelium transitions to squamous epithelium at the columns of Morgagni at the level of the dentate line. Semilunar folds of epithelium called anal valves connect the inferior borders of the anal columns. At the base of each anal valve is an anal crypt, into which opens the ducts of the anal glands. The anal glands secrete mucous to aid in the evacuation of feces. The anal glands are located in the space between the internal and external anal sphincter muscles. Most anorectal infections begin in this intersphincteric space due to blockage and resultant infection of the anal glands.[6]

The spread of an infection is determined by the anatomy of the anorectal region. There are five anatomic spaces into which an infection can spread (**Figure 110-3**).[5] The perianal space is located at the area of the anal verge. The ischiorectal space, which is continuous with the perianal space, extends from the levator ani muscle to the perineum. The intersphincteric space lies between the internal and external anal sphincter muscles. It connects inferiorly with the perianal space and superiorly with the rectal wall. The supralevator (or pelvirectal) space is located superior to the levator ani muscle and is bounded superiorly by the peritoneum. The rectum forms its medial border and the pelvic wall forms the lateral boundary. The deep postanal space is located between the tip of the coccyx and the anus. It courses through the superficial external anal sphincter and the levator ani. The superficial postanal space lies posterior to the anal verge and is subcutaneous. The retrorectal space is high in the pelvis. It occupies the area between the distal rectum and the sacrum.

Most anorectal infections begin in the intersphincteric space. Natural barriers are broken down by formation of an abscess and the infection can spread to contiguous spaces. Abscesses are classified according to their location. Perianal abscesses are common,

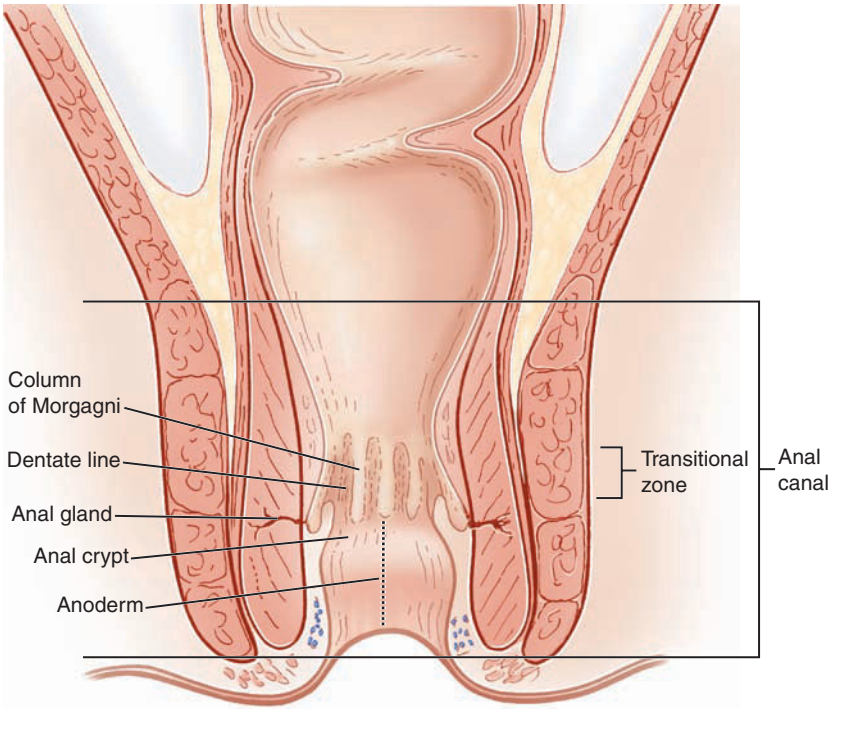


FIGURE 110-1. The anatomy of the anal canal.

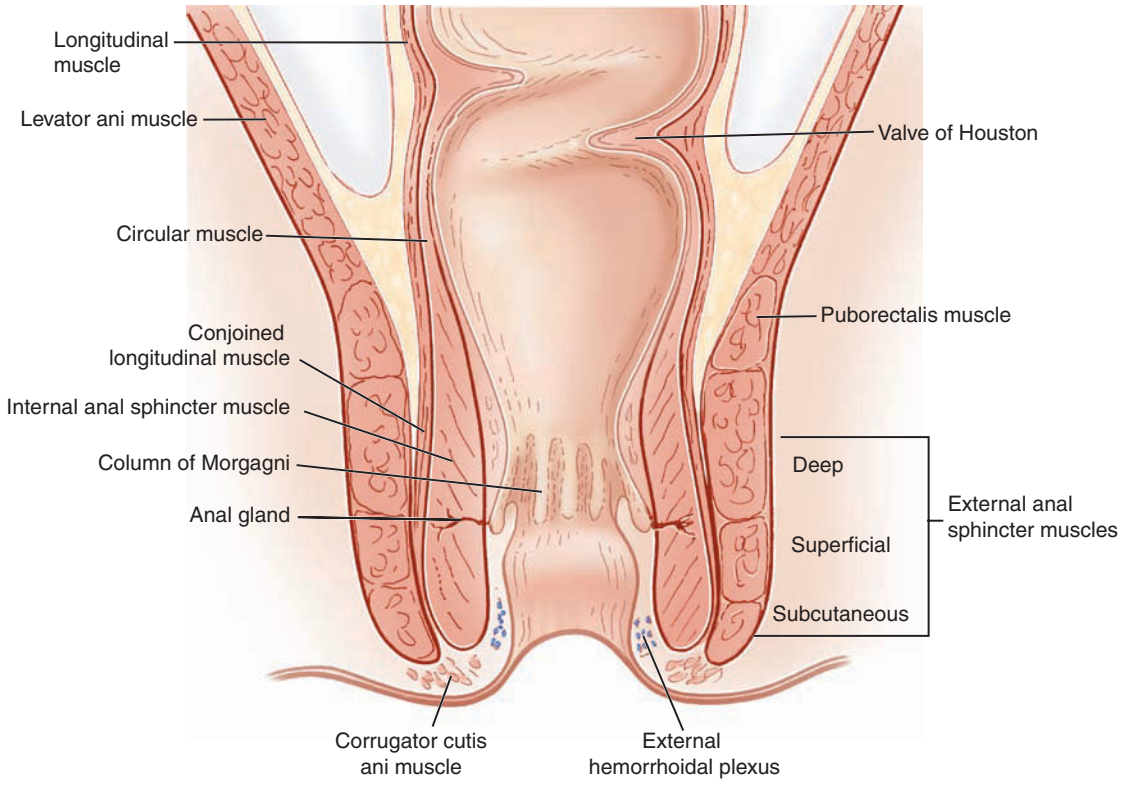


FIGURE 110-2. The major supporting structures of the anal canal.

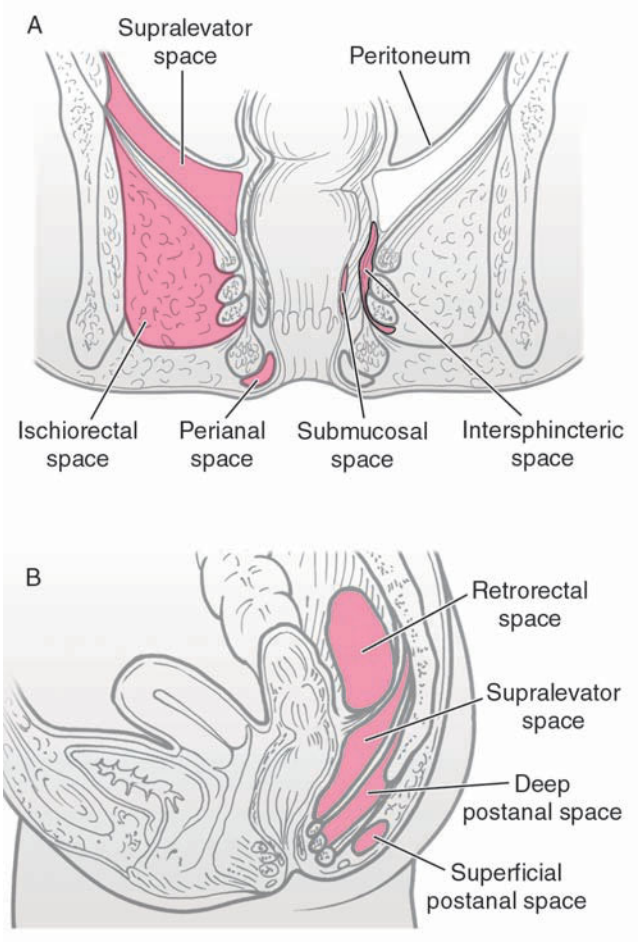


FIGURE 110-3. The anorectal spaces. **A.** Coronal section through the pelvis. **B.** Sagittal section through the pelvis.

ischiorectal abscesses occur less frequently, and supralevator abscesses are least common.[7] Bilateral involvement may occur when an infection spreads circumferentially via the deep postanal space, resulting in a horseshoe abscess.

Patients with anorectal abscesses present with buttock pain and swelling. There is, occasionally, spontaneous drainage from the abscess site. Symptoms depend upon the location of the abscess. Patients with perianal infections have anal pain that increases with defecation or sitting. Pain associated with deeper infections may be atypical. Patients with supralevator abscesses may have deep rectal pain, gluteal pain, dysuria, or other urinary symptoms.

Erythema, swelling, and fluctuance are often present at the abscess site. The location of the swelling and fluctuance of a perianal abscess is at the anal verge. Ischiorectal space infections track farther from the anus onto the buttock. Supralevator and intersphincteric abscesses may have minimal or no external signs.[8] **The diagnosis of perianal cellulitis is highly suspect. These patients have either an anorectal abscess or Fournier's Gangrene until proven otherwise. Patients with gluteal pain and a small amount of erythema in the perianal area have a deep-seated abscess until proven otherwise.**

A digital rectal examination is necessary as intersphincteric, deep postanal, and submucosal abscesses may be palpated but often cannot be appreciated on external examination. **A superficial digital examination of the anal canal alone is inadequate for detection of some abscesses. The gloved finger must extend into the rectum seeking tenderness and a mass.** Unfortunately, digital rectal exam may fail to detect some deep abscesses due to patient discomfort. If unable to obtain an adequate exam due to pain or if a deep abscess is suspected, obtain a CT scan of the pelvis with rectal and intravenous contrast.

A fistula-in-ano represents the chronic phase of an unhealed perianal abscess. Fistulas may form due to persistent obstruction of the anal gland or inadequate drainage of an abscess. The tract eventually becomes epithelialized with glandular tissue. Fistulas may also form

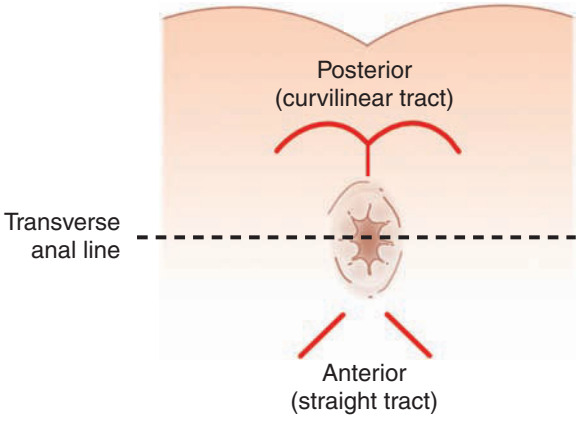


FIGURE 110-4. Goodsall's rule.

as a result of epithelialization by cells derived from the transitional zone of the anal canal and thus may be unrelated to persistent anal gland disease.[9] Patients with a fistula-in-ano will often give a history of a previous abscess in the same area that was either drained surgically or spontaneously. Patients may complain of chronic drainage from the site or subacute pain.

Physical examination of a fistula-in-ano reveals an external opening with scant drainage and visible surrounding granulation tissue. Digital rectal examination may reveal an indurated cord-like structure beneath the skin within the anal canal. The internal opening may be palpable along the dentate line. Pus may be expressed externally or from within the anus upon palpation of the fistulous tract.

The greater the distance from the anus that the external opening is located, the more complex is the fistulous tract. Goodsall's rule describes the likelihood of the location of fistulous tracts and the internal opening based upon the location of the external opening (**Figure 110-4**). Anterior external openings tend to communicate in a linear fashion with the internal opening in the anal canal. Fistulas with posterior external openings tend to communicate in a curvilinear fashion with the internal opening.

Patients with multiple or recurrent fistulas require evaluation of the bowel for Crohn's disease. This is particularly true if associated with chronic diarrhea or cramping, both of which suggests inflammatory bowel disease. Recurrent fistulas may be indicative of tuberculosis or a sexually transmitted disease such as lymphogranuloma venereum. **It is imperative that these patients be referred to a Surgeon who is experienced in managing anorectal disease.**

INDICATIONS

Incision and drainage is the treatment for an anorectal abscess. Uncomplicated perianal abscesses and submucosal abscesses may be drained in the Emergency Department. Management of deeper or more extensive abscesses should be in consultation with a Surgeon. Use caution in draining abscesses. The ischiorectal space is quite large, particularly in the obese patient, and adequacy of drainage is not assured except under general anesthesia. It is not uncommon for an abscess to have a small erythematous and swollen area on the buttock overlying an extensive and deep abscess. Attempts at drainage in the Emergency Department may be inadequate.

Perianal disease is commonly encountered in the HIV-infected patient. Complication rates were noted to be high in the past and a hands-off approach was espoused. However, more recent data suggest that those patients with a relatively preserved immune system may safely undergo standard surgical drainage. Small perianal abscesses may be drained in the Emergency Department. Consult a General or Colorectal Surgeon for those patients with late-stage HIV disease. Infections are more likely to be extensive and anorectal sepsis is more common because these patients have poor wound healing.[10]

CONTRAINDICATIONS

Most small, uncomplicated perianal and submucosal abscesses can be drained in the Emergency Department. **A General or Colorectal Surgeon should drain all other types of anorectal abscesses. Caution is urged when an abscess is on the buttock for it may manifest an ischiorectal abscess.** Patients with bleeding disorders, taking anticoagulants, or thrombocytopenia should be managed by a Surgeon. Consult a Surgeon if the infection is extensive or if the extent of the abscess cannot be determined. Surgical consultation is also necessary for patients with purulent drainage from inside the anus. Internal findings may indicate that the patient has an intersphincteric or a supralevator abscess; the full extent of which can be determined only under general anesthesia. The procedure should be conducted by a surgeon under general anesthesia in the Operating Room if adequate anesthesia cannot be obtained and pain limits the procedure.

Patients with fever or toxicity should be admitted to the hospital for parenteral antibiotics, incision and drainage in the Operating Room, and observation. Anorectal infections occasionally progress to necrotizing fasciitis, a true surgical emergency. Physical examination findings in such cases may initially be minimal except for systemic signs or symptoms. Patients who are immunocompromised or with late-stage HIV infection should be referred to an experienced Surgeon due to the higher complication rate and increased risk of extensive infection.

Chronically draining fistulas without an acute infection should be referred to a General or Colorectal Surgeon for care. Patients with purulent drainage from the anus, even if there is no significant tenderness, should be examined under general anesthesia as they may still have an internal abscess along with a fistulous tract.

EQUIPMENT

- Gown, face mask, and gloves
- Povidone iodine or chlorhexidine solution
- 10 mL syringe
- 25 or 27 gauge needle, 2 in. long
- Local anesthetic solution with epinephrine, lidocaine, or bupivacaine
- #11 scalpel blade on a handle
- #15 scalpel blade on a handle
- Curved hemostat
- 4 × 4 gauze squares
- 10 to 16 French mushroom (de Pezzer) catheter, optional
- Adhesive tape
- Feminine napkin, optional
- Normal saline
- 18 gauge angiocatheter
- 20 mL syringe
- 2-0 nylon suture
- Needle driver
- Scissors

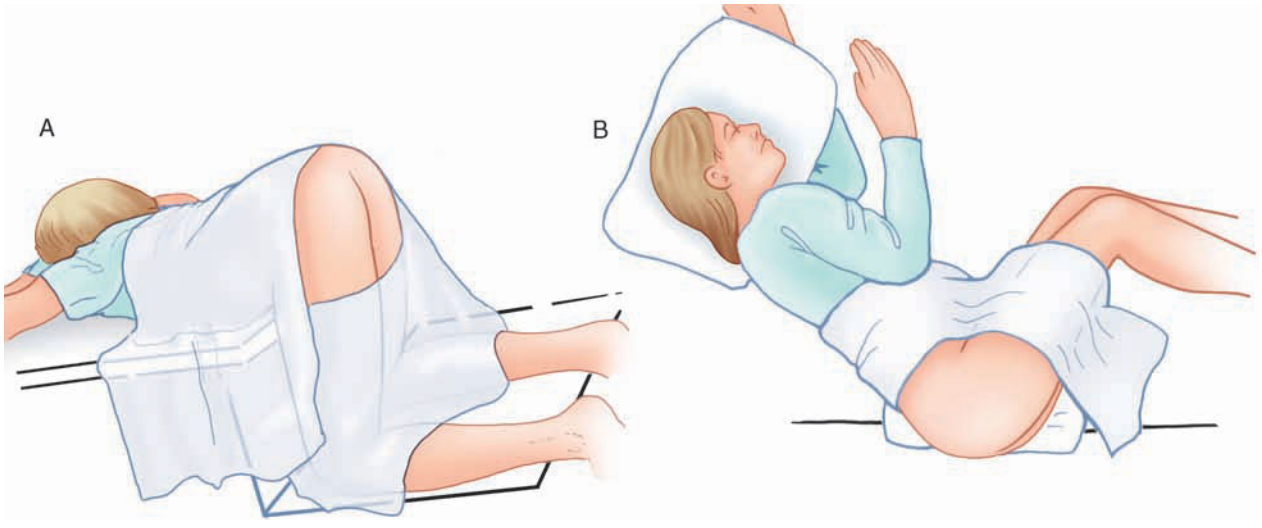


FIGURE 110-5. Patient placement. **A.** Prone on a proctoscopy table. The patient may also be placed prone on a gurney. **B.** The lateral knee-chest position.

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The postprocedure care should be explained as well. Document the discussion of the risks and benefits of the procedure. Obtain an informed consent for the procedure. Wear a face mask, gown, and gloves for the entire procedure. The injection of local anesthetic solution can force abscess contents to shoot out. Incision of a tense abscess can also result in contamination.

The best visualization of the sacral region, particularly in obese patients, occurs with the use of a proctoscopic examination table, if available (**Figure 110-5A**). Place the patient prone on a gurney or on the proctoscopy table. Alternatively, place the patient in the prone or lateral knee-chest position on a gurney or examination table to expose the affected area (**Figure 110-5B**). Apply benzoin solution to the buttocks and allow it to dry. Apply adhesive tape to the buttocks and tape them open (**Figure 110-6**). Clean any dirt and debris from the skin overlying the abscess or cyst. Apply povidone iodine or chlorhexidine solution and allow it to dry. Shave the surrounding area, if the patient is hirsute, to aid in the application of the dressing after the procedure.

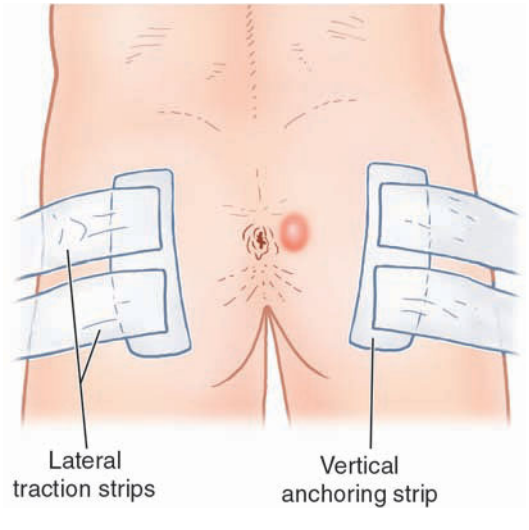


FIGURE 110-6. Exposing the abscess.

ANESTHESIA

Local anesthesia should be administered, recognizing that it is often difficult to obtain complete anesthesia by direct infiltration of an abscess. Local anesthetics are weak acids and are less effective in the acidic environment of an abscess. The skin over the abscess cavity usually becomes insensate, but anesthesia of the abscess cavity itself is not possible. The pain caused by injection of the local anesthetic solution is related to the rate that the anesthetic is injected and the force necessary to inject it. **Inject the local anesthetic solution slowly through a small-bore needle (25 or 27 gauge) as the needle is withdrawn through the dermis.** The needle bore will create a passage through the subcutaneous tissue as it is inserted that enables the local anesthetic solution to be infiltrated slowly and with less discomfort.

Hold the syringe horizontal in reference to the skin surface. Inject 3 to 4 mL of local anesthetic solution intradermally over the dome of the abscess (**Figure 110-7**). The skin will blanch if the injection is given properly. **Do not inject the local anesthetic solution into the abscess cavity.** The increased pressure within the cavity will cause more discomfort to the patient and may cause the solution to be forcefully expelled if there is an opening in the skin.

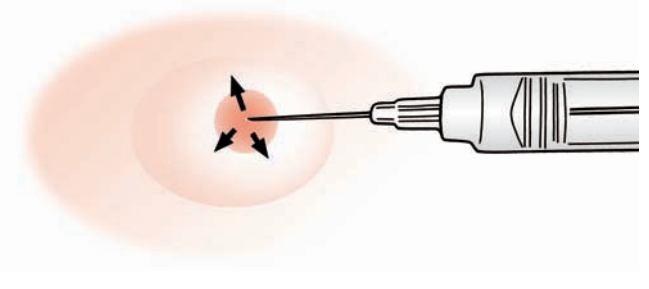


FIGURE 110-7. Subcutaneous infiltration of local anesthetic solution. The needle and syringe are held parallel to the skin. The needle is inserted into the subcutaneous tissue overlying the abscess. Infiltrate the local anesthetic solution as the needle is withdrawn. The skin should blanch (shaded area) if injected properly.

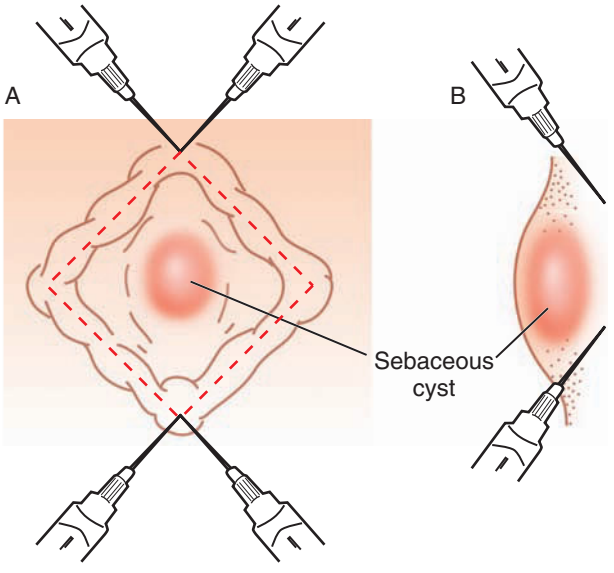


FIGURE 110-8. Field block anesthesia. **A.** Local anesthetic solution is infiltrated subcutaneously on all four sides of the abscess. **B.** The local anesthetic solution is infiltrated deep to the abscess cavity in a fan-like pattern.

Additional anesthesia is accomplished by performing a field block (**Figure 110-8**). Inject local anesthetic solution subcutaneously around the periphery of the abscess (**Figure 110-8A**).[11] Inject local anesthetic solution deep to the abscess in a fan-like pattern (**Figure 110-8B**).

Systemic analgesia (i.e., procedural sedation) is usually required since it is difficult to obtain adequate anesthesia of an abscess locally. Refer to Chapter 129 regarding the details of procedural sedation. Self-administered nitrous oxide, with or without opioid supplementation, is an alternative. Refer to Chapter 128 regarding the details of nitrous oxide anesthesia. Obtain an additional informed consent for the procedural sedation or nitrous oxide procedure. **The procedure should be conducted by a surgeon under general anesthesia in the Operating Room if adequate anesthesia cannot be obtained and pain limits the procedure.**

TECHNIQUES

INCISION AND DRAINAGE OF PERIANAL ABSCESSES

Make a stab incision with a #11 scalpel blade in the skin overlying the area of fluctuance to decompress the abscess. **Make the incision as close to the anus as possible so that if a fistula forms, its size will be limited.** This maneuver will minimize the length of a fistulotomy, should it become necessary, in the future. Extend the incision with the #11 scalpel blade or a #15 scalpel blade in a full-thickness elliptical pattern along the length of the abscess cavity or the area of fluctuance (**Figure 110-9A**). Remove the ellipse

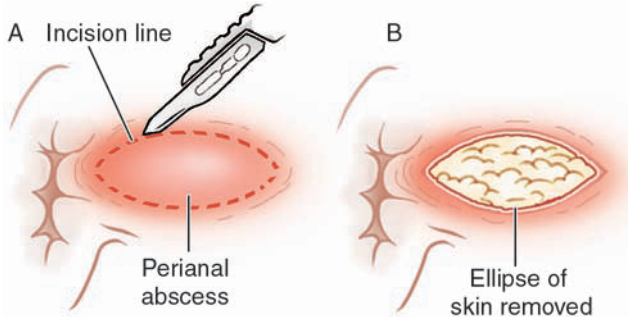


FIGURE 110-9. Drainage of a perianal abscess. **A.** An elliptical incision is made in the skin. **B.** The ellipse of skin is removed to prevent premature closure of the skin edges.

of skin (**Figure 110-9B**). A full-thickness ellipse of skin is excised to prevent premature closure of the skin edges. Some prefer to make a cruciate incision over the abscess and excise the edges (**Figure 110-10**).[5] Both of these techniques delay cutaneous healing while the abscess is decompressing and allow it to drain freely without the need for packing.

A linear incision is acceptable instead of the above incisions, but is not recommended for a perianal abscess. The body location and excessive skin often result in premature closure before the cavity has healed. A linear incision requires repeated packing at 24 to 48 hour intervals to prevent premature closure. The area is difficult to access by the patient to pack the cavity. The pain of repeated packing often results in noncompliance. It is also difficult for the patient to wash out the cavity in the shower or bathtub.

It is important that loculations be lysed and the area thoroughly drained to minimize recurrence. Several methods can be used to lyse adhesions within the abscess cavity. A gloved finger may be used to bluntly break up the adhesions. Hemostats can be inserted and spread within the cavity. A useful technique employs a gauze 4 × 4 square clamped in a hemostat and swirled inside the abscess cavity to break adhesions and remove debris. Irrigate the cavity with normal saline.

It is not necessary to pack an incised and drained perianal abscess that has been incised by removing a full-thickness skin ellipse or a cruciate incision. Consider temporarily packing the abscess cavity in the Emergency Department to control any hemorrhage. Remove the packing before discharging the patient to reassess the need for further hemorrhage control. Cover the wound with a thick layer of absorbent gauze to soak up continued drainage. A feminine napkin may also be used to absorb drainage and obviates the need for taping the dressing in place.

CATHETER DRAINAGE OF PERIANAL ABSCESSES

Another method used to drain perianal abscesses, and preferred by some Colorectal Surgeons, is catheter drainage. The mushroom or

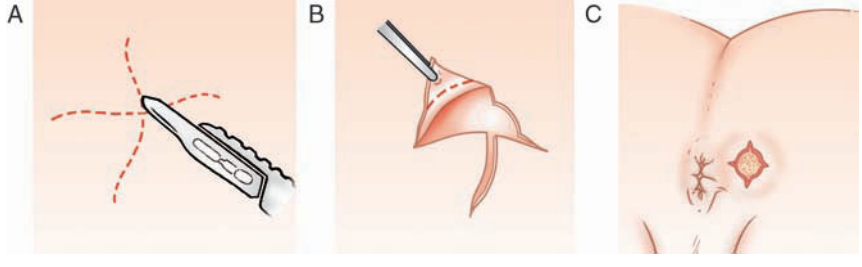


FIGURE 110-10. Drainage of perianal abscess employing a cruciate incision. **A.** The cruciate incision is made over the abscess. **B.** Excision of the skin flap edges. **C.** The final appearance.

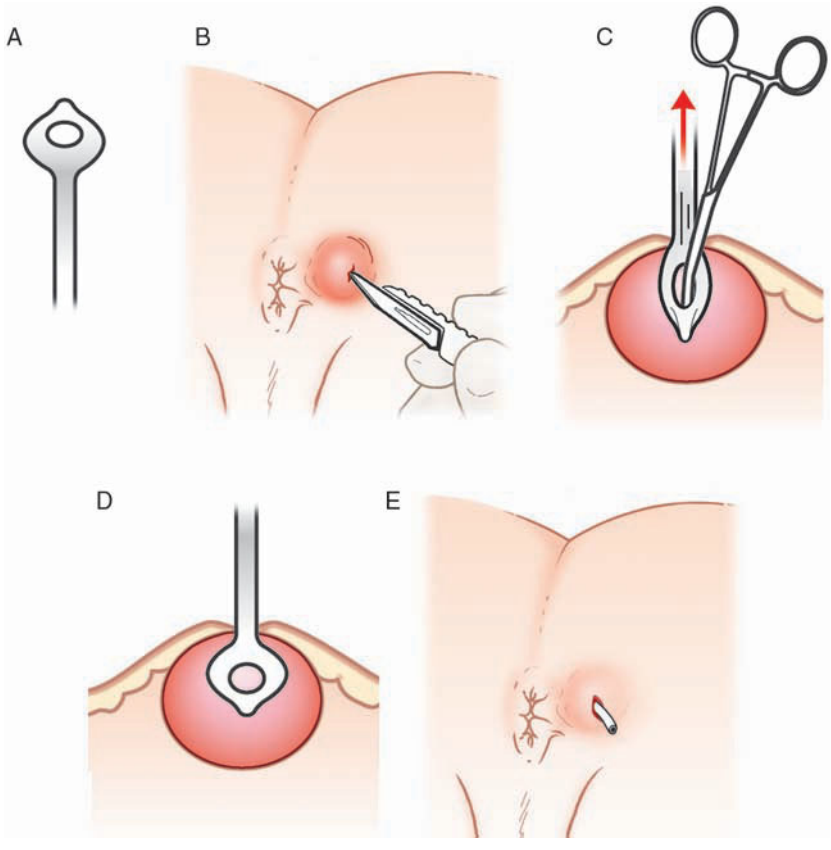


FIGURE 110-11. Catheter drainage of an abscess. **A.** The mushroom (de Pezzer) catheter. **B.** A stab incision is made over the area of maximal fluctuance. **C.** Place the tip of the hemostat through the side hole to stretch the tip of the catheter. Insert the stretched catheter through the stab incision. **D.** Remove the hemostat to expand the head of the catheter so that it remains within the abscess cavity. **E.** The catheter is cut so that it protrudes 2 to 3 cm from the skin incision.

de Pezzer catheter has a tunnel through a solid mushroom-shaped tip (**Figure 110-11A**).[12] Make a stab incision with a #11 scalpel blade over the anal side of the area of fluctuance (**Figure 110-11B**). Insert a hemostat into the abscess cavity. Open and close the jaws of the hemostat to lyse any adhesions and express the pus. Flush the abscess cavity with normal saline using an 18 gauge angiocatheter on a 20 mL syringe.

Insert a 10 to 16 French latex mushroom catheter using a hemostat to stretch the tip so that it will fit through the incision. Place the tip of the hemostat through the hole in the mushroom catheter. With one hand holding the hemostat, use the other hand to pull on the tubing to stretch the mushroom tip and enable it to fit into the abscess cavity (**Figure 110-11C**). Insert the stretched mushroom tip into the abscess cavity (**Figure 110-11C**). Release the traction on the hemostat once the catheter tip is within the abscess cavity and the mushroom shape will be restored (**Figure 110-11D**). Remove the hemostat from the abscess cavity.

Suture the catheter in place. Place a single simple interrupted stitch using 2-0 nylon adjacent to the stab incision. Leave both ends long, tie the suture knots, and do not cut the suture. Pass the needle through the catheter as it exits the skin incision. Tie the needle end of the suture to the tail end of the suture to secure the catheter. Cut off the excess suture. Cut the catheter so that it protrudes only 2 to 3 cm from the incision (**Figure 110-11E**). Apply a dressing of gauze squares or a feminine napkin.

Many Colorectal Surgeons prefer the catheter method. On subsequent visits they can assess the wound for the presence of a fistula without removing the catheter. Hydrogen peroxide can be infused through the catheter. Bubbles seen escaping from an opening within the anal canal are diagnostic for a fistula. Hydrogen peroxide is also used to produce an ultrasound interface that facilitates the definition of a fistulous tract and the internal opening.[5] The smaller stab incision takes less time to heal than the larger incision and drainage wound.

SUBMUCOSAL ABSCESSES

The majority of submucosal abscesses may be drained in the Emergency Department. The procedure requires the use of an anoscope to visualize the abscess. Refer to Chapter 70 for the complete details regarding the use of an anoscope. Make a superficial stab incision in the abscess with a #11 scalpel blade. Gently insert a hemostat and lyse any adhesions. Remove a small ellipse of the mucosa to allow the abscess to drain. Arrange follow-up with a Colorectal Surgeon within 24 hours.

AFTERCARE

Antibiotics are generally unnecessary to treat a simple abscess when there is no cellulitis surrounding the wound.[13] No data could be found on the optimal duration of antibiotic treatment if the overlying skin is cellulitic. The conventional 7 to 10 day course of antibiotics is likely adequate. Likewise, there is no data in the literature regarding the treatment of patients with diabetes, cardiac valve disease, those who have hardware in their body, or those who are immunocompromised with antibiotics for a perianal abscess. These patients are at risk for infectious complications. It is advised that they be treated with antibiotics. Bacteriology of anorectal abscesses is polymicrobial, with coliforms and anaerobes predominating.[14] Recommended antibiotics include an extended spectrum β-lactams, a second- or third-generation cephalosporin with metronidazole or clindamycin, or a newer fluoroquinolone with metronidazole or clindamycin.

The patient may change the gauze dressing as often as necessary to keep the outside of the dressing dry. Instruct the patient to return for follow-up in 48 hours for removal of packing if placed and a wound check. The patient may begin sitz baths or showers 24 hours after the procedure. They should thoroughly clean the wound with soap and water at least once a day until the wound is fully healed. It

is helpful to let the stream of shower water run inside the wound to aid in irrigation. Healing may take several weeks depending upon the size of the abscess. Additional measures to aid in healing and comfort include stool bulking agents and stool softeners. Pain can be controlled with nonsteroidal anti-inflammatory drugs supplemented with occasional narcotics analgesics.

Advise the patient that the condition is likely to recur. They must be referred to a General or Colorectal Surgeon who is experienced in the management of anorectal infections. Inform the patient that they may require an operation to prevent future recurrences. Instruct the patient to immediately return to the Emergency Department if they develop a fever, increased pain or redness to the area, or a foul-smelling discharge.

COMPLICATIONS

Perianal abscesses may recur or a fistula may form. Recurrence is more likely if the patient has had abscesses in the same location in the past. Occasionally, anorectal infections progress to necrotizing fasciitis. Patients with any systemic signs and symptoms require surgical consultation, hospital admission, parenteral antibiotics, and a drainage procedure.

Complications associated with the incision and drainage procedure are rare. A linear incision or too small of an incision can result in premature skin closure, incomplete healing of the cavity, and recurrence. Too large of an incision can result in delayed healing. An overly aggressive incision can damage adjacent structures. Postprocedural bleeding is rare.

SUMMARY

Anorectal infections are commonly seen in the Emergency Department. They are thought to be due to obstruction and subsequent infection of the anal glands that in turn form an abscess. Small perianal abscesses and submucosal abscesses can safely be drained in the Emergency Department. A digital rectal examination may aid in determining the extent of an abscess. A General or Colorectal Surgeon should manage patients with fever, signs of toxicity, evidence of a deep or extensive infection beyond the perianal area, or who are immunocompromised. Be alert that abscesses with maximum fluctuance on the buttock are more likely to have ischiorectal extension, are more complex, and greater in size. Perianal abscesses must be drained expeditiously to prevent their spread. Approximately 50% of anorectal abscesses will develop a fistulous tract. Patients require referral for follow-up with a General or Colorectal Surgeon who can provide wound care as well as manage chronic cases.

111 Sebaceous Cyst Incision and Drainage

Carlos J. Roldan

INTRODUCTION

Sebaceous cysts are common, present with a very benign evolution, may be located anywhere on the body, and frequently become infected. They are most commonly found on the face, neck, and trunk. Sebaceous cysts are usually asymptomatic unless they become infected. The Emergency Physician must be acquainted with the principles involved in treating infected sebaceous cysts, particularly if they are located on cosmetically important areas such as the face.

ANATOMY AND PATHOPHYSIOLOGY

Sebaceous cysts are the result of obstruction of sebaceous gland ducts. They are freely mobile, slow growing, round shaped, painless, and located in the subcutaneous tissues. The cysts are made of a thin white capsule filled with a thick, cheesy, and keratinous material. Their size is variable and ranges from less than a quarter of an inch to more than 2 inches. These keratin-containing lesions are usually seen in young and middle-aged adults in relation to a pilosebaceous follicle.[1] Sebaceous cysts may be present for many years before infection occurs. Physical examination often reveals a subcutaneous mass that is fluctuant and tender. The overlying skin may appear normal or erythematous.

The initial treatment of choice of an infected sebaceous cyst is incision and drainage. The sebaceous material is too thick to allow for spontaneous drainage and it must be expressed. **The sebaceous cyst will likely recur, however, unless the capsule of the cyst is removed.** Patients may have the initial incision and drainage performed in the Emergency Department with follow-up at some later date to remove the cyst capsule. Alternatively, the cyst capsule may be removed at the time of the initial incision and drainage.

INDICATIONS

Incision and drainage in the Emergency Department is indicated whenever a patient presents with a tender sebaceous cyst consistent with an abscess. The procedure will relieve the patient's pain. Antibiotics without drainage are ineffective in treating abscesses.[2] The vast majority of infected sebaceous cysts may be drained in the Emergency Department, clinic, or office setting. A noninfected sebaceous cyst may be removed electively and for cosmetic purposes in the clinic or office setting by a Primary Care Provider or a Surgeon.

CONTRAINDICATIONS

There are no absolute contraindications to the incision and drainage or removal of an infected sebaceous cyst. Caution is advised in those patients with bleeding disorders, taking anticoagulants, or with thrombocytopenia. Incision and drainage is preferred if the overlying skin is cellulitic. The capsule can be removed at a later time. Extremely large abscesses or those in which adequate anesthesia is not possible should be managed in the Operating Room by a General Surgeon or Plastic Surgeon. The procedure should be conducted under general anesthesia in the Operating Room if adequate anesthesia cannot be obtained and pain limits the procedure. Refer patients with noninfected sebaceous cysts to their Primary Care Physician, a General Surgeon, or a Plastic Surgeon for removal.

EQUIPMENT

- Gown, face mask, and gloves
- Povidone iodine or chlorhexidine solution
- 10 mL syringe
- 25 or 27 gauge needle, 2 in. long
- Local anesthetic solution, with or without epinephrine
- #11 scalpel blade on a handle
- #15 scalpel blade on a handle
- Curved hemostat
- Iris scissors
- Ribbon gauze, plain or iodinated

- 2 × 2 gauze squares
- Adhesive tape
- Sterile saline
- Nylon sutures for skin closure, various sizes
- 3-0 Vicryl suture
- Needle driver

PATIENT PREPARATION

Explain and document the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The postprocedure care should be explained as well. Obtain an informed consent for the procedure. Obtain an additional informed consent for the procedural sedation or nitrous oxide procedure if it applies. Wear a face mask, gown, and gloves for the entire procedure. The injection of local anesthetic solution can force abscess contents to shoot out. Incision of a tense abscess can also result in contamination.

Antibiotic resistance is a growing concern. The incision and drainage of a simple and noncomplicated skin abscess does not require antibiotic therapy.[3,4] The incision and drainage procedure may release bacteria into the circulation. Consider the use of preprocedural intravenous antibiotics in those patients suspected or known to be immunocompromised, a history of prosthetic heart valve replacement, a history of artificial joint replacement, or signs of systemic toxicity.

Clean any dirt and debris from the skin overlying the abscess or cyst. Apply povidone iodine or chlorhexidine solution and allow it to dry. Apply drapes to delineate a procedural field and absorb any material or blood that escapes from the abscess cavity.

ANESTHESIA

Recognizing that it is often difficult to obtain, local anesthesia should be considered the first choice. Direct infiltration of the skin and soft tissues in a fan-like pattern surrounding an abscess or "field block" provides sufficient anesthesia to tolerate the procedure (**Figures 111-1A & B**).[5] Local anesthetics are weak acids and less effective in the acidic environment of an abscess and should not be directly injected in the abscess cavity. The pain caused by injection of the local anesthetic solution is related to the rate that the anesthetic is injected and the force necessary to inject it. Inject the local anesthetic solution slowly through a small-bore needle (25 to 30 gauge) as the needle is withdrawn through the dermis. The needle bore will create a passage through the subcutaneous tissue as it is inserted that enables the local anesthetic solution to be infiltrated slowly and with less discomfort.

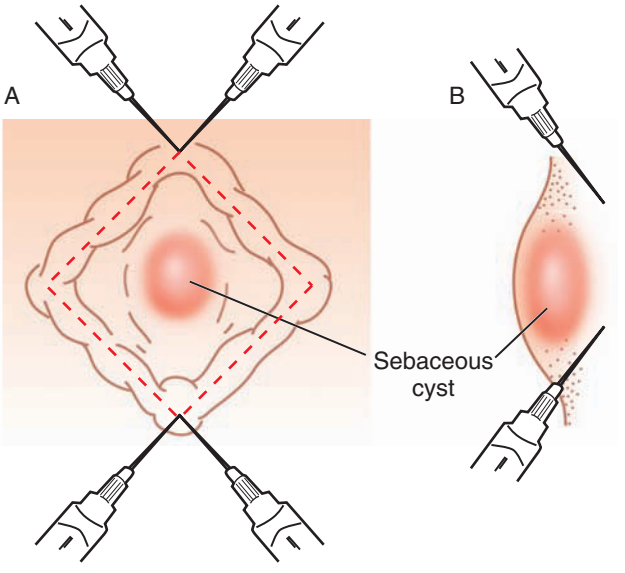


FIGURE 111-1. Field block anesthesia. **A.** Local anesthetic solution is infiltrated subcutaneously on all four sides of the infected sebaceous cyst. **B.** Local anesthetic solution is infiltrated deep to the infected sebaceous cyst in a fan-like pattern.

Hold the syringe horizontally in reference to the skin surface. Inject 3 to 4 mL of local anesthetic solution intradermally over the dome of the abscess (**Figure 111-2**). The skin will blanch if the injection is given properly. The increased pressure within the cavity will cause more discomfort to the patient and may cause the solution to be forcefully expelled if there is an opening in the skin therefore some practitioners prefer to skip this step. Alternative anesthesia could be accomplished with regional or individual nerve blocks when the abscess is located in an anatomical area of innervation.

Systemic analgesia (i.e., procedural sedation) is strongly recommended in the pediatric population, it may occasionally be required as well in adults when a field anesthesia has suboptimal results. In rare occasions, the procedure should be conducted under general anesthesia in the Operating Room if adequate anesthesia cannot be obtained and pain limits the procedure.

TECHNIQUES

INCISION AND DRAINAGE

Make a stab incision with a #11 scalpel blade in the skin overlying the area of fluctuance (**Figure 111-3A**). The incision should be

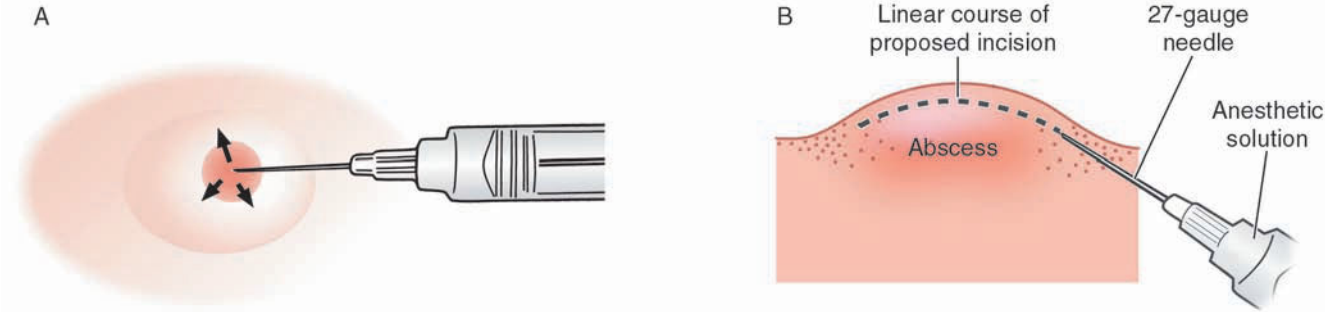


FIGURE 111-2. Subcutaneous infiltration of local anesthetic solution. The needle and syringe are held parallel to the skin. The needle is inserted into the subcutaneous tissue overlying the infected sebaceous cyst. Infiltrate the local anesthetic solution as the needle is withdrawn. The skin should blanch (shaded area) if injected properly. **A.** Superior view. **B.** Lateral view.

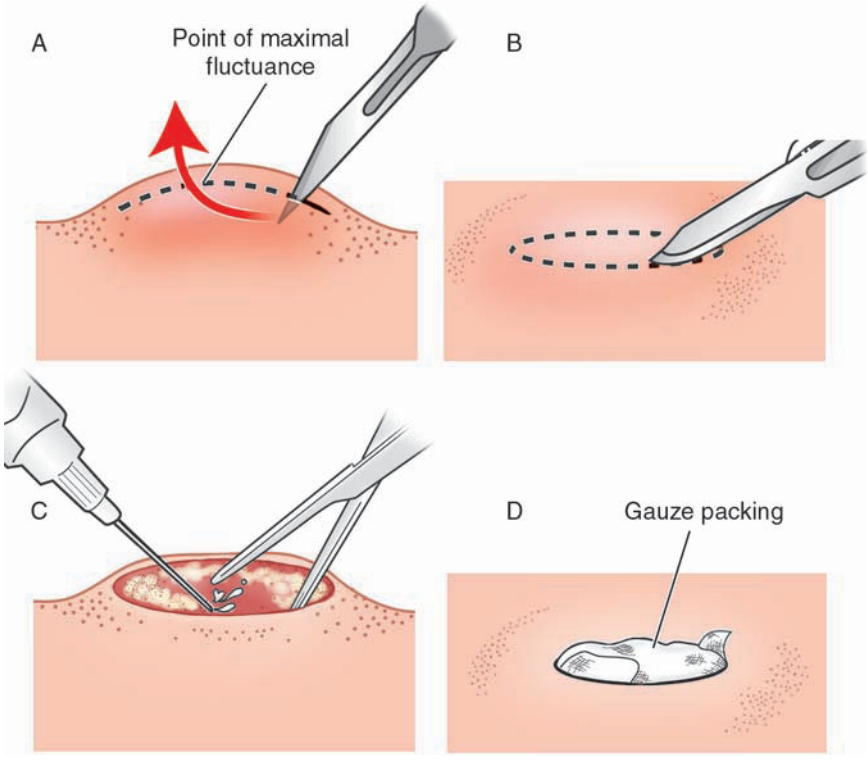


FIGURE 111-3. Incision and drainage of an infected sebaceous cyst. **A.** A straight incision to drain the abscess. **B.** An elliptical incision to drain the abscess. **C.** The wound is irrigated with sterile saline. Pockets of purulent material are opened with the hemostat. **D.** The wound is packed open.

parallel to any lines of tension to produce the least conspicuous scar, particularly in cosmetically important areas such as the face. Extend the incision the length of the fluctuant area with a #11 or #15 scalpel blade unless the abscess is in a cosmetically important area. A linear incision is adequate, although some advocate a cruciate incision (**Figure 110-10**). The cruciate incision results in greater scarring, however, and probably is not necessary. An elliptical incision can be performed in noncosmetically important areas (**Figure 111-3B**). The purpose of the elliptical incision is to remove a full thickness wedge of tissue so that the wound will remain open. **Limit the length of the incision on cosmetically important areas to 3 to 4 mm.** This is just large enough to drain the abscess.

Express the pus and the sebaceous material. It is too thick to drain spontaneously. It is important that loculations be lysed and the area be thoroughly drained to minimize recurrence. Insert a hemostat and spread the jaws within the cavity (**Figure 111-3C**). Useful technique employs gauze clamped in the jaws of a hemostat and swirled inside the abscess cavity to break adhesions and remove debris. Irrigate the cavity with normal saline (**Figure 111-3C**).

Loosely pack the wound cavity with ribbon gauze or gauze squares to prevent the skin edges from closing prematurely if a linear incision was made (**Figure 111-3D**). Cruciate and elliptical incisions do not require packing of the wound. Cover the wound with a bulky gauze dressing to soak up continued drainage.

INCISION AND DRAINAGE WITH PRIMARY CYST REMOVAL

The entire sebaceous cyst, including the capsule, can be removed at the time of the incision and drainage with a simplified technique.[6] Make an incision in the skin overlying the center of the sebaceous cyst. Extend the incision to be slightly longer than the diameter of the sebaceous cyst. **Do not cut into the dermis or subcutaneous tissues.** Sharply dissect the sebaceous cyst free of the surrounding subcutaneous tissues with an iris scissors. The delineation between the thin, shiny, white capsule and the surrounding tissues is very obvious. **Do not puncture the capsule of the sebaceous cyst.** Doing so and spilling some of the contents sets up a nidus for subsequent infection or reformation of the sebaceous cyst. Start at both ends of the incision and free the cyst circumferentially. Once the sides of the cyst are free from the surrounding adipose tissue, gently grasp the top of the cyst with a hemostat or forceps and gently elevate it. Dissect the inferior border of the cyst free until it can be removed. Irrigate the wound with at least 200 mL of normal saline solution. Allow the cavity to heal by granulation. Alternatively, close the pocket with 3-0 Vicryl deep sutures and approximate the skin edges with nylon sutures.

The cyst capsule can often rupture when attempting to remove it intact. If this occurs, express the contents as if incising and draining an abscess. Gently flush the cyst cavity with normal saline. Grasp the shiny, cut edges of the capsule with a hemostat. Gently elevate the cyst capsule edges and dissect the complete cyst capsule free from the surrounding adipose tissue. Irrigate the wound with at least 200 mL of normal saline solution. Allow the cavity to heal by granulation. Alternatively, close the pocket with 3-0 Vicryl deep sutures and approximate the skin edges with nylon sutures.

Submit the complete cyst and capsule or the ruptured capsule for pathologic diagnosis in a sterile container. Several pathologic conditions can mimic a sebaceous cyst. This includes adenomas, adenocarcinomas, dermoids in children, and melanomas. Preauricular tender masses can be parotid gland tumors.

This technique results in fewer days to heal, less pain for the patient, and less scarring than with incision and drainage alone.[6] This was not a blinded study and no other studies could be found to verify their results. The researchers noted that primary resection (average of 50 minutes) takes longer than simple incision and drainage (average of 10 minutes). This may limit its use in the Emergency Department.

AFTERCARE

Antibiotics are generally unnecessary to treat a simple abscess unless there is cellulitis of the skin surrounding the wound.[2] No data could be found regarding patients with an abscess who are diabetic, have cardiac valve disease, who have hardware in their body, or who are immunocompromised. These patients are at risk for infectious complications. It is advised to cover these patients with antibiotics. Likewise, there is no data on the optimal duration of antibiotic treatment. The conventional 7 to 10 day course of antibiotic coverage is probably adequate.

Bacteriology of cutaneous abscesses remote from the rectum usually show aerobic skin flora, with *Staphylococcus* and *Streptococcus* being the most common etiologies.[4] Antibiotics recommended are a first-generation cephalosporin, a penicillinase-resistant penicillin, or a newer fluoroquinolone. Prescribe clindamycin, doxycycline, or trimethoprim-sulfamethoxazole if methicillin-resistant *Staphylococcus aureus* is suspected as the etiology.[7]

Instruct the patient to change the gauze dressing as often as necessary to keep the outside of the dressing dry. Patients should have scheduled follow-up in 48 hours for a wound check and removal of the packing. The packing should be removed in 24 hours if the wound is on the face. If the wound is large, reinsert the packing upon follow-up. Incisions that remain open or that have an elliptical or cruciate incision do not require packing. Advise the patient to change the packing every 24 to 48 hours, depending on the amount of drainage. Decrease the amount of packing each time to allow the wound to heal from the base outward. The patient should thoroughly wash the wound with soap and water in the shower each time the packing is removed. It is helpful to let the stream of shower water run inside the wound to aid in wound irrigation. Discontinue the packing once the wound is well granulated and there is no concern that the skin edges will adhere to each other. The patient must continue to clean the wound thoroughly every day until it is fully healed.

Healing may take one to several weeks depending upon the size of the abscess cavity, the patient's age, and any comorbidities. Instruct the patient to return to the Emergency Department immediately if they develop a fever, increased pain, or worsening redness of the skin surrounding the abscess. Pain relief can be provided with nonsteroidal anti-inflammatory drugs. Occasionally, narcotic analgesics may be required in the first 24 hours after the procedure.

Inform the patient that incision and drainage in the acute care setting is not definitive treatment and that the condition is likely to recur unless the cyst is removed. Refer the patient to a physician who can provide wound care as well as remove the cyst capsule.

COMPLICATIONS

Sebaceous cyst infections may spread if the wound is inadequately drained. Attention must be paid to underlying anatomical structures, such as cranial nerve VII, when draining facial abscesses to avoid complications caused by inadvertently incising these structures. Incomplete removal of the cyst wall or spillage of the cyst contents sets up a nidus for future infection and/or recurrence of the sebaceous cyst. A linear incision or too small of an incision can result in premature skin closure, incomplete healing of the cavity, and recurrence. Too large of an incision can result in delayed healing and significant scarring. Postprocedural bleeding is rare.

SUMMARY

Infected sebaceous cysts are commonly seen in the Emergency Department. They are thought to be due to blockage of the ducts of sebaceous glands that subsequently become infected and form an abscess. Most cutaneous abscesses can be drained in the Emergency Department. Consult a Surgeon for those patients with large abscesses who require drainage in the Operating Room. Patients with signs of fever or toxicity should be admitted for parenteral antibiotics, incision and drainage, and observation. Refer patients to a physician who can provide wound care as well as definitive excision of the sebaceous cyst.

112 Hemorrhage Control

Christopher Freeman and Eric F. Reichman

INTRODUCTION

Control of external hemorrhage from an injury is a priority of basic first aid, beginning with the first responder in the prehospital setting and continuing with Emergency and Trauma Physicians in the resuscitation suite. Bleeding from extremity wounds is common. Most extremity bleeding is a minor inconvenience for the busy Emergency Physician in the crowded Emergency Department, prolonging wound closure and complicating wound healing. However, major exsanguinating extremity hemorrhage can be a life threat. Hemorrhage from extremity injuries was a leading cause of death in the Vietnam War and Operation Desert Storm.[1,2] Hemorrhage remained the leading cause of death in Operation Iraqi Freedom and Operation Enduring Freedom; however, torso hemorrhage was the leading cause of death.[3] **Methods for rapid and effective control of bleeding are essential in managing traumatic injuries and optimizing wound management.**

ANATOMY AND PATHOPHYSIOLOGY

Hemostasis is the first biological response to injury.[4–6] Hemostatic platelet plugs form at the ends of transected vessels within seconds of traumatic disruption of the skin. Fibrin fibers gather about the platelet plug within minutes. This fibrin mesh becomes part of an early matrix that initiates wound healing.[4]

Hemostasis is also the first priority in wound management for the Emergency Physician caring for traumatic wounds. **Control of bleeding is necessary to establish hemodynamic stability and prevent further blood loss.** Hemostasis is the first step in preparing for wound closure. Inadequate hemostasis with hematoma formation impairs wound healing, increases the risk of wound infection, leads to tissue ischemia, and results in hypertrophic scars.[7,8] Large hematomas may cause delayed wound dehiscence.

Bleeding from wounds may be superficial or deep. Superficial wounds, such as abrasions, avulsions, or simple lacerations involve damage to the epidermis, dermis, and subcutaneous tissue. Bleeding from most superficial wounds is predominantly from capillaries, small veins, or arterioles. Wounds deep to the fascia involve larger vessels and are typical of deep puncture or stab wounds, gunshot wounds, or major crush injuries. The approach to the bleeding wound will depend upon the nature of bleeding (e.g., large vessel vs. small, discrete source vs. diffuse), the site of injury, and its association with other major organ injury.

INDICATIONS

The immediate control of excessive bleeding is always a priority and should occur during the first contact with the patient. All bleeding must be controlled. Exsanguinating hemorrhage must be

immediately controlled. All other bleeding can wait until the ABC's and life-threats are addressed. The timing and selection of specific measures to isolate and treat the bleeding source will depend upon the management priorities of each patient. A simple compressive dressing or tourniquet may be used as a first-line measure to control bleeding in a multiple trauma patient. Measures that are more definitive may be taken early to identify and treat the specific injury if it is isolated.

CONTRAINDICATIONS

There are no absolute contraindications to any particular technique to control bleeding. The Emergency Physician should choose the technique best suited to the individual situation. An impressive wound should not distract or divert attention away from other injuries that may be less dramatic but more immediate life threats. **The simplest and most effective techniques should be used to control hemorrhage when faced with multiple injuries.**

EQUIPMENT

Pressure Control

- Blood pressure cuff
- Sterile 4 × 4 gauze pads
- Elastic bandage

Wound Manipulation

- Hemostats
- Needle driver
- Assorted suture
- Scissors
- Sterile saline
- 20 mL syringes
- 10 mL syringes
- 18 gauge needles
- 27 gauge needles

Anesthetics

- Lidocaine, with and without epinephrine
- Bupivacaine, with and without epinephrine
- 18 gauge needles
- 27 gauge needles
- 10 mL syringes

Wound Cautery

- Silver nitrate ($AgNO_3$)
- Electrocautery unit
- Monsel's solution (20% ferric subsulfate solution)
- Drysol (30% aluminum chloride solution)

Vasoconstrictors

- Epinephrine, 1:1000
- Cocaine, 1% to 4%
- Tetracaine, epinephrine, and cocaine (TEC) solution

Topical Hemostatic Agents

- Gelfoam
- Surgicel
- Cellulose
- Dry gelatin
- Thrombin
- Microfibrillar collagen
- Cyanoacrylate
- Various agents as listed in the techniques section

Miscellaneous Supplies

- Povidone iodine or chlorhexidine solution
- Penrose drain
- Finger tourniquet
- Hemoclips
- Hemoclip applicator
- Bone wax
- Raney scalp clips and applier

PATIENT PREPARATION

Control of hemorrhage is the priority. Attention to wound preparation should not delay definitive action to control bleeding. Obtain intravenous access and a type and crossmatch for blood products in any patient with active bleeding and hemodynamic compromise while applying direct pressure to the bleeding site. Explain the procedures to the patient while preparing for and performing the procedures. A local anesthetic can be administered prior to significant wound manipulation if the injury is minor and the patient is stable. Contaminated wounds should be irrigated free of foreign bodies and debris and the surrounding area cleaned with an antiseptic solution (i.e., povidone iodine or chlorhexidine). Refer to Chapter 92 for the complete details of wound cleansing and preparation.

TECHNIQUES

DIRECT PRESSURE

The quickest and easiest method to stop bleeding is the application of direct pressure to the bleeding site.[9–11] Poor lighting may prevent the exposure and visualization necessary to identify discrete bleeding sites in the prehospital setting. A compressive dressing may be the best option to control bleeding. Unfortunately, most compressive bandages apply too little pressure over too wide an area and act more like a sponge than a pressure dressing. Significant blood loss can be hidden within a bulky dressing.

Explore a bleeding wound as soon as lighting is sufficient and circumstances allow. Even brisk bleeding frequently has a few discrete sources that can be easily managed once identified. Direct pressure over bleeding vessels allows time for a platelet plug to form and gives a chance for the body's natural mechanisms of hemostasis to take place. Apply pressure over arterial wounds for 10 to 15 minutes to control most bleeding. Apply pressure to a proximal artery to impede arterial inflow and control, or slow, the bleeding when wound exploration is not practical.[12,13]

TOURNIQUETS

The use of tourniquets for extremity hemorrhage has received a great deal of attention throughout history. In reality, tourniquets are seldom necessary to control hemorrhage, even in major crush wounds, amputations, and in wilderness settings.[14] Direct pressure is more effective and causes less tissue ischemia. Tourniquets may be required to control bleeding and free rescue personnel to attend to other concerns if there is significant bleeding in a mass

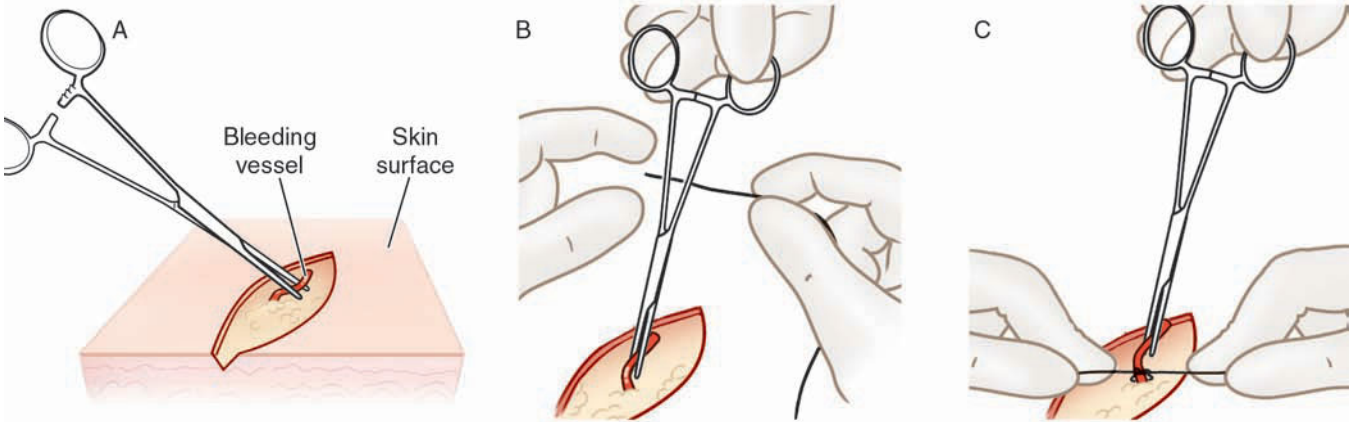


FIGURE 112-1. Control of the bleeding vessel that is visualized. **A.** Clamp the cut end of the vessel with a hemostat. **B.** Wrap a suture ligature about the base of the vessel. **C.** Tie and secure the suture around the base of the bleeding vessel.

casualty disaster. Tourniquets should be used as a last resort when other methods fail and the patient's life is in jeopardy.[12,14] Some of the currently available tourniquets include the Combat Application Tourniquet (Composite Resources, Rock Hill, SC), the Special Operations Forces Tactical Tourniquet (Tactical Medical Solutions, Anderson, SC), and the Emergency and Military Tourniquet (Delfi Medical, Vancouver, Canada).

There is no definitive time period to safely apply a tourniquet. There is a risk of limb ischemia and eventual limb loss any time a tourniquet is used. It is generally accepted that 2 hours is a safe time period.[38–40] Beyond this time, it is believed that permanent muscular or neurologic injury may occur. However, a tourniquet has been safely applied for up to 6 hours without permanent complications.[40–42] Use the minimal tourniquet pressure necessary to maintain hemostasis. Release the tourniquet periodically and reassess the extremity. **It is best to limit the use of a tourniquet for the minimum time required to temporarily be lifesaving and until definitive care can be received.**

BALLOON CATHETERS

Physicians have been using balloon catheters to tamponade exsanguinating bleeding from deep wounds or wound tracks. These devices were not specifically designed for this purpose, but used as an improvised technique to temporarily tamponade the hemorrhage. Devices used have included Fogarty catheters, Foley catheters, and Sengstaken–Blakemore tubes. These devices are blindly placed in the wound and inflated to tamponade bleeding from vascular and solid organ injuries.

Tourniquets specific for deep wound hemorrhage are being developed. These devices may be used when conventional external methods (e.g., clotting agents, direct pressure, and tourniquets) do not control the hemorrhage. This group of devices are inserted into the wound or wound track and inflated to tamponade the bleeding. One of these devices is the Tournicath (CardioCommand, Tampa, FL). These devices have not yet been fully evaluated for use in the prehospital setting or in the Emergency Department.

SUTURE LIGATION

Thoroughly inspect briskly bleeding wounds. Place a blood pressure cuff proximally and inflate it until a dry bloodless field is obtained. Large vessel bleeding will first become apparent as the cuff pressure is slowly dropped. Large and intermediate-sized vessels will need to be ligated or oversewn for effective control. Familiarity with the vascular supply to the extremities will help the Emergency Physician anticipate major arterial injuries and look for likely bleeding sources. **Whenever a transected vessel is seen, the other end should be searched for.** A retracted artery in spasm will likely bleed later and should be actively sought and ligated.

Bleeding vessels that can be visualized should be ligated with suture (**Figure 112-1**). Grasp the cut end of the bleeding vessel with a hemostat (**Figure 112-1A**). Pass an appropriate sized suture around the vessel (**Figure 112-1B**). Use absorbable sutures that do not lose their tensile strength too soon (e.g., Vicryl, Monocryl, and PDS). Tie and secure the suture around the base of the bleeding vessel (**Figure 112-1C**). Gently release the hemostat from the blood vessel.

Cut blood vessels, especially arteries and arterioles, often retract into the tissue and are difficult to visualize. A suture can be used to control the bleeding (**Figure 112-2**). Place a figure-of-eight stitch (**Figure 112-2A**) or a pursestring stitch (**Figure 112-2B**) to encompass the blood vessel. These sutures are simple, quick, and easy to place.

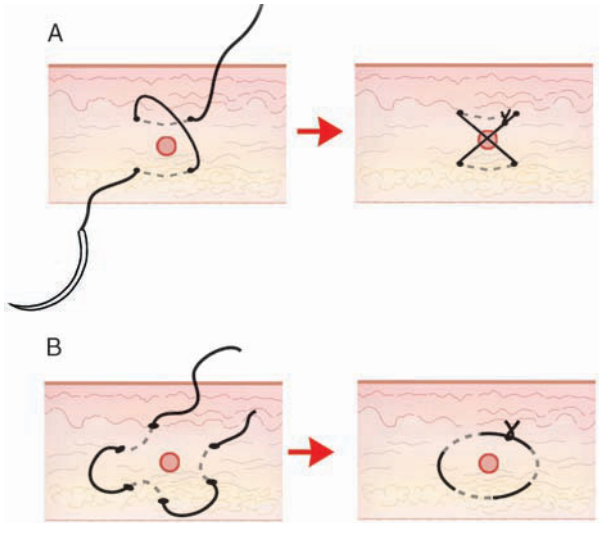


FIGURE 112-2. Control of a bleeding vessel deep or embedded in tissue. **A.** The figure-of-eight stitch. **B.** The pursestring stitch. Note that both of these stitches are not tied tightly for the sake of clarity. In real use, both of these stitches will be tied tightly to seal the bleeding vessel.

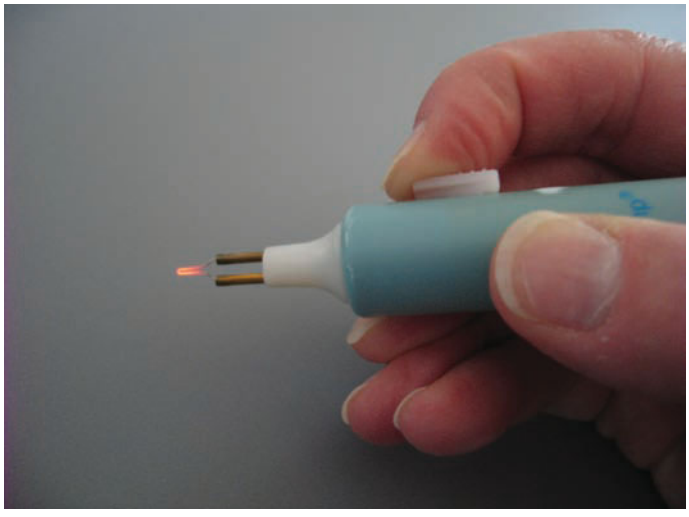


FIGURE 112-3. The battery-powered electrocautery device.

CAUTERY

Place a blood pressure cuff proximally and inflate it until a dry bloodless field is obtained. Small bleeding vessels will be identified as the inflated blood pressure cuff pressure is gradually reduced. The most likely source of significant bleeding from small vessels are from veins and dermal arterioles. Venous bleeding usually stops with direct pressure alone. Dermal arterioles tend to resist direct pressure and cause persistent oozing from the wound edges. Blood vessels are best identified by picking up the wound edge and inspecting the dermis. These bleeding vessels can be effectively treated with electrocautery or chemical cauterization.

Electrocautery is surprisingly easy and effective against aggressive bleeding from small vessels less than 2 mm in diameter.[9] Handheld battery-driven electrocautery units use a heated electrode to deliver a thermal burn to the tissue and char the ends of vessels (**Figure 112-3**). They are simple to use, inexpensive, and stocked in most Emergency Departments. More versatile electrosurgical units, such as the Bovie and Hyfrecator, are extremely effective coagulators.[15] Unfortunately, they are not routinely available in most Emergency Departments.

Chemical cauterization with silver nitrate ($AgNO_3$) is an effective alternative. The silver nitrate is a dark material that is provided on the end of a wooden applicator stick, resembling a large matchstick (**Figure 112-4**). Rub the silver nitrate over the cut end of the vessel.



FIGURE 112-4. The silver nitrate ($AgNO_3$) applicator.

It forms an insoluble precipitate with tissue protein to form an artificial clot or an eschar that occludes the vessel lumen. Silver nitrate cannot be used on briskly bleeding vessels as it will coagulate the blood and not the vessel. The cut vessel must not be bleeding or just oozing for silver nitrate to coagulate the tissue.

The reduced silver nitrate salts stain the tissue it contacts black. Most of the black silver salts are resorbed by the body over several weeks. There is the possibility of permanent staining or tattooing of the skin. Thus, do not use silver nitrate on light skin individuals or close to the skin surface in cosmetically sensitive areas. Minimize tissue contact with silver nitrate to prevent damage to the underlying tissue.

Two topical solutions can be used for chemical cauterization. Monsel's solution is a 20% ferric subsulfate solution that is thick and dark brown to black in color. Like silver nitrate, it can permanently stain or tattoo the skin. Drysol solution is a 30% aluminum chloride solution that is colorless. It will not stain or tattoo the skin. Drysol solution may not be as effective as Monsol's solution for cauterization. Both of these solutions are applied to a relatively dry or slightly moist area with a cotton-tipped applicator.

Briefly apply the electrocautery or chemical cautery directly to the bleeding source. Neither technique will work well unless the field is dry. This can be achieved with the use of suction, the wound can be dabbed dry with gauze or cotton-tipped applicators, or external pressure. More liberal use to the surrounding tissue will leave unnecessary damage and impair wound healing. Overzealous use of electrocautery and chemical cautery can cause unnecessary tissue necrosis and increase the risk of infection.

VASOCONSTRICTORS

Smaller bleeding vessels will usually constrict and eventually stop on their own once major vessels have been treated. If not, the use of local vasoconstrictors and topical hemostatic agents is effective.[16] Epinephrine is a convenient and effective vasoconstrictor.[17] It can be injected into the wound edges with local anesthetic or placed directly into the wound. Epinephrine and other vasoconstrictors should not be used in a finger, toe, ear, nose, or penis where ischemia may cause tissue loss. **Topical vasoconstrictors should be used with diligent attention to the total dose administered to avoid systemic side effects such as hypertension, tachycardia, and seizures.**

Commonly available local anesthetic solutions containing epinephrine that are available in the Emergency Department include lidocaine and bupivacaine. Inject 1 to 2 mL of local anesthetic solution containing epinephrine into the tissue surrounding the bleeding vessel, cover the wound with saline-moistened gauze, and apply external pressure for 2 to 4 minutes. **Use caution and aspirate prior to the injection to ensure that the solution is not being injected intravascularly.** Alternatively, spray 1 to 2 mL of 1:1000 epinephrine or epinephrine containing local anesthetic solution over the wound surface with a 25 gauge needle, cover the wound with a sterile saline-moistened gauze, and apply external pressure for 2 to 4 minutes.[18]

A more dilute epinephrine solution can be used in larger wounds to minimize potential side effects. Solutions as dilute as 1:100,000 to 1:1,000,000 are used to control the brisk bleeding that accompanies tangential burn wound excision and graft donor sites.[19] Topical cocaine (1% to 4%) is a potent vasoconstrictor commonly used on mucous membranes. Combinations of 0.5% tetracaine, 1:2000 epinephrine (adrenalin), and 11.8% cocaine (TEC) are used for topical anesthesia and hemostasis in pediatric wounds.[20] Apply 1 to 2 mL of these solutions directly into the wound followed by an occlusive dressing.

TOPICAL HEMOSTATIC AGENTS

This group of agents has seen most of the recent innovation in hemorrhage control. Most of these agents were originally developed for operative hemostasis. There use has expanded into the Emergency Department. More and more hemostatic agents are being developed for hemorrhage control outside the operating room or for life-threatening hemorrhage when other standard agents have failed. Topical hemostatic agents used in the Emergency Department include cellulose, dry gelatin, thrombin, microfibrillar collagen, cyanoacrylate, inorganic, and polysaccharide-based agents. **Injudicious reliance on hemostatic agents should not replace a methodical approach to wound care and a meticulous search for bleeding vessels.**

Oxidized cellulose (i.e., Surgicel) or dry gelatin (e.g., Gelfoam, Surgifoam) based agents can be used to provide hemostasis in wounds when there is diffuse oozing, especially where a small amount of blood impedes wound closure and jeopardizes a cosmetic outcome. These agents provide a matrix for platelet deposition and aid hemostasis.[7,16] Troublesome wounds can be treated with these agents and covered with a pressure dressing. After a few minutes, the dry field can be approximated with sutures. Another option is to simply leave the hemostatic agent in the wound, close the wound, and apply a pressure dressing. These techniques will be effective for many wounds. These substances are not free of complications. Absorbable gelatin in a wound can produce excessive granulation tissue and fibrosis. Cellulose can cause a foreign body reaction.

In cases where the bleeding persists, topical thrombin or microfibrillar collagen (e.g., Avitene, Instat, Helistat) may be useful hemostatic agents in these problematic cases.[16] Apply topical thrombin in powder form, or diluted with saline and sprayed on the wound. Concentrations of 100 units/mL are usually effective. Concentrations of 1000 to 2000 units/mL can be used if the bleeding is severe. Alternatively, microfibrillar collagen can be used to encourage platelet aggregation. Both thrombin and microfibrillar collagen are expensive and are not usually supplied outside the Operating Room. Their use should be restricted to the unusual patient with a coagulopathy or severe bleeding unresponsive to other measures.

Cyanoacrylate tissue adhesives are commonly used in the Emergency Department for wound closure. It is also a helpful adjuvant for hemostasis. In simple wounds where cyanoacrylate is used for wound closure, it forms an occlusive dressing that provides hemostasis. There is little human data demonstrating the hemostatic activity of cyanoacrylate. It has been shown to promote clot formation, decrease bleeding time, and decrease rebleeding in porcine models for epistaxis and femoral arterial injury.[21,22] It is important to note that cyanoacrylate works best in a dry, bloodless field that can be obtained by a combination of direct pressure, irrigation, and temporary tourniquet use. Hemostasis was achieved in a porcine arterial hemorrhage model in 90% of the animals after temporary tourniquet placement, irrigation, and cyanoacrylate application via spray.[22] Given the occlusive nature of cyanoacrylate, the wound can remain uncovered after its application, allowing for easier recognition of rebleeding if it occurs.

A relatively new area in topical hemostasis is the management of life-threatening bleeding in the nonoperative setting. This has focused on hemostatic dressing and agents, which when applied, lead to rapid hemorrhage control. These products are placed in the wound, covered with gauze, and pressure is then applied. More definitive management can be planned after hemostasis is achieved. These agents fit into two broad categories, inorganic and polysaccharide-based hemostatic agents.

The inorganic hemostatic agents include Quickclot (Z-Medica, Wallingford, CT) and Woundstat (TraumaCure, Bethesda, MD). Quickclot is a zeolite powder that adsorbs water and produces an exothermic reaction, releasing heat into the surrounding tissue.[23] The exact composition is proprietary, but the company states that it contains no biological or botanical substances. It is available as a loose powder and granular beads in a meshwork fabric. While zeolite provided hemostasis in some animal models, there were mixed outcomes and the exothermic reaction can cause temperatures in excess of 212°F or 100°C, leading to thermal tissue injury.[24,25] A new formulation now produces heat of approximately 105°F or 40.5°C to reduce the potential for thermal injury. This may limit Quickclot's clinical use. Woundstat is a smectite nonmetallic mineral that is composed of sodium, calcium, and aluminum silicates. It adsorbs water without producing an exothermic reaction, concentrates blood products, and promotes hemostasis. It is available as granular powder that is packed into wounds. Woundstat use demonstrated decreased blood loss and improved survival compared to Quickclot in animal studies.[26,27]

The polysaccharide-based agents are classified as *N*-acetylglucosamines containing glycosaminoglycans and microporous polysaccharide hemispheres. The data supporting the use of these agents are limited, mostly derived from animal studies with multiple differing models making direct comparison between the products difficult. *N*-Acetylglucosamine glycosaminoglycans are a complex polysaccharide derived from marine microalgae or crustacean shells in the form of chitin or chitosan.[24] These agents are thought to provide hemostasis through multiple mechanisms including tissue adhesion, attraction of circulating red blood cells, and vasospasm.[28] *N*-Acetylglucosamine-based agents include Hemcon and ChitoFlex (Hemcon Medical Technologies, Portland OR), Celox (SAM Medical Products, Portland OR), and Modified Rapid deployment Hemostat (Marine Polymer Technologies, Danvers, MA). Hemcon is available as a coated bandage. Celox is available as granules, granules in a disposable bag, coated flexible gauze, and in a plunger for deep application. Modified Rapid deployment Hemostat is available as a coated gauze. Hemcon, one of the best studied agents, has demonstrated mixed results in animal studies but has favorable reports from its limited use with the United States military.[29] A limited study of 10 trauma patients with intraabdominal injuries achieved hemostasis in 90% of the patients with Modified Rapid deployment Hemostat.[30]

Microporous polysaccharide hemispheres are derived from potato starch. The agent in this class is Traumadex (Medafor, Minneapolis, MN). Traumadex functions as a sponge, dehydrating the blood, concentrating the blood constituents, and promoting clot formation.[24] It is available as a powder and an impregnated bandage. Similar products are available as a spray and plunger for deep application. It performed better than a standard dressing in a swine model of lethal hemorrhage, but worse than both Hemcon and Quickclot.[31]

Dry Fibrin Sealant Dressing (DFSD) is composed of clotting proteins purified from donated blood and plasma. The DFSD is a multilayered dressing composed of fibrin, calcium chloride, thrombin, and an absorbable mesh. The dressing combines with blood to become activated and adhere to the tissues. These DFSD's require special handling and are very expensive, both of which will limit its use in the Emergency Department.

The limited human evidence, case reports, and small studies make comparison of the various hemostatic agents difficult. The application of these agents is simple. Determining which of these agents to use is difficult. It is likely that one or more of these products will become a useful adjunct in topical hemostasis in the early phase of trauma management in the Emergency Department.

The Defense Advance Research Projects Agency (DARPA) is looking into novel methods of hemorrhage control for the battlefield.

They are in the process of developing a wound dressing with an embedded ultrasound device that would be tuned at the resonant frequency of blood. The ultrasound would emit and focus high-power energy toward the bleeding site and stimulate coagulation. If practical and effective, its use can be expanded to the prehospital environment and the Emergency Department.

WOUND CLOSURE VERSUS PACKING

The wound can be approximated, a pressure dressing applied, and the limb elevated when oozing cannot be controlled by any other method. Alternatively, the wound can be packed with saline-moistened gauze until better hemostasis is achieved. Obtain a coagulation profile in anyone with persistent diffuse bleeding. If a correctable coagulopathy is identified, the wound can be approximated after the coagulopathy is corrected.

ALTERNATIVE TECHNIQUES

The general techniques discussed above apply to bleeding from most sites. There are a number of techniques applicable to specific anatomic sites.

THE HAND

Hand injuries pose special problems. Strict hemostasis is necessary to examine the wound and identify any associated damage to tendons, nerves, and joint capsules. A tourniquet can be placed to exsanguinate the extremity and facilitate wound inspection. Elevate the limb and wrap it with an elastic bandage to "milk" the venous return toward the heart. Apply a blood pressure cuff to the forearm or arm and inflate it above the systolic blood pressure. This prevents arterial inflow while minimizing the backflow from venous engorgement to reliably provide a bloodless field.

A digital tourniquet may expedite the examination if the injury is confined to a single digit.[32,33] A number of methods are effective. A Penrose drain can be wrapped about the base of the finger and secured with a hemostat (**Figures 104-3 & 112-5A**). Mark a 0.25 in. Penrose drain with two lines placed 26 mm apart. Stretch the Penrose drain about the base of an average adult finger until the lines meet. Clamp the Penrose drain with a hemostat to generate a sufficient but safe pressure.[32] An alternative is to use a surgical glove with the fingertip cut off and rolled down to leave a tight band at the base of the digit (**Figures 104-4 & 112-5B**). Use a glove size larger than what would typically fit the patient for general use to avoid generating excessive pressure.[32] Disposable, preformed, rubber digital tourniquets are commercially available (**Figures 104-5, 104-6, and 112-5C**).[34] Refer to Chapter 104 for a more complete discussion of digital tourniquets. These tourniquets exsanguinate the digit and prevent arterial inflow. **Tourniquets should be applied for no more than 20 to 30 minutes to avoid injury to the digital nerves.**

Hemostasis is important but should not be pursued without regard to the surrounding tissues. **Hand wounds should not be explored or probed deep to surface structures. Blind exploration or clamping is never advised.** Probing and clamping can damage small nerves and other structures. **Vasoconstrictors, such as epinephrine, should not be used on the digits.** Consult a Hand Surgeon if wounds require deep exploration, a digital artery is injured, or hemostasis is difficult to achieve.

THE SCALP

Scalp wounds frequently occur in association with other major intracranial, spinal, thoracic, and intraabdominal injuries. Control of scalp bleeding is frequently not the first priority in the multiple trauma patient, although continued brisk bleeding from the scalp can contribute to hemorrhagic shock.[35] Techniques for vascular control of the damaged scalp should be simple, fast, and not interfere with the ongoing assessment and treatment of other injuries.

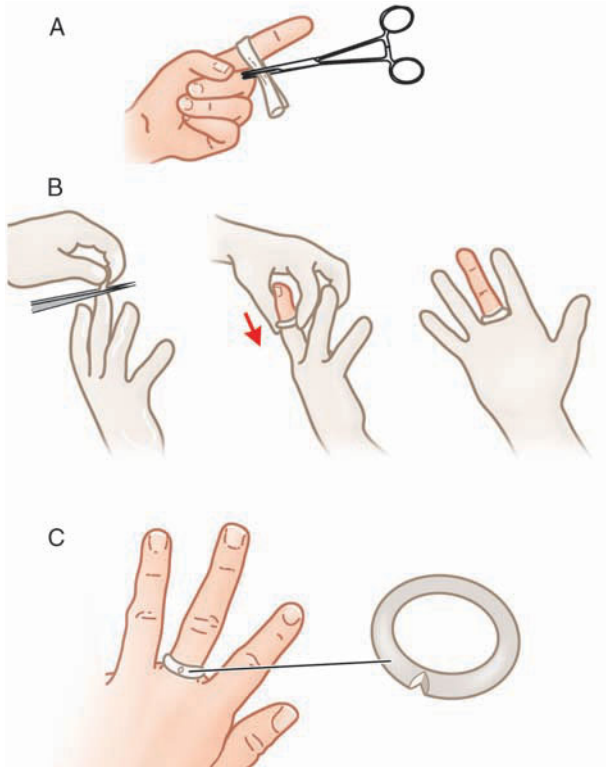


FIGURE 112-5. Finger tourniquets. **A.** A Penrose drain wrapped about the base of the finger provides effective hemostasis. **B.** A finger of a surgical glove has been cut and rolled down the finger. **C.** A commercial finger tourniquet.

A few techniques can help gain rapid control of scalp bleeding with a minimal investment of time or personnel (**Figure 112-6**). The fastest and most effective method is the application of Raney scalp clips (**Figure 112-6A**). These have been used for years by Neurosurgeons performing craniotomies.[36] **Scalp clips should only be used on the thick skin of the scalp. Use elsewhere can crush and devitalize thin skin or damage subcutaneous structures.** If these are not available, apply hemostats at the wound edges where the bleeding is brisk (**Figure 112-6B**). Inject local anesthetic solution with epinephrine into the wound edges to constrict smaller vessels. A Penrose drain can be wrapped about the head as a temporary tourniquet (**Figure 112-6C**).[12] A last method is to place a figure-of-eight suture, simple running sutures, mattress sutures, or surgical staples to temporarily close the wounds and achieve hemostasis. A more definitive closure can be performed after the patient has been stabilized.

The use of Raney clips can be cumbersome. This is especially true if the Emergency Physician has little or no experience with the system. It requires a special applier, individually loading the clips on the applier, and manipulating the clips. A much simpler system is a Raney clip gun (**Figure 112-7**). The clips are preloaded in a magazine that snaps into the clip gun. A clip is applied by touching the tip of the gun to the scalp edge and squeezing the handle. The clip gun then ejects and applies a clip, loads the next clip, and is set to apply the next clip. The process and technique of applying a clip is similar to using a skin stapler. The clip gun is much easier, quicker, and simpler to use than the traditional method.

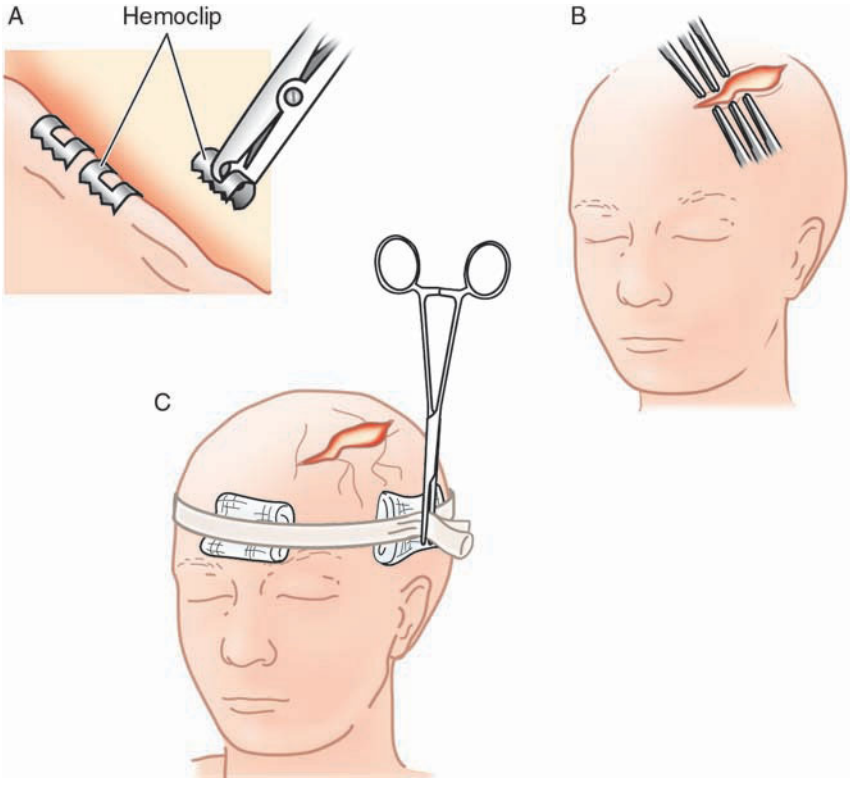


FIGURE 112-6. Hemorrhage from scalp wounds can easily be controlled. **A.** Hemostatic Raney scalp clips seal the wound edge. **B.** Hemostats applied about the edge of the wound. **C.** A Penrose drain wrapped about the head.

MAJOR EXTREMITY INJURY

Amputations, major crush wounds, soft tissue avulsions, and fractures of the extremity may present with active bleeding. Diffuse bleeding from muscle and soft tissue may be difficult to localize and treat. Immobilize the extremity and apply direct pressure if discrete bleeding sites cannot be identified. Reduction of long bone fractures and immobilization of soft tissue injuries can stabilize the damaged tissue and minimize blood loss. The application of a MAST suit or air splint may stabilize bony fragments and tamponade active bleeding.[37] Consider the application of a topical hemostatic agent such as Hemcon, QuickClot, or Traumadex. These conservative and simple measures can dramatically reduce ongoing blood loss.



FIGURE 112-7. The Medtronic Clip Gun Kit (Medtronic Neurosurgery, Goleta, CA). It contains the clip gun, three magazines preloaded with Raney-type clips, a clip remover tool, and an instruction manual.

EXPOSED BONE

Exposed bone will tend to ooze. This can be especially troublesome in amputations and crush wounds. Bone wax can tamponade these sites and temporarily halt the bleeding until more definitive action can be taken. Open a sterile package of bone wax and hold it in a sterile-gloved hand to warm it up and make it more pliable. Remove a piece of the bone wax and mold it over the end of the broken bone. Firmly push the bone wax into the bone to seal the edges. **Use care to prevent lacerating your glove and finger, resulting in a potentially significant bloodborne pathogen exposure.** Possible complications associated with the use of bone wax include granulomatous reactions, infection, and interference with osteogenesis. An alternative to bone wax is Ostene (Ceremed Inc., Los Angeles, CA), a water-soluble alkylene oxide copolymer that dissolves within 24 hours.

ARTERIAL INJURIES

Puncture wounds, open fractures, amputations, and deep lacerations may be complicated by arterial injuries. These may be obvious if they present with dramatic pulsatile bleeding. However, the elastic recoil of arteries frequently causes the damaged vessel to retract deep within the wound, only to rebleed after wound closure. Recurrent pulsatile bleeding and deep hematoma formation are characteristics of unrecognized arterial injuries. This is particularly true of puncture wounds where the damage may be deep and not visible to the examiner's eye. These wounds may require angiography, embolization, or wound exploration to identify the source if they rebleed despite local measures.

ASSESSMENT

The ideal goal in wound care is to achieve a dry bloodless field without compromising the vitality of the tissue. Simply controlling the hemorrhage and preserving life is the goal in major trauma victims. Expediting wound closure and preventing hematoma formation is a more modest goal for minor injuries.

AFTERCARE

A healthy wound is proof of adequate hemostasis. Routine wound care should verify a healthy incision line and the absence of a hematoma or an infection. Refer to Chapters 92 through 96 regarding the details of wound care and repair.

COMPLICATIONS

The techniques in this chapter are all safe and effective when used as described. Complications occur when the described techniques are used in excess or in the wrong setting. The specific complications of each technique are discussed under each specific section in this chapter.

SUMMARY

There are a number of techniques available for the control of hemorrhage. A methodical approach to the bleeding wound will optimize the outcome. Simple measures should be used first and progressive systematic steps taken until hemostasis is achieved. All bleeding eventually stops! The goal is to halt the bleeding before irreparable harm occurs.

113 Trigger Point Injections

Danielle Campagne

INTRODUCTION

Musculoskeletal pain is a significant health problem for the North American population.[1–9] Such pain affects between 10% and 20% of the population and is a major cause of morbidity.[1] It is estimated that approximately half of the chronic pain complaints result from a musculoskeletal origin.[2] It is hypothesized that myofascial trigger point (MTrP) injections may alleviate much of this pain. It is imperative that the Emergency Physician perform a thorough history and physical examination, with an emphasis on the neurological and orthopedic examination to exclude other causes of musculoskeletal pain.[3]

ANATOMY AND PATHOPHYSIOLOGY

The etiology and pathogenesis of MTrPs have yet to be elucidated. Likewise, the precise mechanism by which MTrP injections inactivate the trigger point is unknown. Researchers do agree that acute trauma or repetitive microtrauma appears to lead to the development of a MTrP.[6] The risk for a MTrP is increased when other factors are present, including poor physical conditioning, poor posture, and prolonged bending.[7] MTrPs mostly affect the muscle groups used to maintain posture (i.e., muscles of the neck, shoulders, and back). When the head and neck region is affected, the patient may present with a tension headache or temporomandibular joint pain.[6]

MTrPs are hyperirritable points located within a taut band of skeletal muscle or fascia.[2] When these points are compressed, they may cause referred pain, local tenderness, and autonomic changes.[2] Pain may be localized or diffuse. It can be described as burning, dull, sharp, or some combination of these. Autonomic changes associated with a MTrP include dizziness, edema at the site, lacrimation, piloerection, salivation, and tinnitus. The compression of a MTrP can further lead to muscle spasm, stiffness, shortening, and fatigue.[1] This may progress to impaired muscle coordination, reduced muscle strength, and decreased range of motion.[1]

DIAGNOSIS OF MTrPs

The diagnosis of a MTrP relies on the following criteria: a tender spot with an underlying taught band, pain on palpation of the tender spot, and a local twitch response (i.e., a transient local contraction of skeletal muscle fibers in response to palpation or needling).[3] While the data on clinical outcomes provide no definitive answer, the best outcomes appear to occur in patients who exhibit a local twitch response with palpation.[4] The current literature provides no pathophysiologic explanation for this result. There are no laboratory, pathology, or radiology studies to identify or verify a MTrP.

Identifying the palpable, taut band is critical in locating the MTrP. The MTrP can be identified by flat palpation, snapping palpation, pincer palpation, and/or deep palpation. Flat palpation uses a fingertip to slide across the skin over the affected muscle to find the MTrP (**Figure 113-1**). The taut band may be felt under the sliding fingertip. Snapping palpation uses the tip of the index finger to pluck the skin in an attempt to feel the underlying taut band. This motion is similar to plucking a guitar string. Pincer palpation uses the dominant thumb and index finger to firmly grasp the skin and

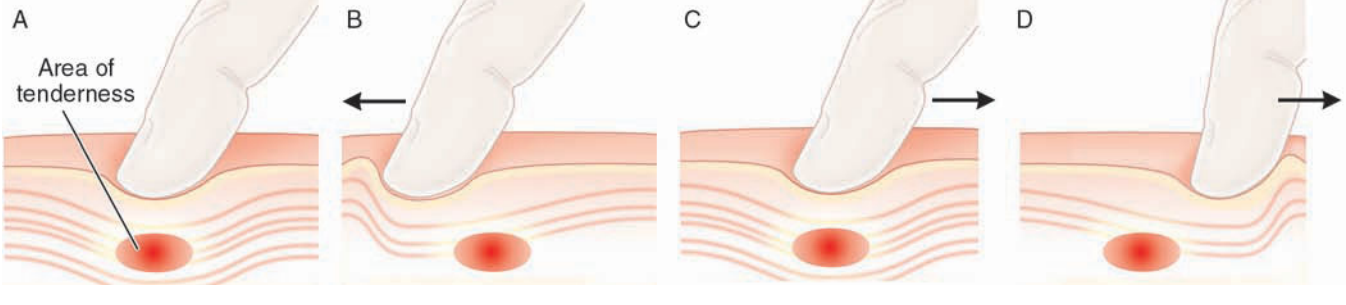


FIGURE 113-1. Flat palpation to identify a MTrP or taut band. **A.** The index finger pushes down over the MTrP or taut band. **B.** The index finger rolls off the tender spot and pushes the skin to one side. **C.** The index finger pushes the skin back to the tender spot to feel the taut band. **D.** The index finger rolls off the tender spot and pushes the skin to the opposite side.

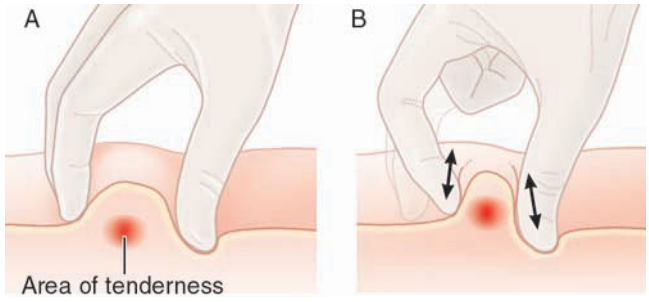


FIGURE 113-2. Pincer palpation to identify a MTrP or taut band. **A.** The skin, subcutaneous tissue, and muscle are grasped between the thumb and index finger. **B.** The fingers are moved back and forth (*arrows*) to feel the taut band as it is rolled between the fingertips.

muscle as a unit and roll it to identify the taut band (**Figure 113-2**). Deep palpation can be used to identify a deep MTrP or a superficial MTrP in an obese patient. Use the tip of the index finger to press slowly and deeply to reproduce the patient's symptoms and identify the MTrP.

Studies have utilized a variety of injectant fluids and solutions during injections of MTrPs including sterile water, sterile saline, local anesthetic solutions, corticosteroid suspensions, ketorolac, and botulinum toxin.[1] No specific fluid or solution has demonstrated a clearly superior clinical outcome. Rather, it appears that the optimal injectant fluid or solution varies by Physician preference. The duration of pain relief has been found to last longer than the duration of action of the injectant. A recent meta-analysis of eight randomized and controlled clinical trials examined the type of injectant used and the resulting effect on symptom relief.[1] The authors concluded that the injection of either lidocaine or botulinum toxin provided greater symptom relief than placebo (i.e., dry needling alone). No particular injectant was more efficacious than any other injectant. This finding is consistent with the general medical literature on the topic, which is still in its infancy, and provides no clear indication of effectiveness. More research is required in this area.

NONINVASIVE MTrP MANAGEMENT

Numerous noninvasive techniques have been used to treat a MTrP.[2,5,8] One of the more common techniques uses spray vapocoolant (e.g., ethyl chloride) in combination with passive muscle stretch to relax the taut band. Ischemic compression therapy is the application of pressure to the MTrP to produce ischemia and ablate the MTrP. Digital pressure is applied and increased until the taut band relaxes. A deep pressure or stroking massage can be used to stretch the affected muscle and relax the taut band. Physical therapy can stretch and relax the affected muscles. Transcutaneous electrical stimulation units with the electrodes placed over the MTrP can be used to stimulate and relax the underlying muscle. Ultrasound can transmit heat and vibration to a superficial MTrP with the goal of muscle relaxation.

INDICATIONS

MTrP injections have been advocated for points of muscle pain that are not assisted by noninvasive therapy such as ischemic compression therapy, massage, physical therapy, spray vapocoolant, transcutaneous electrical stimulation (TENS), and ultrasound.[8] There is no emergent indication for a MTrP injection in the Emergency Department.

TABLE 113-1 Determining Isolated MTrPs Versus MTrPs Associated with Fibromyalgia

Characteristic	Isolated MTrPs	Fibromyalgia
Sexual predilection	None	Female
Pain and tenderness	Local or regional	Generalized and widespread
Muscle tissue	Taut bands palpable	Soft, no taut bands palpable
Muscle range of motion	Stiff and decreased	Normal
MTrPs	Few, discrete, and localized	Many and widespread
Immediate response to injection therapy	Resolution of symptoms	Poor or none

Source: Data from Simmons et al.[2]

CONTRAINDICATIONS

Contraindications to MTrP injections are similar to other injection procedures. This includes the presence of a local or systemic infection, malignancy, anticoagulation therapy, a bleeding disorder, or a dermatologic condition over the injection site.[5] Relative contraindications include allergies to local anesthetic agents, patients with needle phobias, and uncooperative patients.

It is important to differentiate between a patient with one or more isolated MTrPs and fibromyalgia (**Table 113-1**). **A patient with fibromyalgia can have multiple MTrPs. Do not perform MTrP injections in a patient with fibromyalgia.** The injection may worsen their pain.

EQUIPMENT

- Sterile gloves
- Povidone iodine or chlorhexidine solution
- Alcohol swabs
- Sterile gloves
- Gauze 4 × 4 squares
- 25 or 27 gauge, 1.5 in. needle for superficial trigger points
- 25 or 27 gauge, 2 in. needle for deeper trigger points
- 3 or 5 mL syringe
- Injection solutions:
  - Lidocaine without epinephrine
  - Bupivacaine without epinephrine
  - Sterile water
  - Sterile normal saline
  - Botulinum toxin A, 20 units or 0.4 mL (50 U/mL) (Botox, Allergan, Irvine, CA) diluted to 1 mL with normal saline
- Ultrasound machine with a 5 to 7.5 MHz probe
- Ultrasound gel

PATIENT PREPARATION

Explain the risks and benefits of the procedure to the patient and/or their representative. Obtain an informed consent, either signed or verbal, with adequate documentation to support the latter method. Place the patient in a comfortable position on a gurney with the MTrP(s) exposed. Ideally, the muscle with the MTrP(s) positioned so that it is relaxed. Identify the MTrP site(s). Clean the skin of any dirt and debris. Use ultrasound to ensure there are no neurologic, tendinous, or vascular structures in the area that can be injured

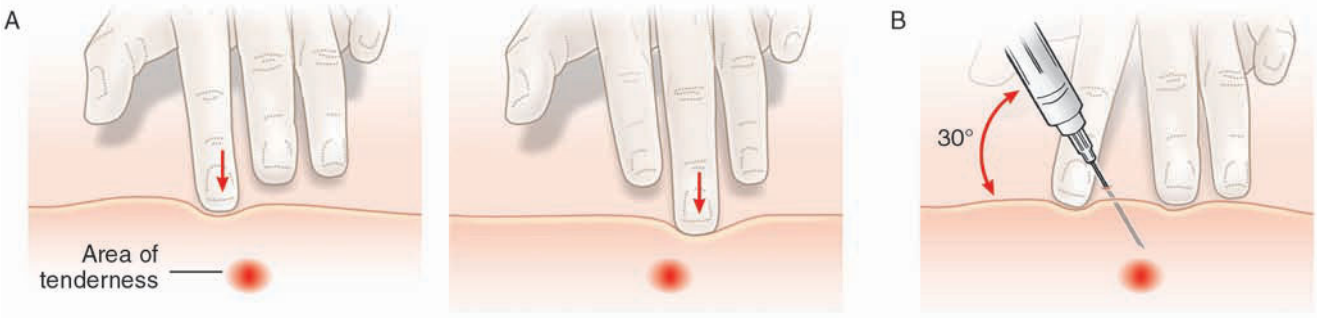


FIGURE 113-3. Identifying and securing the MTrP or taut band. **A.** Push with the index finger and middle finger, alternating between the fingers, to identify and isolate the MTrP or taut band. **B.** Compress the skin with both fingers to secure the MTrP or taut band and inject it.

by the MTrP injection. Mark the MTrP skin site with a pen. Apply povidone iodine or chlorhexidine solution over the injection site(s) and surrounding skin and allow it to dry. Follow aseptic technique for the injection procedure.

Prepare multiple 3 or 5 mL syringes armed with a 25 or 27 gauge needle and containing the injection solution. The editor recommends local anesthetic solution as the injectant in the Emergency Department. The number of syringes to prepare depends upon the number of MTrP sites to be injected and the volume injected at each site.

TECHNIQUES

INJECTION TECHNIQUE

Reidentify the MTrP site. Use the nondominant index and middle fingers to locate and isolate the MTrP or taught band (**Figures 113-3A & B**). Insert the needle into the skin approximately 1 cm away from the MTrP or taught band, at a 30° angle to the skin, and aimed at the MTrP or taut band. Advance the needle into the MTrP or taut band. **Insert the needle briskly, but also in a controlled manner.** Use a "fast in, fast out" approach to elicit a local twitch response when the tip of the needle hits the MTrP or taut band.[8] Aspirate to ensure that the tip of the needle is not within a blood vessel. Inject the solution within the syringe.

Common practice is to inject between 0.5 and 2.0 mL total per MTrP.[5] This volume can be injected into the one location of maximal tenderness or numerous sites in a fanlike pattern within the MTrP (**Figure 113-4**).[9] Once the injection is completed, withdraw the needle to the skin surface but do not completely remove it from the skin. Allow the injection solution to work for up to a minute. Reinsert the needle into the MTrP in a fanlike pattern until the local twitch response is no longer elicited or resisting muscle tautness is no longer palpable.[7] Completely withdraw the needle. Apply pressure over the injection site to prevent bleeding and hematoma formation. Instruct the patient to slowly and fully stretch the affected muscle group.[8]

DRY NEEDLING

The technique of dry needling involves inserting a needle into multiple sites within the MTrP or taut band without injecting any fluid or solution. This is similar to acupuncture. Insert the needle as described above. Withdraw the needle until the tip is just below the skin surface. Redirect and reinsert the needle in a fanlike pattern into a different location within the MTrP or taut band. Continue this process several times until the local twitch response is no longer elicited or resisting muscle tautness is no longer palpable.[7] Completely withdraw the needle. Apply pressure over the injection site to prevent bleeding and hematoma formation. Instruct the patient to slowly and fully stretch the affected muscle group.[8]

ASSESSMENT

The patient should experience relief of their symptoms after the injection. Passively and actively stretch the affected muscle in a slow manner to stretch it out. Apply digital compression to the injection site, the MTrP, and the taut band. If symptoms are still

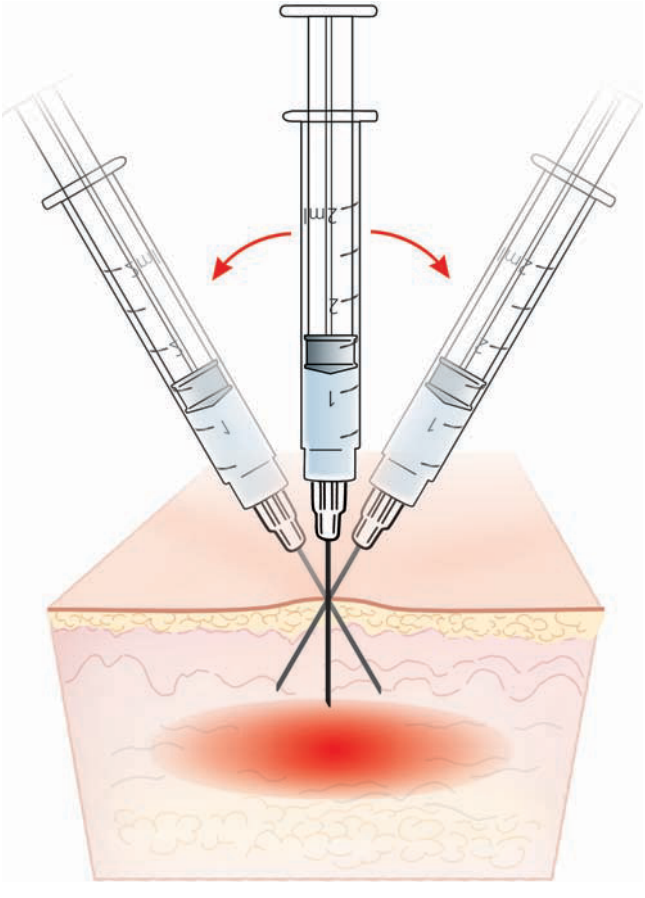


FIGURE 113-4. Injection of the MTrP or taut band. The needle is inserted through a single skin puncture and into multiple places within the MTrP or taut band in a fanlike pattern.

present, repeat the procedure with local anesthetic solution or by dry needling. Observe the injection site and apply pressure to control any bleeding.

AFTERCARE

Apply a simple adhesive bandage over the injection site. Postinjection soreness is expected and can be managed with acetaminophen or nonsteroidal anti-inflammatory drugs. Encourage the patient to use the affected muscle through its full range of motion, but avoid strenuous activity for 1 to 3 days after the injection. Instruct the patient to return to the Emergency Department immediately if they develop fever, chills, swelling at the injection site, redness at the injection site, or any drainage from the injection site.

COMPLICATIONS

The complications are the same as any injection procedure, including infections and needle breakage. An allergic reaction to the injection fluid or solution is possible. Treat this as any other allergic reaction. A thorough history may prevent an allergic reaction to the injectate. Never aim the needle at an intercostal space to prevent an iatrogenic pneumothorax.[7] Hematoma formation following injection can be minimized with proper technique and the application of pressure over the soft tissue after the needle is withdrawn.[2] Never inject the patient when they are standing or sitting in a chair. Ensure that the patient is always on a gurney and the side rails are upright to prevent injury if the patient becomes vasovagal or experiences syncope. Injury and inadvertent injection to adjacent structures can be avoided by knowing the local anatomy and using ultrasonography before the injection to identify adjacent structures.

SUMMARY

MTrP injections can be performed in the Emergency Department. They are simple, quick, and effective to manage a patient's pain. The efficacy of MTrP injections has not yet been established. However, MTrP injections may serve as part of a treatment plan to offer quick relief of myofascial pain when other noninvasive therapies have been unsuccessful.

114 Escharotomy

Michael A. Schindlbeck

INTRODUCTION

Few injuries have the same capacity for physical destruction and emotional devastation as do thermal burns. They are relatively common presentations that often require resource-intensive management. The preceding decade saw nearly 500,000 burn injuries per year receiving medical care in the United States. Over 40,000 of these patients required inpatient treatment for their injuries, and up to 25% of these injuries were work related. The associated expenses are staggering. The mean hospital stay was in excess of 1 week and at an average cost over 50,000 dollars per admission. Over this same 10-year period, an average of over 4000 individuals per year died as a result of burn-related injuries. Fires and burns now represent the fifth leading cause of unintentional injury deaths in the United States.[1] Conversely, less than 6% of the above patients who were admitted to a recognized burn center subsequently died as a result of their injuries.[2–4] **These data underscore the need for rapid and effective emergency care focused on facilitating the successful transfer of these patients to specialized burn centers.** The initial management of these patients invariably falls upon the Emergency Department. The Emergency Physician needs to be well versed in the recognition of acute thermal injuries, their associated complications, and their appropriate treatment.

Thermal injuries have the potential to affect any body surface, both internally and externally, that a heated medium comes into contact. The overall depth and degree of injury is multifactorial. It is also typically proportional to the temperature of the source medium, its unique specific heat, the actual rate of energy transfer, and the overall duration of tissue exposure. This chapter focuses on the skin and its response to burn injuries.

ANATOMY AND PATHOPHYSIOLOGY

Skin exposure to any significant heat source results in a spectrum of pathophysiological responses. An initial coagulation necrosis occurs as thermal energy is transmitted directly into living tissue. These cells subsequently die and lyse, spilling their intracellular contents and increasing the surrounding interstitial oncotic pressure. These processes serve to trigger a secondary edematous reaction in the surrounding tissues. Cellular breakdown releases a host of generalized inflammatory markers including histamines, prostaglandins, cytokines, and interleukins. These agents further exacerbate the localized edematous reaction via vasodilation and increased capillary permeability.[5]

Burns involving over 20% of a patient's total body surface area (TBSA) can result in secondary injury extending beyond the locally involved tissues. The previously described inflammatory outburst can become significantly large enough to produce a systemic pathophysiologic response of internal fluid shifts and external fluid losses. Inadequate fluid resuscitation can result in tissue hypoperfusion and multisystem organ dysfunction. Moreover, a secondary systemic inflammatory response syndrome (SIRS) can further complicate the clinical course of patients whose burns involve greater than 30% TBSA. This frequently results in widespread intravascular hemolysis, acute renal failure, and acute lung injury.[6,7] A global hypermetabolic state tends to accompany these injures. When greater than 30% to 40% of a patient's TBSA is involved, secondary catecholamine release can raise the resting metabolic rate approximately two to three times above baseline. The consequent catabolic tissue breakdown further exacerbates the emerging multisystem organ dysfunction.[5,8] These burns are associated with significant morbidity and mortality. Survivability rates are indirectly proportional to the TBSA involved. Of special note is the loss of a protective functioning epidermis as severe and overwhelming infection becomes a significant potential complication in those who survive beyond the initial resuscitative period.[9] Systemic organ failure from the "burn sepsis" continues to be a leading cause of death in these individuals.

Burns are classified based upon the overall depth of injury sustained. First-degree burns are limited solely to the epidermal layer. They typically present as a tender erythematous region of skin. This redness arises as the underlying dermal capillaries dilate in response to the overlying injury. Deeper tissues are not directly involved and the capillary walls remain intact. This explains the blanchable nature of these burns on physical examination. Blistering of the skin, indicating involvement of the underlying dermis, is not seen with first-degree burns. Classic examples include flash burns and sunburns. Despite extensive surface area involvement, these burns

do not generally illicit the systemic pathophysiologic response described above. Do not include first-degree burns when calculating the overall TBSA affected.

Second-degree burns are the partial thickness injuries. These burns extend into but not through the dermis. They are subdivided into superficial second-degree and deep second-degree burns. Superficial second-degree burns are typically moist to the touch, pink to reddish in color, blanchable with gentle pressure, and covered with tensely distended blisters. Cutaneous nerves, located in the uninvolved underlying deeper dermal layer, remain viable bestowing an exquisitely painful character to these burns. Conversely, deep second-degree burns involve the deeper reticular dermis and differ noticeably in appearance. They tend to be drier in texture and have a more blanched whitish complexion. These injuries tend to be less painful than their superficial counterparts due to destruction of the cutaneous nerves.

Full thickness burns involve the destruction of the entire epidermal and dermal tissues and are classified as third-degree burns. Coagulation necrosis imparts a dry leathery appearance to these burns. The overlying tissue is insensate secondary to the obliteration of the cutaneous nerves. The dermal proteins in third-degree burns are heated and tend to contract, facilitating the formation of a constrictive eschar of scar tissue. Rare scenarios where the tissue destruction extends through the dermis and into the underlying tissues (e.g., muscle, bone, and fascia) are categorized as fourth-degree burns. These injuries are catastrophic in appearance and tend to result in extensive tissue loss.[10]

Burn injuries can generate an extensive redistribution of fluids into the interstitial spaces. Aggressive fluid resuscitation will help to limit the consequent invariable hypoperfusion but does nothing to limit further leakage of fluids into the interstitium. This third spacing can lead to significant elevations in the localized hydrostatic pressures in tissues already constricted by an extensive overlying eschar. Impairment in regional lymphatic and venous drainage further exacerbates this adulteration of the local pressure gradient. Eventually, the normal arteriolar perfusion pressure will be overwhelmed and result in distal tissue hypoperfusion. Distal tissue necrosis can progress to limb loss if the burn occurs on an extremity. Swelling and scarring can result in the loss of a functional airway if the burn occurs over the neck. Burns occurring across the torso can produce an abdominal compartment syndrome, progressing to intra-abdominal organ ischemia, impaired diaphragmatic excursion, and reduced cardiac output secondary to diminished venous return.[11–13] Significant thoracic burns can also impede the dynamic chest wall motions of respiration producing a further restrictive ventilation that can progress to respiratory failure.[14]

INDICATIONS

The general indication to perform an escharotomy is to limit the circulatory or respiratory insult caused by an overlying circumferential burn. These indications can also be present with a significant noncircumferential burn. The development of a significant restrictive physiology often requires several hours after the initial burn. Most patients could be successfully transported to a specialized burn center within this time span. Invasive means to assess compartmental pressures (Chapter 74) should not be undertaken at the expense of proper fluid resuscitation and preparation for transport. The Emergency Physician must maintain a high index of suspicion to limit any further injury to viable tissues. **Once the decision to perform an escharotomy is made, it should be performed without delay.** If possible and time permits, perform the escharotomy in consultation with the accepting burn center and/or Burn Surgeon.

Any signs and symptoms of limb hypoperfusion should be taken seriously. **A restrictive etiology should be considered only if hypoperfusion persists despite adequate volume resuscitation as hypovolemia is the most likely etiology of impaired tissue perfusion immediately after the burn injury.** Perform and document frequent and repeat physical examinations including an assessment of overall skin appearance, distal capillary refill, peripheral pulse checks, any motor deficits, and any sensory deficits. **Depending upon the presence of palpable pulses as the sole means to approximate compartmental pressures will grossly underestimate the need for decompression.**[15] Several methods are available to aid the Emergency Physician in frequently assessing for tissue hypoperfusion. Bedside arterial Doppler provides an easy means to gauge peripheral perfusion. It is concerning if any signs of a progressive reduction in arterial flow occurs. The absence of arterial flow on a bedside Doppler is an indication for emergent escharotomy. **Keep in mind that the presence of Doppler pulses does not necessarily indicate adequate perfusion.** Pulse oximetry provides another useful adjunct. A distal oxygen saturation of less than 95% in a circumferentially burned extremity has been shown to be an indicator for an emergent escharotomy.[16] Compartmental pressures can usually be measured quickly at the bedside. An intracompartmental pressure of ≥40 mmHg is an indication for an escharotomy. Consider an escharotomy for intracompartmental pressures between 25 and 40 mmHg. Refer to Chapter 74 regarding the complete details of compartment pressure measurement.

Significant burns to both the chest and abdomen can result in restricting ventilation. Respiratory distress is generally multifactorial in burn patients. A concurrent inhalation injury or secondary ARDS should be entertained in the differential diagnosis. **Early intubation and mechanical ventilation is essential in any burn patient exhibiting respiratory distress.** Mechanically ventilated patients with severe truncal burns, persistent arterial hypercapnia, and elevated peak inspiratory pressures (although often confounded by concurrent airway edema and secondary bronchospasm) are objective signs suggesting a significant restrictive respiratory physiology. An emergent escharotomy in these patients could be a lifesaving procedure.

Facial burns can result in eschar formation around the eyes and mouth. Measure intraocular pressure if an eschar surrounds the eye. Elevated intraocular pressure should be decompressed with a lateral canthotomy. Refer to Chapters 156 and 162 regarding the complete details of intraocular pressure measurement and a lateral canthotomy, respectively.

CONTRAINDICATIONS

No specific contraindications exist for performing an escharotomy provided the above indications are satisfied. Concern for possible medical futility should arise in those patients with no chance of salvageability, although this is very difficult to determine within the Emergency Department.

EQUIPMENT

- Glove, gown, and face mask
- Povidone iodine or chlorhexidine solution
- #10 scalpel blade on a handle
- Electrocautery unit, optional
- Gauze 4 × 4 squares
- Local anesthetic solution
- Needles and syringes

PATIENT PREPARATION

This procedure is considered life and/or limb sparing. Inform the patient for the need to perform an escharotomy, its risks and benefits, and the outcome if not performed. Document the discussion in the medical record. The patient's medical condition often precludes them from signing a consent form. Despite the fact that escharotomies are performed upon tissues previously destroyed by full thickness burns, some intermittent nerve function can persist. This may necessitate the use of local anesthesia and/or procedural sedation. If not contraindicated, administer some form of procedural sedation (Chapter 129) in the conscious patient for pain control as well as to limit the profound anxiety elicited by this procedure. Strict aseptic technique should be followed. Clean the skin of any dirt or debris. Apply dilute povidone iodine or chlorhexidine solution to the skin and allow it to dry. This procedure has the potential to introduce a devastating infection.

TECHNIQUES

Make the skin incisions along the proper plane with a #10 scalpel blade or an electrocautery unit. Electrocautery has the added ability to coagulate the potential bleeding encountered from inadvertently incised superficial subcutaneous vessels. **Limit the depth of the incision to the dermis.** Use extreme caution to avoid overaggressively extending these incisions too deeply and injuring the underlying deep investing fascia, muscles, and/or tendons. There is a pressure buildup underlying the constricting tissue. **A properly placed incision should elicit a rapid separation of the eschar exposing the underlying subcutaneous fat.** Carefully run a gloved fingertip along the incision lines to detect any residual connecting bands of tissue requiring further incision. To ensure an adequate release, continue the incision across the entire eschar and extending 1 to 2 cm into the unscarred tissue on either end. Cosmetic concerns are not a concern as the incised tissue will often require eventual skin grafting, provided the patient survives.

FACE ESCHAROTOMY

The face is commonly involved in burn injuries. Eschars can form on the face just as they can form on other areas of the body. A patient complaint of any visual disturbance or burns around the eye requires a thorough investigation. This includes measuring visual acuity, a topical fluorescein examination, a fundoscopic examination, and measurement of intraocular pressure. Refer to Chapters 153 and 156 regarding the complete details of these examinations. Elevated intraocular pressure may require a decompressive lateral canthotomy and cantholysis. Refer to Chapter 162 regarding the complete details of this procedure.

Perioral burns can form eschars. These eschars may limit or prevent mouth opening. An escharotomy may be required to aid in oropharyngeal suctioning and orotracheal intubation. Make the escharotomy incisions at the bilateral corners of the mouth and extending directly posterior (in the supine patient) and approximately 4 to 5 cm long (**Figure 114-1A**). **Make the incisions very superficial to prevent injury to the underlying facial artery, cranial nerves, superficial facial structures, and the parotid gland.**

NECK ESCHAROTOMY

Significant burns to the neck can result in the formation of a constrictive eschar that can compromise the airway. Make paired vertical incisions on the posterolateral surfaces of the neck from the mastoid process to the clavicle (**Figure 114-1A**). **Meticulous care and attention should be given to always remain posterior to the clavicular border of the sternocleidomastoid muscle.** This will avoid injury to the internal jugular vein, carotid artery, thyroid gland, trachea, and vagus nerve.

TORSO ESCHAROTOMY

Perform a thoracic escharotomy by extending bilateral vertical incisions from the lateral clavicle to the costal margins along

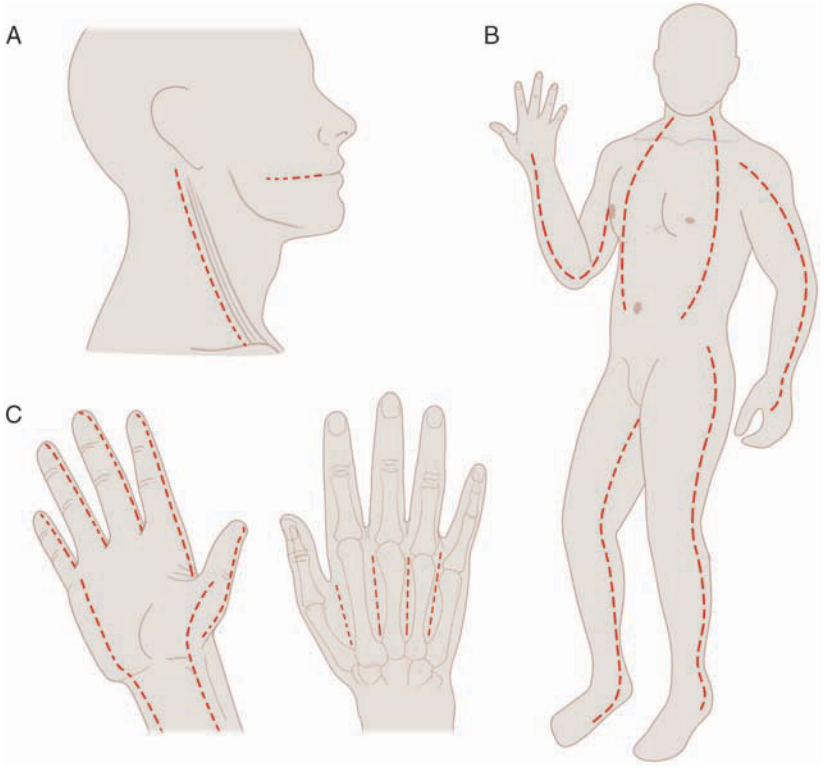


FIGURE 114-1. The location of incisions for escharotomies. **A.** The head and neck. **B.** The extremities and torso. **C.** The hand and fingers.

the anterior axillary lines (**Figure 114-1B**). Use caution in female patients to avoid incising directly through the breast tissue. Instruct an assistant to grasp the breast and move it medially to avoid the escharotomy incision line. In those patients whose burns also involve a significant portion of the abdominal wall, extend the thoracic incision inferiorly beyond the costal margins and across the entire eschar to ensure adequate decompression (**Figure 114-1B**). Make a horizontal bridging incision along the inferior costal margin in those patients whose burns extend from the thorax and onto the abdomen to support proper respiratory mechanics (**Figure 114-1B**).

Circumferential burns of the penis require an escharotomy to decompress the area and prevent ischemia. Distal ischemia can rapidly progress and produce significant tissue loss. Make bilateral incisions along the lateral margins of the body of the penis. **Meticulous care and attention should be given to avoid injuring the dorsally located neurovascular structures that lie between the 10 o'clock and the 2 o'clock position.**

UPPER EXTREMITY ESCHAROTOMY

Perform an upper extremity escharotomy on the medial and lateral aspects of the involved limb, extended along the line dividing the flexor and extensor surfaces (**Figure 114-1B**). Place the upper extremity supine to ensure adequate landmark identification. The areas surrounding joints are sites of severe potential restriction due to relatively tight tissue adherence. Use caution when extending the incisions across these locations. **Meticulous care and attention should be given to avoid the ulnar nerve along the medial surface of the elbow as it courses posterior to the median epicondyle and the superficial branch of the radial nerve along the lateral surface of the wrist as it courses superficially above the radius.** If the hand is involved, extend the forearm incisions to include the thenar and hypothenar eminences (**Figure 114-1C**). Further hand decompression can be accomplished by making vertical incisions down the four intermetacarpal grooves on the dorsum of the hand (**Figure 114-1C**). The fingers can be decompressed with linear incisions along the middle of the radial and ulnar surfaces, between the flexor and extensor surfaces (**Figure 114-1C**). In an attempt to limit the potential damage to a patient's grasping surfaces, incise the ulnar finger surfaces (radial surface on the thumb) and assess if this unilateral incision is sufficiently adequate to restore perfusion prior to automatically incising the corresponding opposing surface.[17]

LOWER EXTREMITY ESCHAROTOMY

The lower extremity should be approached in a similar manner, with incisions extending along the groove between the flexor and extensor surfaces (**Figure 114-1B**). **Meticulous care and attention should be given to avoid damaging the common peroneal nerve along the lateral knee as it courses superficial to the fibular head and the posterior tibial artery along the medial ankle as it courses posterior to the medial malleolus.** If the foot is involved, extend the incisions along the medial and lateral borders of the foot to the great toe and the fifth toe, respectively (**Figure 114-1B**). Decompress the toes in a manner similar to the fingers.

TECHNIQUE FOR PEDIATRIC PATIENTS

Pediatric patients have a higher surface area to volume ratio than does an adult. Consequently, burns pose a greater risk for significant external fluid losses and the rate of fluid resuscitation needs to be adjusted accordingly. More aggressive fluid resuscitation, however, increases the likelihood for pathologically significant elevations in the perfusion pressures of affected tissues. Infants and younger children depend to a greater extent upon diaphragmatic excursion and abdominal wall mobility for normal respiratory function. They are therefore more susceptible to significant respiratory compromise from extensive truncal burns. This necessitates that the treating Emergency Physician possesses both a high index of suspicion and the technical ability to intervene surgically. The patient preparation and escharotomy techniques are the same as in an adult.

ASSESSMENT

The response to an escharotomy should be almost immediate with the signs of improving distal perfusion of the extremities or improved ventilation. The distal extremity should demonstrate decreased pallor and return of a natural skin color, return of sensation, appropriate Doppler arterial flow, and appropriate pulse oximetry. Provided adequate respiratory mechanics, distal pulse oximetry readings should rapidly climb into a normal range.[18] **Lack of improvement in distal perfusion should alert the Emergency Physician to either an inadequate surgical decompression or an insufficient fluid resuscitation.** If there is no improvement in perfusion despite appropriately addressing these two concerns, consider an underlying intrafascial compartment syndrome that would require an emergent fasciotomy. Please refer to Chapter 74 regarding compartment pressure measurements and Chapter 75 for the details of performing a fasciotomy.

AFTERCARE

Continue routine burn care and fluid resuscitation as necessary. Manage any continued bleeding from the escharotomy incisions with the application of pressure or electrocautery. Cover the escharotomy incisions with sterile saline-soaked gauze and an outer dressing. Frequently reassess the patient to rule out the development of additional tissue ischemia or respiratory compromise that would indicate the need for further extension of the initial escharotomy incisions. Transfer the patient to a specialized burn center or an intensive care unit to continuously monitor and manage the patient.

COMPLICATIONS

As with any invasive procedure, bleeding can be a significant complication. This is rare when the escharotomy incisions are properly limited to the dermis. Bleeding can be extensive when an underlying subcutaneous vessel is incised. This is often complicated by the consumptive coagulopathy that frequently accompanies these burns. Electrocautery is an attractive option to limit such bleeding if encountered. Otherwise, direct pressure should generally suffice. Some blood vessels may require ligature for definitive hemostasis.

The burn-damaged epidermis can no longer function to protect deeper tissues from the external environment. Furthermore, the overlying eschar of necrotic tissue provides an ideal environment for uncontrolled bacterial colonization. Escharotomy incisions provide a direct route for bacterial penetration into susceptible subcutaneous tissues if sterile precautions are not properly maintained. This can result in catastrophic infection and burn sepsis.

Inadvertent injury of deeper structures such as blood vessels, nerves, and tendons can occur. This is preventable by controlling the depth of the incisions and not extending into and through the subcutaneous tissues. This is especially true when incising over high-risk areas as previously described.

Making an escharotomy incision on the fingers is controversial. There is little to no muscle at risk of ischemia in the fingers. The fingers primarily consist of bone, ligaments, subcutaneous fat, and

tendons. These structures are quite resistant to ischemia. A finger escharotomy can expose the metacarpophalangeal and interphalangeal joints, make them prone to infection, and require a subsequent fusion or amputation.

A final complication is the inadequate release of the overlying restrictive eschar. Ongoing tissue ischemia can lead to permanent disability from disfiguring muscle contractures, irreparable neurologic damage, or limb loss. Rhabdomyolysis can lead to life-threatening electrolyte abnormalities and acute renal failure. Several authors advocate extending the escharotomy incisions 1 to 2 cm beyond the eschar border into viable tissue. A secondary reperfusion injury can follow the primary decompression as blood once again streams into previously hypoperfused tissue. The consequent swelling can cause the formation of a secondary underlying intrafascial compartment syndrome.

SUMMARY

Thermal burns are frequently encountered injuries prompting patients to seek medical care. Their associated morbidity, mortality, and costs of treatment can be astronomical. Emergency Physicians often provide an essential role in the acute resuscitation and stabilization of these patients prior to their ideal transfer to a specialized burn center. Severe burns can destroy the natural elastic properties of skin and result in the formation of constrictive overlying eschars. If not recognized and treated, these eschars can result in catastrophic limb loss, airway compromise, or respiratory failure. When performed properly, an escharotomy can be a limb and life-saving procedure that, at the least, grants the patient a significant chance to undergo more specialized and definitive burn care.

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SECTION 8

Neurologic and Neurosurgical Procedures

115 Lumbar Puncture

Eric F. Reichman, Kevin Polglaze, and Brian Euerle

INTRODUCTION

Meningitis and subarachnoid hemorrhage (SAH) are serious life-threatening conditions. They require prompt and accurate diagnosis in the Emergency Department due to their significant morbidity and mortality. There are many diagnostic modalities available to the Emergency Physician to assist in the diagnosis. However, the lumbar puncture (LP) is still considered the gold standard. The LP is a procedure that is often performed in the Emergency Department to obtain information about the cerebrospinal fluid (CSF) to aid in the diagnosis of a variety of medical conditions. Knowledge about the proper indications, contraindications, various techniques, equipment, and recognition and treatment of its complications is vital to any Emergency Physician who performs this procedure. **An LP should be performed after a thorough neurological exam. Significant morbidity and mortality can result if the procedure is performed on the wrong patient.**

ANATOMY AND PATHOPHYSIOLOGY

While the entire cavity of the brain and spinal cord has a volume of approximately 1650 mL, CSF occupies approximately 150 mL of this volume. The brain literally floats in the CSF because the specific gravity of the CSF and brain are approximately the same. Approximately 500 mL (0.35 mL/min) of CSF is produced each day. Most (over two-thirds) of the CSF is produced by the choroid plexus within the lateral ventricles. Small amounts of choroid plexus can also be found in the third and fourth ventricles. Small amounts of CSF are secreted by the ependymal surfaces of the ventricles. A minimal volume of CSF is produced by the brain through the small perivascular spaces that surround the blood vessels entering the brain substance.

The flow of CSF through the ventricular system is rather simple (**Figure 115-1**). CSF produced in the lateral ventricles flows through the foramina of Monro into the midline third ventricle. It then passes through the Aqueduct of Sylvius into the fourth ventricle. From the fourth ventricle, the CSF flows into the cisterna magna via two lateral openings (foramina of Luschka) and one midline opening (foramen of Magendie). The cisterna magna is located beneath the medulla and cerebellum and is continuous with the subarachnoid space that surrounds the brain and spinal cord. The CSF then flows through the subarachnoid space to

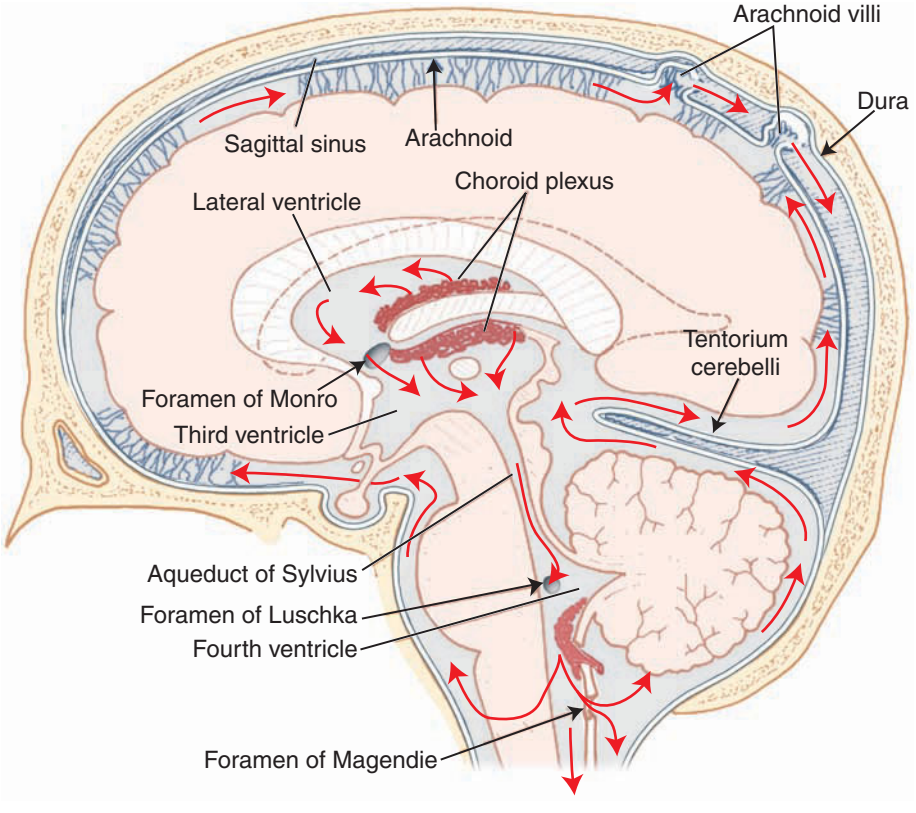


FIGURE 115-1. CSF circulation around the brain and upper spinal cord.

bathe the brain and spinal cord. The CSF is absorbed back into the venous system by way of arachnoid villi.

CSF pressure should average 130 mmH_2O when measured in the lateral decubitus position. It can range from 70 to 180 mmH_2O in a normal person. Since the CSF production rate is constant, the pressure is regulated by the rate of CSF absorption by the arachnoid villi that act as one-way valves into the venous blood of the dural sinuses. Certain disease states may impede reabsorption and lead to increased intracranial pressure (ICP).[1]

Familiarity with the anatomy of the spinal column is important when performing an LP. The anatomy will be briefly reviewed from superficial to deep as the spinal needle traverses the midline structures. The skin and subcutaneous tissue are the first layers encountered. These are followed by the supraspinous and intraspinous ligaments, located between the spinous processes of adjacent vertebrae. Deep to these ligaments is the thick ligamentum flavum that accounts for the characteristic "pop" that is described when performing an LP. The next layers encountered are the epidural fat, in the epidural space, followed by the dura mater, and finally the subarachnoid space.

When considering the lateral approach, there are subtle anatomic differences. The layers include skin and subcutaneous tissue followed by the paraspinal ligaments. The intraspinous ligament is less likely to be encountered with an extreme lateral approach, as this is a midline structure. The ligamentum flavum and deeper structures should be encountered in the same fashion regardless of the approach.

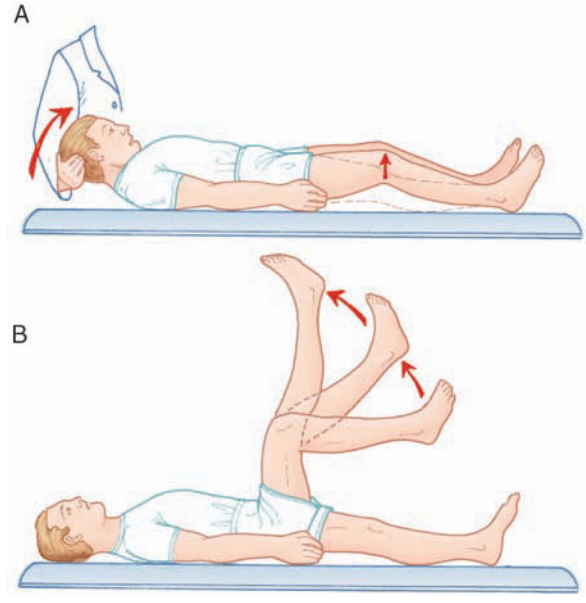


FIGURE 115-2. Physical examination of meningeal signs. **A.** Brudzinski's sign. Upon passive elevation of the head by the examiner, the patient complains of neck and low back pain, and may have involuntary flexion of the knees and hips suggesting meningeal irritation. **B.** Kernig's sign. Begin with the patient starting in a supine position with their hips and knees flexed 90°. Gradually extending the knee causes the patient to complain of neck or lower back pain.

INDICATIONS

There are many indications for performing an LP. The primary indications to perform an LP are the suspicion for a central nervous system infection, such as meningitis, or for a SAH. It may also be performed for the evaluation of new-onset seizures, to obtain CSF biomarkers, to relieve CSF pressure, and confirm the diagnosis of pseudotumor cerebri. Other indications include CSF evaluation for central nervous system diseases (e.g., Guillain–Barré, multiple sclerosis, and systemic lupus erythematosus), to confirm demyelinating or inflammatory diseases, to administer antibiotics or chemotherapeutic agents, to aid in radiologic imaging procedures (e.g., cysternography or myelography), and to diagnose meningeal carcinomatosis.

SUSPICION OF MENINGITIS IN ADULTS

An LP should be performed in adults when there is a clinical suspicion of a central nervous system (CNS) infection. While a fever is often present (most sources consider a fever >100.4°F or >38°C), it is not a dependable sign. Meningeal signs include nuchal rigidity, Kernig's sign, and Brudzinski's sign. Other signs of a possible CNS infection include a severe headache, photophobia, or a petechial rash. Unfortunately, these signs may or may not be present. This is especially true in the elderly, the young, or the immunocompromised patient. **An LP should be a routine procedure in febrile adults with an altered mental status and no source of fever.**

The most commonly looked-for signs of meningitis include the Kernig's sign and the Brudzinski's sign (**Figure 115-2**). Place the patient supine to test for these physical examination signs. Passively flex the patient's head until their chin touches the sternum. Flexion of the patient's hips and knees in response to the head flexion is known as the Brudzinski's sign (**Figure 115-2A**). The patient may also experience neck pain and resistance to flexion if meningitis is present. Passively flex one of the patient's legs to 90° at the hip and to 90° at the knee (**Figure 115-2B**). Passively extend the knee. Pain in the lower back or resistance to knee extension is known as the Kernig's sign.[2]

SUSPICION OF MENINGITIS IN CHILDREN

When evaluating the febrile infant, the decision of whether to perform an LP will be based on the clinical suspicion of meningitis, the age and appearance of the child, and whether an identifiable source of fever is present. The Emergency Physician will often be faced with a well-appearing febrile infant with no obvious source of fever. Until recently, many institutions managed all febrile infants less than 3 months old with a full sepsis workup (including LP) and admission to the hospital.

Guidelines based on an extensive literature review and a meta-analysis by an expert panel identify patients at low risk for serious bacterial infection (SBI), where LP and hospitalization may or may not be indicated.[3] Examples of serious bacterial infections include meningitis, sepsis, osteomyelitis, septic arthritis, urinary tract infections, pneumonia, and enteritis. Since clinical evaluation alone is inadequate to exclude serious bacterial infections in infants, it must be combined with laboratory studies that can define low-risk criteria. These criteria apply to nontoxic-appearing infants with reliable parents and prearranged follow-up. A more detailed discussion regarding the evaluation of the child with a fever is beyond the scope of this chapter.

It should be noted that any febrile child, regardless of age, who appears "toxic" should have an LP as an integral part of the sepsis workup. Certain bacterial infections have a high propensity for dissemination and systemic bacteremia. Examples include epiglottitis, buccal cellulitis, periorbital cellulitis, and septic arthritis. These children should also be considered for a LP in their evaluation and work-up.

IS AN LP INDICATED FOR THE FIRST FEBRILE SEIZURE?

The Emergency Physician will be faced with the decision of whether to perform an LP when evaluating infants and children with a first

febrile seizure. The American Academy of Pediatrics recommends that a LP be "strongly considered in infants less than 12 months of age" and "considered in children 12 to 18 months of age."[4] This is based on the lack of clinical signs and symptoms often associated with meningitis in this age group. For children over 18 months of age, an LP should only be performed if there is a clinical suggestion of meningitis. Clinical signs and symptoms that have been shown to correlate with the presence of meningitis include petechiae, nuchal rigidity, coma, persistent drowsiness, Kernig's or Brudzinski's sign, status epilepticus, and paralysis.[5]

Benign febrile seizures are those that occur in children 3 months to 5 years of age, are associated with a fever at the onset of an illness, have a single generalized seizure lasting less than 15 minutes in a child with normal psychomotor development, have no history of prior febrile seizures with this current illness, and have no evidence of an intracranial infection or acute neurological illness. These children generally appear well except for the fever and generally do not require a LP. This is based upon the level of Emergency Physician comfort in a nontoxic-appearing child.

Complex febrile seizures are those that do not meet the criteria of a benign febrile seizure. These children require a complete septic work-up including an LP. Criteria include seizures that begin focally, seizures lasting over 15 minutes, children with a prolonged postictal period, suspicious findings on physical examination, children less than 12 months of age, children already receiving antibiotics, children who have seen a Physician for an illness in the preceding 24 hours, or those who have had multiple seizures during a single period of illness. Seizures not associated with the onset of an illness have an increased risk of being due to meningitis or bacteremia. Children seizing upon presentation to the Emergency Department are considered to be seizing over 15 minutes or to have recurrent seizures. Suspicious findings on physical examination that suggest a complex seizure include rashes, petechiae, cyanosis, hypotension, abnormal respirations, increased or floppy tone, stiff neck, difficult to console, deviated eyes, doll's eyes, nystagmus, ataxia, photophobia, bulging or tense fontanelles, unable to fix and follow, or children that do not respond to voice or painful stimuli.

SUBARACHNOID HEMORRHAGE

A suspected SAH is the other common indication for an LP. The classic description of a SAH is the sudden onset of an excruciating headache ("thunderclap") during exertion that may or may not be associated with syncope, nausea, vomiting, diaphoresis, or meningeal signs. Physical examination findings may include nuchal rigidity, an altered level of consciousness, papilledema, retinal hemorrhage, third-nerve palsy, sixth-nerve palsy, bilateral lower leg weakness, nystagmus, ataxia, aphasia, or hemiparesis. Additional risk factors for a SAH include cigarette smoking, hypertension, alcohol abuse, a family history of SAH, polycystic kidney disease, connective tissue disorders, or sickle cell anemia.

It is estimated that 20% to 50% of patients with a SAH may have sentinel bleeds or small leaks that precede the major bleeding event. **It is important to diagnose a sentinel bleed because early management and intervention can improve the overall outcome for the patient. A sentinel bleed may precede a major SAH by hours, days, weeks, or months.**[6,7]

A CT scan of the head is often the first study used to investigate a patient complaining of the sudden-onset headache. The sensitivity of CT scan for SAH can range from 92% to 98% when performed within 24 hours of the onset of symptoms.[8–10] The sensitivity decreases markedly (about 76%) when performed 48 to 72 hours after onset of symptoms.[11–12] The head CT scan can be negative in the patient with a sentinel bleed.

An LP must be performed if the CT scan is negative and a SAH is still suspected.[10] The presence of xanthochromia or red blood cells in the CSF will confirm the presence of bleeding. While the CSF will usually confirm a SAH, it is possible that the LP may be negative despite a recent SAH if there has not been sufficient time for the red blood cells to migrate to the lumbar spine area. In this case, despite a negative head CT scan or a negative LP, a cerebral angiogram or follow-up LP in 12 to 18 hours should be performed.

CONTRAINDICATIONS

Knowledge of the contraindications to performing an LP is important. The Emergency Physician will often have to weigh the potential risks of performing the procedure with the benefits of obtaining the CSF. The decision must be made whether the procedure should be performed immediately or can be delayed until further studies are completed. Absolute contraindications to performing an LP include a cellulitis or abscess at the skin puncture site or signs and symptoms of increased ICP except for idiopathic intracranial hypertension (IIH, previously known as pseudotumor cerebri). The LP should be delayed in patients with an unstable airway, hypotension, shock, or status epilepticus until the patient has been stabilized. Hypoxemia, clinical deterioration, apnea, and cardiopulmonary arrest are reported complications of LP in unstable patients. Relative contraindications to performing an LP include the presence of a brain abscess, epidural or subdural fluid collection, brain tumors, and spinal cord tumors.

Note that antibiotics should not be delayed if meningitis is suspected and the LP must be delayed. If meningitis is highly suspected but the patient is unstable, treatment should be initiated with parenteral antibiotics and the LP delayed until the patient's condition is stabilized.

INCREASED ICP

An LP is relatively contraindicated in the presence of increased ICP.[13–15] This includes patients with space-occupying lesions (e.g., tumor or abscess), lateralizing signs such as hemiparesis on the physical examination, or when signs of uncal herniation are present (unilateral third-nerve palsy). Brain herniation or coning has also been reported in patients with meningitis and increased ICP. The sudden drop in ICP induced by an LP may precipitate a pressure cone or herniation.

Pseudotumor cerebri, now known as IIH, has been treated with a combination of medicines and repeated LPs to decrease ICP. Removal of CSF for IIH is a common diagnostic and therapeutic procedure in the Emergency Department. The use of LP in IIH is sometimes questioned. Many of these patients are obese, making an LP more difficult to perform, often requiring multiple attempts, and painful for the patient. The CSF removed reforms within a few hours, thus the LP provides only temporary relief of the patient's symptoms. Consult a Neurologist before performing an LP in the patient with IIH. An LP may be required to make the initial diagnosis of IIH, but may be unnecessary in the patient when the diagnosis has been made previously.

BRAIN ABSCESS

Patients with brain abscesses are at high risk for herniation.[16,17] Brain abscesses may present with a progressively worsening headache, low-grade fever, and the development of focal neurological signs (e.g., hemiparesis, papilledema, visual field deficits, and mild obtundation). Suspect a brain abscess in patients with a history of otic or paranasal sinus infection, orbital cellulitis, chronic pulmonary or

abdominal infection, endocarditis, congenital heart disease, recent dental procedures, dental abscesses, recent neurosurgery, craniofacial trauma, open skull fractures, or recent meningitis.

WHEN IS A CT SCAN INDICATED BEFORE AN LP?

It should be emphasized that increased ICP by itself is not necessarily a contraindication to an LP. ICP is usually mildly elevated in patients with IIH or meningitis.[18–20] A CT scan does not need to be routinely performed in straightforward cases of suspected meningitis in the patient with a normal neurological examination.[21–25] The inability to visualize the optic discs does not constitute a focal finding and, by itself, is not an indication for a head CT scan prior to an LP.[23] Despite this, there are occasional cases of herniation in patients with a normal CT scan.[13,14,19]

Most literature suggests that CT scans be performed prior to LP when patients are comatose or altered, have focal neurological signs, are HIV positive, have a progressively worsening headache, or have papilledema.[23–25] **The lack of papilledema is not always a reliable sign of normal ICP, as it often takes greater than 48 hours to develop papilledema.**[21] Papilledema may be absent in up to 15% of adults and up to 50% of children with early increased ICP.

The CT scan should be evaluated for mass lesions, shift of midline structures, or hydrocephalus due to obstructing masses, cisternal obstruction, and cerebral edema.[25] There are three findings that may predispose a patient to herniation if an LP is performed.[26] The first finding is midline shift. This suggests unequal pressures across the midline. The second finding is a loss of the suprachiasmatic and basilar cisterns. This suggests unequal pressures between the supratentorial and infratentorial compartments. The third finding is any evidence of a posterior fossa mass, obliteration of the superior cerebellar cistern, or obliteration of the quadrigeminal plate cistern caudal to the midbrain. These findings all suggest the presence of increased infratentorial pressure.

Do not delay the initiation of antibiotics if meningitis is suspected and a CT scan is indicated before performing an LP. Administer the antibiotics before the patient undergoes CT scanning. Several studies have shown that delays in the initiation of antibiotics are common in the Emergency Department. These delays are often Emergency Physician generated and result from the need for a CT scan prior to LP, waiting for LP results before administering antibiotics, and not giving antibiotics before a patient is transferred to the ward.[27–30]

COAGULATION DEFECTS

An LP is relatively contraindicated in patients with a coagulopathy. This includes hemophiliacs, those on anticoagulants, and patients with thrombocytopenia. An LP can result in a spinal epidural or subdural hematoma with subsequent spinal cord compression. Appropriate replacement of platelets and/or clotting factors should be undertaken prior to attempting an LP if the procedure can be delayed.[31] **The most experienced Emergency Physician should perform the procedure with a small gauge needle when an immediate LP is indicated in these patients.**

BACTEREMIA

Some sources list bacteremia as a contraindication to an LP, especially in children. While there is some suggestion that there may be an association between performing an LP in a bacteremic patient and the later development of meningitis, the risk of this is low. **An LP should not be withheld for fear of inducing meningitis.** The risk of delaying the diagnosis of meningitis clearly outweighs the small chance of causing meningitis with an LP.[32]



FIGURE 115-3. A commercially available LP kit.

EQUIPMENT

- Sterile gloves and gown
- Face mask and cap
- 1% lidocaine solution
- Povidone iodine or chlorhexidine solution
- LP needles, various gauges and lengths
- Topical anesthetic agent (e.g., EMLA), optional
- LP kit

Most of the equipment necessary for performing an LP is available in prepackaged, sterile, disposable, and single-patient use commercial kits (**Figure 115-3**). These kits usually contain a 20 gauge Quincke spinal needle, syringes, needles (25 gauge and 22 gauge) for local anesthesia, a manometer with a stopcock, sterile drapes, specimen tubes, 1% lidocaine, gauze, brushes for prepping the skin, and bandages. Some kits provide povidone iodine or chlorhexidine swab sticks whereas other kits have a small basin that needs to be filled. The Emergency Physician should become familiar with the kit used at their institution.

Additional supplies may be needed to perform the procedure without interruption. For example, some Emergency Physicians prefer a smaller gauge Quincke needle or a nontraumatic needle such as a Sprotte or Whitacre that are not often provided in the commercial kits (**Figure 115-4**). The use of a 25 gauge spinal needle is

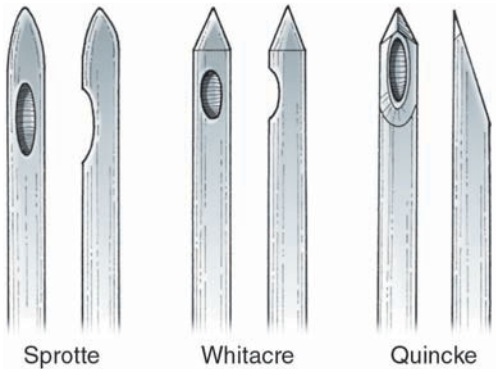


FIGURE 115-4. The three types of spinal needle tips. The standard Quincke needle has a sharp, beveled end. The Whitacre and Sprotte needles are designed to spread atraumatically, rather than cut dural fibers.

recommended as it causes a smaller puncture hole and less postprocedural headaches.[33–37] It has been suggested that atraumatic needles should be the standard when performing an LP.[38,39] In general, it is a good idea to have extra spinal needles, lidocaine, gauze, and skin antiseptic (e.g., povidone iodine or chlorhexidine solution) when performing an LP. There are numerous formulae to determine the LP depth and the length of the spinal needle required.[40,41] A reliable formula for estimating the required LP needle length is LP depth (cm) = 1 + [17 × (weight (kg)/height (cm))].[41]

There are subtle differences among the spinal needles commonly available (**Figure 115-4**). The standard Quincke needle has a sharp tip with a broad bevel at the end. The Whitaker and Sprotte needles have smaller tips with smaller diameter bevels. The bevel of the Sprotte needle is broader with a rounded tip so as to separate fibers of the dura as opposed to cutting through them. **Always remember to keep the bevel oriented parallel to the fibers of the dura when performing an LP regardless of needle style.**

PATIENT PREPARATION

Explain the risks, benefits, and complications of the procedure to the patient and/or their representative. Obtain a signed informed consent for the procedure. If the patient is a child or minor, ask the parents or caregivers whether or not they would like to be present for the LP.

There are a variety of different patient positions that can be used to perform the LP (**Figure 115-5**).[33,42,43] Knowledge and proficiency in more than one approach will be useful for the Emergency Physician, especially when encountering a difficult tap. The position of the patient will be chosen based upon the patient's body habitus, their ability to assume a position, their level of cooperativeness, and Emergency Physician preference.

The sitting position is more commonly used in adults than the lateral decubitus position. It is easier to identify the midline and palpate the spinous processes with the patient sitting (**Figure 115-5A**). The sitting position is particularly useful when patients are obese. While the LP can still be performed in the lateral decubitus position for obese patients, palpating the spinous processes and identifying the midline can be difficult. The measurement of hydrostatic pressure in the CSF is not accurate with the patient sitting. It gives a falsely elevated pressure reading.

The lateral decubitus position is often the most comfortable position for the patient (**Figure 115-5B**). Place the patient with their knees flexed, the upper back arched to spread the interlaminar spaces, and the neck slightly flexed. Ensure that the patient's shoulders, back, and hips are exactly perpendicular to the stretcher and

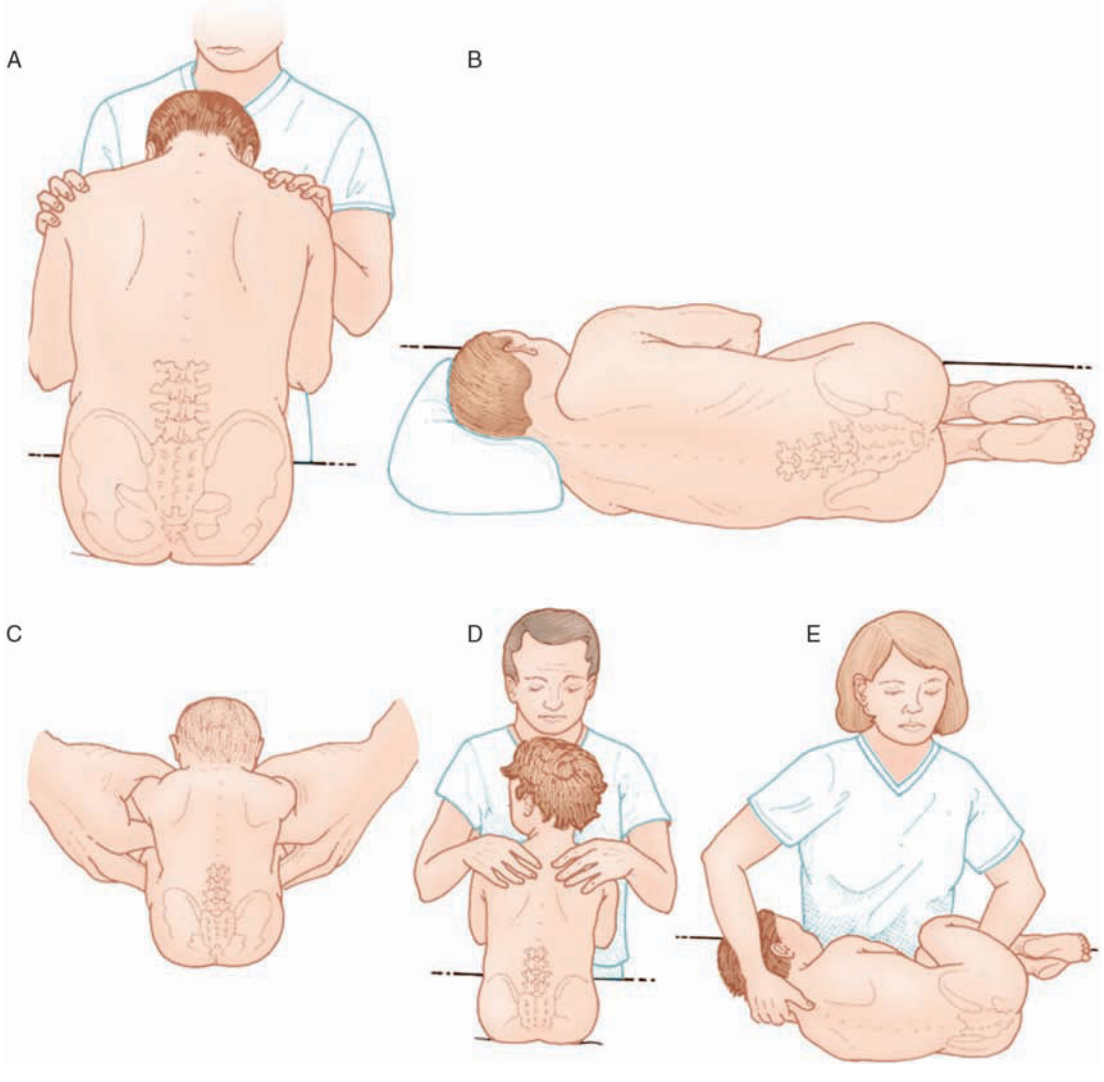


FIGURE 115-5. Patient positioning for an LP. **A.** An adult in the sitting position. **B.** An adult in the lateral decubitus position. **C.** An infant restrained in the sitting position. **D.** A child restrained in the sitting position. **E.** A child restrained in the lateral decubitus position.

floor. This will increase the chances of keeping the needle in the midline as it is introduced parallel to the surface of the stretcher. This is particularly important in infants and children where an assistant may be called upon to hold the patient in position. Severe neck flexion is not necessary and can lead to airway obstruction or lack of CSF flow.

Children can be placed in the sitting or lateral decubitus position. An assistant can easily maintain neonates and infants in the sitting position (**Figure 115-5C**). Toddlers and school-aged children can also often be maintained in the sitting position (**Figure 115-5D**). The lateral decubitus position can be used for any child (**Figure 115-5E**). **It is important to assess the child visually and with pulse oximetry during the procedure. These positions may cause improper neck flexion that can result in respiratory compromise, oxygen desaturation, hypoxemia, and anoxic encephalopathy.[44,45] The largest interspinous space is achieved with the patient sitting upright with their hips flexed, leaning forward, and with slight neck flexion based on ultrasonographic studies.[45–48]**

The subarachnoid space must be entered below the termination of the spinal cord that is situated at the lower level of L1 or the body of L2 (Figure 115-6). Identify by palpation the vertebral spinous processes in the midline and the posterior superior iliac spines. The patient can help to determine the midline.[179,180] Just ask them if the needle is in the midline. Another option is to draw a line between the spinous process of C7 and the gluteal cleft.[49] An imaginary line connecting the posterior superior iliac spines should intersect the midline at approximately the L4 spinous process or the L3-L4 interspace. One can select any of the spaces between L2-L3 and L5-S1 to perform an LP. Palpate the intended interspace before prepping the area. Some Emergency Physicians mark the site lightly with a pen or make a small indentation with the hub of a needle. Adjust the bed height so that you can sit in a comfortable position while performing the procedure.

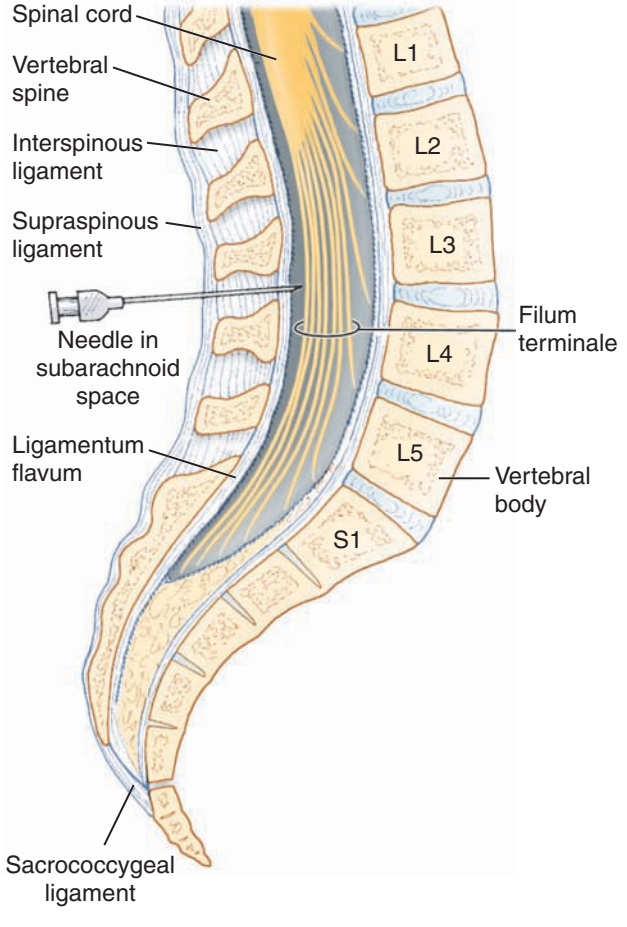


FIGURE 115-6. Midsagittal section of the lumbosacral region with a spinal needle in the L3-L4 interspace. The needle has penetrated the supraspinal ligament, the interspinous ligament, the ligamentum flavum, the dura mater, and the arachnoid mater.

Prepare the LP kit. Open the kit using sterile technique and place it on a bedside table. Place povidone iodine or chlorhexidine solution into the basin provided with the kit. Place any additional needles or supplies onto the sterile field. **This procedure requires strict aseptic technique. The Emergency Physician should don full sterile and personal protective equipment at this point.[50–52]** This should include sterile gloves, a sterile gown, a face mask, and a cap. Prepare the stopcock and manometer. The manometer is usually in two pieces that slide together. Insert the manometer into the vertical port of the stopcock. Turn the handle toward the outflow side of the stopcock. In general, the stopcock handle will occlude the port that it points to.

Prepare the patient's back. Clean the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution using a circular motion from the intended site of entry outward. Allow the solution to completely dry prior to inserting the spinal needle.[53] Chlorhexidine solution introduced into the spinal canal can result in arachnoiditis and neurotoxicity. Prepare an area of at least 10 cm in diameter. Most kits include a solid drape and a fenestrated drape. Place the solid drape between the patient's hips and the bed. Place the fenestrated drape with the adhesive side toward the patient's back and the opening centered at the desired level for the procedure.

Reidentify the anatomic landmarks. Place a finger over the desired interspace to use for the procedure. Place a skin wheal of local anesthetic solution subcutaneously over the desired interspace using a 25 gauge needle. Infiltrate and anesthetize the deeper tissue of the interspace along the projected needle track using the 22 gauge needle. **The infiltration of local anesthetic solution, unless contraindicated, should be used in all patients, including neonates and young children.** Local anesthetic makes it more likely the LP will be successful.[46,47,54]

Alternatively, a field block can easily be performed to produce anesthesia of the skin, interspinous ligaments and muscles, and the periosteum. The interspinous ligament and the periosteum are supplied by the recurrent spinal nerves branching off the nerve roots exiting the spinal canal at the same level. Inject local anesthetic solution into the interspinous ligaments, between the spinous processes superior and inferior to the intended puncture site, and on either side of the interspinous space (**Figure 115-7**).[33] A topical anesthetic (e.g., EMLA cream) may be applied over the interspace for 30 to 60 minutes prior to performing the LP if the patient is awaiting a CT scan of the head and antibiotics have been administered. Unfortunately, this only anesthetizes the skin and superficial subcutaneous structures. The patient will still require a local anesthetic injection.

It may occasionally be difficult for some patients to remain still and cooperative with the procedure. This can include anxious patients, those with an altered mental status, and small children. These patients may require an intravenous anxiolytic, nitrous oxide administration, or procedural sedation.

TECHNIQUES

LATERAL DECUBITUS POSITION AND MIDLINE APPROACH

Palpate the intended interspace. Introduce the needle in the middle of the interspace and parallel to the bed. **Orient the bevel of**

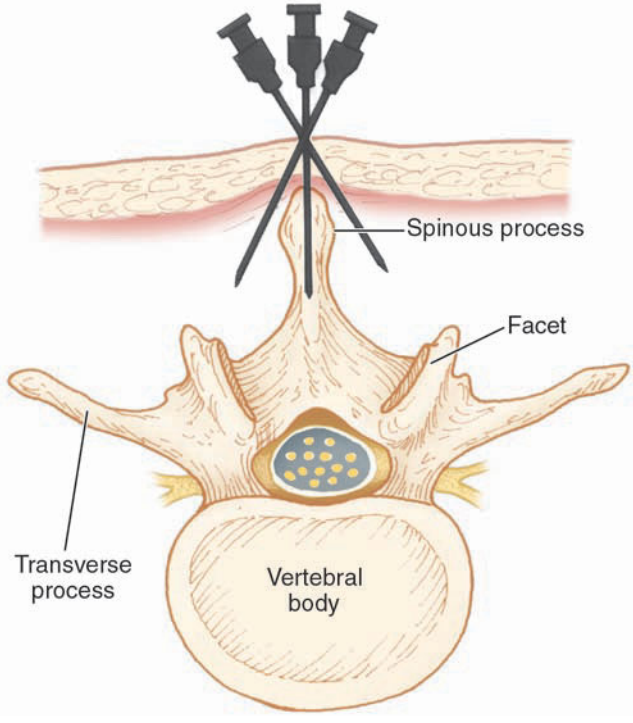


FIGURE 115-7. Field block for LP anesthesia.

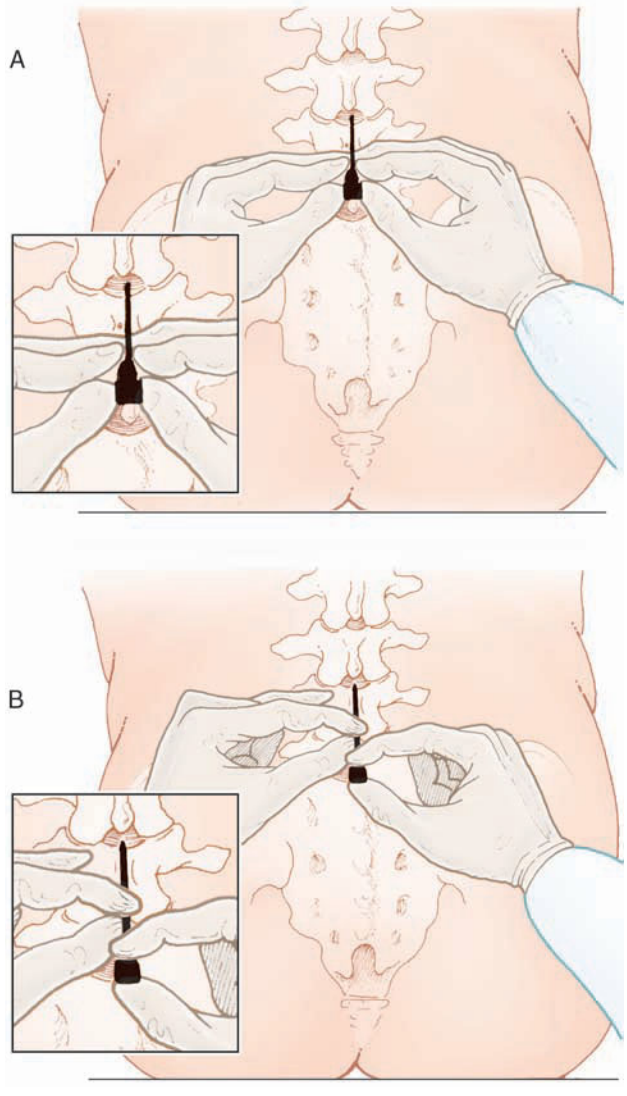


FIGURE 115-8. Two-handed techniques for spinal needle insertion. **A.** The index fingers guide the tip while the thumbs advance the needle. **B.** An alternative technique. One hand is placed at the needle tip and the other is at the base of the needle.

the spinal needle parallel to the longitudinal dural fibers to increase the chances that the fibers will be separated rather than cut by the tip of the needle.[55] This has been shown to decrease the incidence of postdural puncture headache.[56–58] The bevel should point up or down with the patient in the lateral decubitus position. Angle the needle 10° cephalad, or toward the umbilicus, and advance it slowly. The needle can be held between both index fingers and advanced with the thumbs (**Figure 115-8A**). Alternatively, it can be guided with a thumb and forefinger near the puncture site while the other hand holds the hub of the needle and advances it (**Figure 115-8B**).

Resistance will usually be felt as the needle penetrates the interspinous ligaments. Stop advancing the needle and remove the stylet frequently to check for the presence of CSF.[59] Many describe a characteristic "pop" that is felt when the needle enters the subarachnoid space. The commonly used Quincke needles often decrease or eliminate this sensation. It may also not be felt using atraumatic needles.[59] If bone is encountered, withdraw the needle to the subcutaneous tissue, confirm your landmarks, and readvance the needle in the midline. If bone is still encountered, redirect the needle slightly more cephalad and readvance it. Perform the procedure at a different level if still unsuccessful.

CSF should flow freely once the subarachnoid space is entered. The rate of CSF flow from the hub of the spinal needle may be slow. The flow rate can be increased by one of the following: ask the patient to Valsalva by gently coughing or bearing down, rotate the spinal needle 90°, or repeat the procedure with a larger bore spinal needle. Attach the stopcock and manometer directly to the needle. Alternatively, use the short extension tubing provided in most kits to connect the needle to the manometer. **Hold the hub of the needle firmly between the thumb and index finger and brace your hand against the patient's back when attaching or removing anything from the spinal needle.** This will prevent the needle from advancing or withdrawing. The stopcock handle should point posteriorly and CSF will begin to fill the manometer.

Ensure that the manometer hub remains at the level of the needle in order to get an accurate reading if using the extension tubing. Phasic changes with respirations should be noted as the manometer fills. Instruct the patient, or an assistant, to gently extend the patient's legs to decrease intraabdominal pressure and lower the reading. Normal opening pressure is 70 to 180 mmH_2O. Obtain the pressure reading once the CSF flow stops. Turn the stopcock handle toward the needle hub (or patient) to empty the contents of the manometer into the first tube for collection. To continue collection, remove the stopcock or simply remove the manometer and continue collection through the stopcock by pointing the handle toward the manometer port.

In general, 1.0 mL of CSF in each of the four tubes should be adequate to perform the CSF analysis. Collect 2 mL in each tube if cytology or antigen testing is necessary. **When the samples have been collected, carefully replace the stylet and remove the needle.**

There is disagreement regarding the use of the spinal needle stylet.[181] The literature notes an increased incidence of intraspinal epidermoid tumors after an LP if a stylet is not used. This led to the habit of leaving the stylet in place while inserting the spinal needle

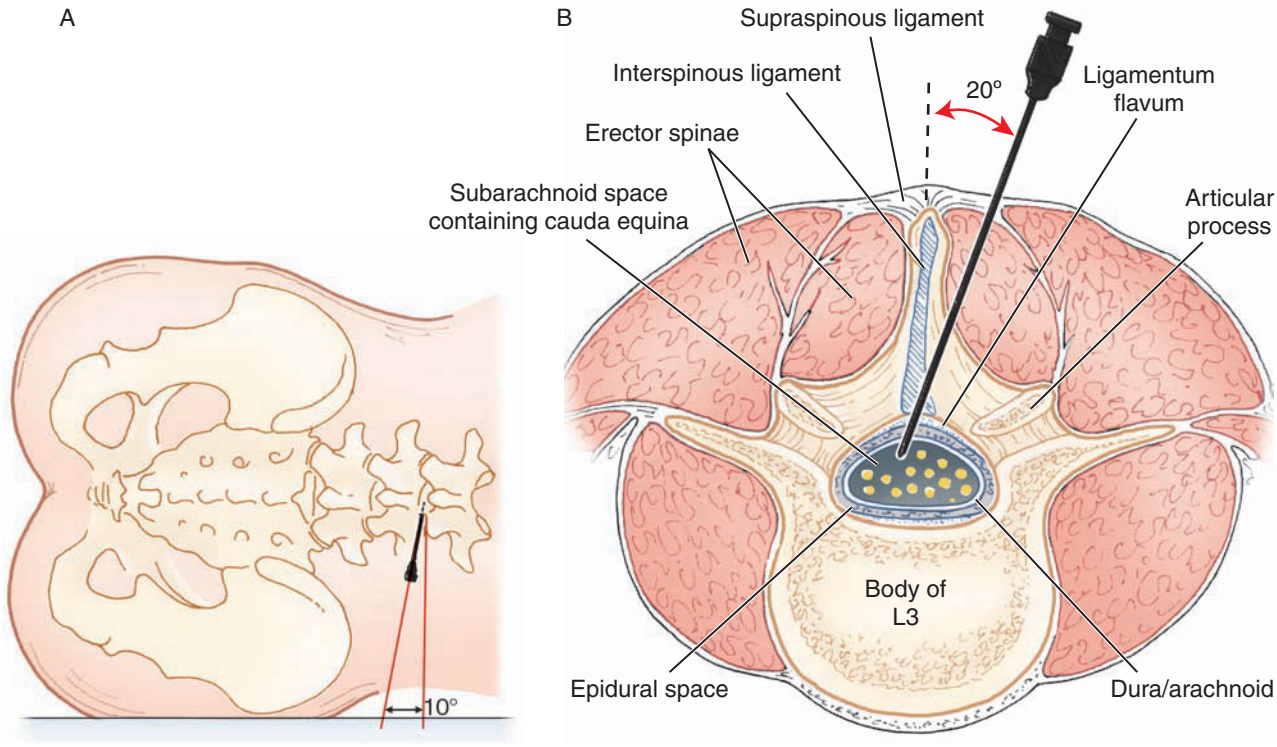


FIGURE 115-9. The lateral approach. **A.** If the patient is in the lateral decubitus position, insert the spinal needle approximately 2 cm below the midline and directed approximately 20° toward the midline, and 10° cephalad. **B.** Cross section of the spinal column showing the path of the spinal needle during the lateral approach. Notice that it avoids the calcified supraspinal and interspinal ligaments.

to prevent transferring epidermal cells into the spinal canal. Some now recommend removing the stylet after the tip of the spinal needle has been inserted past the epidermis.[46,60] This method has shown to result in a greater success rate when performing an LP.

Reinserting the stylet into the spinal needle is potentially problematic. Many will hold and stabilize the spinal needle with one hand and reinsert the stylet with the other hand. This risks a potential needlestick injury. The author inserts the stylet with one hand without using the other hand to stabilize the spinal needle. Reinserting the stylet prior to removal of the spinal needle has been shown to decrease the incidence of the post-LP symptoms of dizziness, headache, nausea, and tinnitus.[61] The method of using the stylet is left to Emergency Physician preference.

SITTING POSITION AND MIDLINE APPROACH

Place the patient sitting on the edge of the bed. Ask the patient to flex their lower back and lean forward onto some support, such as an assistant or bedside stand, in order to open the interlaminar spaces in the lumbar area. Orient the bevel of the needle laterally (to the left or right). The remainder of the procedure is the same as previously described.

LATERAL APPROACH

The lateral approach may be useful in avoiding the calcified supraspinous and interspinous ligaments often encountered in elderly patients. This approach may be performed with the patient in the lateral decubitus position or the sitting position. Though it is less commonly used than the midline approach, it is a good idea for the Emergency Physician to become familiar with this technique as an alternate approach if the midline approach has failed. This may prove easier in the patient who has had multiple previous midline LPs.

Position the patient and select an appropriate interspace. Cleanse, drape, and anesthetize the area as previously described. Insert the spinal needle 1.5 to 2.0 cm lateral to the midline. The needle can approach from either side (left or right) if the procedure is being performed in the sitting position. Approach from the inferior side if performing the LP in the lateral decubitus position (**Figure 115-9A**). Direct the needle 10° cephalad and approximately 20° to the midline. This angle will direct the needle through the erector spinae muscles and lateral to the supraspinous and interspinous ligaments. The needle will penetrate the ligamentum flavum, the dura, and then the subarachnoid space (**Figure 115-9B**). If bone is encountered, partially withdraw the needle and redirect it at the same angle toward the midline but slightly more cephalad. The remainder of the procedure is as described previously.

LP IN INFANTS AND CHILDREN

Performing an LP in an infant or child is similar to that of an adult. Place the patient in the lateral decubitus position or the sitting position. Place the neck in midflexion in the lateral decubitus position. **Severe flexion of the neck does not facilitate the procedure and can result in the lack of CSF flow or airway obstruction.**

Hypoxemia has been reported during LP in infants. The increased intraabdominal pressure caused by flexing the knees into the abdomen may lead to compression of the diaphragm, ventilation-perfusion mismatch, and hypoxemia.[62] For this reason, the sitting position or modified lateral decubitus position (hips only flexed to 90°) is preferred.[63] Preoxygenation with 100% oxygen via face mask for 2 to 5 minutes may prevent hypoxemia.[64] **Consider the use of continuous pulse oximetry in infants and young children undergoing an LP.**

Some authors advocate the use of a butterfly needle and using the tubing as a manometer to get a general idea of the opening pressure.

The use of nonstyletted needles, however, may occasionally result in the implantation of cells and a subsequent epidermoid tumor. In some low ICP syndromes, CSF may fail to flow during the procedure and gentle suction with a 1 mL syringe can be used.

Local anesthesia should be used in all patients, even in neonates. There is evidence that pain perception is present even in premature neonates.[65] The use of local anesthetic is often omitted in the neonate and young infant, possibly in fear of obscuring anatomical landmarks. Pinheiro et al. studied the success rate of LP in neonates given local anesthetic, the amount of struggling during lidocaine injection, and the amount of struggling during spinal needle insertion.[66] They found that local anesthesia did not alter the success rate of the procedure and led to a decreased amount of struggling during spinal needle insertion.

The use of a eutectic mixture of local anesthetics (EMLA) cream or similar topical anesthetic is common and effective for venipuncture in children. It also can be used successfully before LP in children and adults.[67,68] EMLA has been shown in some studies on adults to be more effective than lidocaine infiltration.[69,70] The major disadvantage of EMLA cream is that it requires application for a minimum of 30 minutes before the procedure is performed. In general, it is more effective if it stays on longer. It also does not anesthetize the deeper tissues and local infiltration is still required.

Procedural sedation is usually reserved for those children getting routine LPs for intrathecal chemotherapy. If absolutely necessary, procedural sedation can be used while performing a diagnostic LP. Procedural sedation should not be used unless the child has a normal mental status and is hemodynamically stable. The decision regarding procedural sedation must be considered on a case-by-case basis.

ULTRASOUND-GUIDED LP

For the past several decades, Anesthesiologists have been using ultrasound (US) to assist in various spinal procedures. More recently, Emergency Physicians have reported on the use of US to assist in performing an LP or to evaluate spinal anatomy.[71–75] Peterson and Abele described two patients in whom multiple attempts at landmark-guided LP were unsuccessful. US-guided LP was performed easily and was successful in each patient. The authors concluded that the technique has great potential as a time-saving tool.[73] Nomura and colleagues performed a randomized, double-blind study comparing LP using landmarks identified by palpation versus those identified by US.[75] The use of US significantly reduced the number of failures in all patients and improved the perceived ease of the procedure in obese patients. A group of Radiologists studied US guidance for LPs in children.[76] They found US superior to fluoroscopy as it allows three-dimensional guidance in real time and provides visualization of soft-tissue structures.

With the increasing availability of US machines in Emergency Departments, ultrasonography is more readily available to assist the Emergency Physician in performing many procedures including an LP.[71,72] US can visualize both superficial and deep tissue structures. Emergency Physicians who consider using US in assisting with an LP should be properly trained in the use and theory behind US before attempting to use it in the clinical setting.

There are three possible approaches to establishing the indications for the use of US to guide an LP. US guidance can be used for an LP when the traditional landmark-guided approach has failed. This approach may result in more patients having multiple attempts at an LP. US guidance can be used as the initial method in patients predicted to have a higher failure rate with landmark-guided LP. This includes patients with spinal landmarks that are difficult or impossible to palpate.[72,77,78] The landmarks are increasingly difficult to palpate in the body mass index (BMI) categories of overweight (BMI = 25 to 29.9) and obese (BMI ≥ 30) patients.[71] Under this approach, patients in whom an LP is not predicted to be difficult would have it attempted initially with the landmark palpation method, reserving US guidance for failures. The final approach uses US guidance initially for all patients, regardless of their BMI or the predicted ease of an LP.

US can be used to visualize structures and mark the point of needle insertion. It can also be used to visualize the deep soft tissue structures, allowing the Emergency Physician to estimate the depth that the needle needs to be inserted to enter the subarachnoid space.[79]

A high-frequency linear US probe is the transducer of choice. In patients with a higher BMI, the linear probe may not allow visualization to the depth required. In these cases, use a lower-frequency US probe, generally a curvilinear array. A pen or surgical skin marker is needed to mark the skin at the point of needle insertion. Surgical skin markers have the advantage of using scrub-resistant, non-smearing ink.

Both transverse and longitudinal midline images centered over the lumbar spine are utilized.[71,72] Ferre and Sweeney indicated a preference for the paramedian longitudinal view.[72] This view was felt to allow better visualization of deep soft tissue structures such as the ligamentum flavum and dura mater. In the transverse view, the spinous process causes a shadow that extends from near the top to the bottom on the monitor screen (**Figure 115-10**).[73,77] In the longitudinal view, the distal tips of the spinous processes are seen as a series of echogenic convexities (**Figure 115-11**).

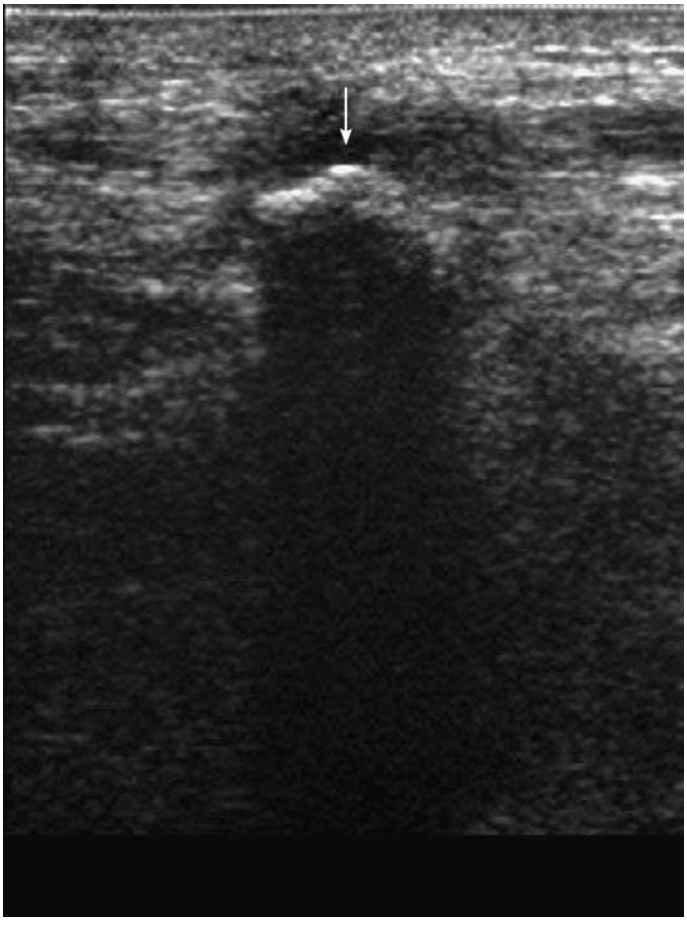


FIGURE 115-10. US image of the lumbar spine in the transverse view. The spinous process (*arrow*) causes a shadow that extends from the top to the bottom of the monitor screen.

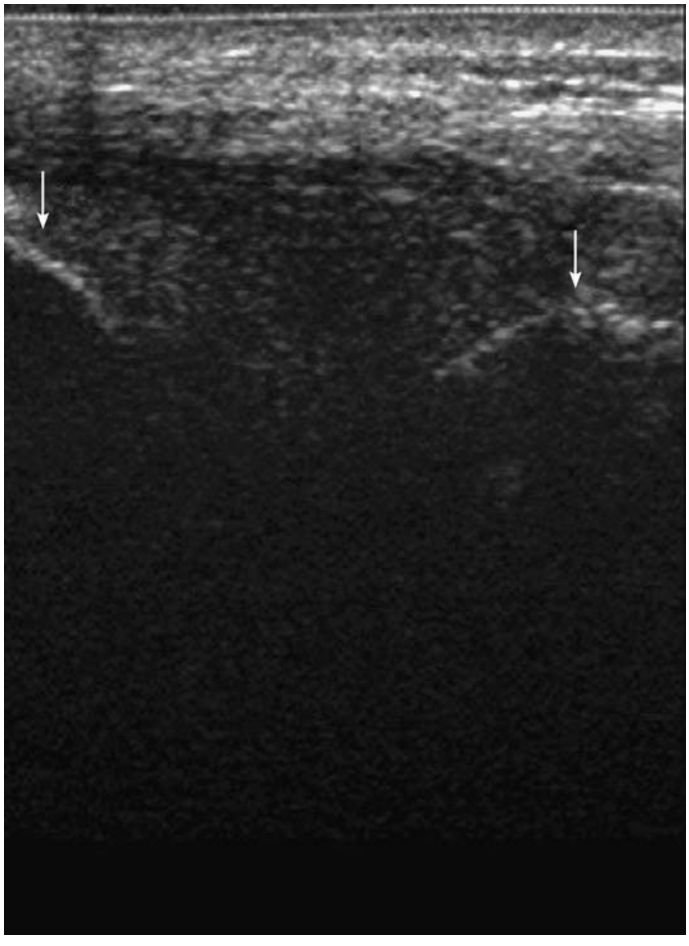


FIGURE 115-11. US image of the lumbar spine in the longitudinal view. The distal tips of the spinous processes are seen as a series of echogenic convexities (*arrows*).

Place the patient into the position they will be in during the LP, whether the lateral decubitus position or sitting upright. It is important that the patient be in the exact position, such as with spinal flexion and their knees drawn up, that will be used during the LP. **Any change in patient position between the time of the US and the LP could change the location of the landmarks and decrease the likelihood of success.**

Use US to locate the entry site of the spinal needle. Using the transverse view at the level of the iliac crests, move the US probe until the shadow caused by the spinous process is centered on the monitor screen (**Figure 115-10**). Use the skin marker to place a mark on each side of the US probe, exactly at its midpoint (**Figure 115-12**). When these two lines are connected, they will form a single line that marks the midline of the spine. Rotate the US probe 90° to a midline longitudinal view. Move the US probe until the tops of two adjacent spinous processes are seen, with the gap between them located in the center of the screen (**Figure 115-11**). Again, make two marks on the patient's skin, one on each side of the US probe at its midpoint (**Figure 115-13**). These two marks, when connected, will form a single transverse line that indicates the center of the gap between adjacent spinous processes.

Set aside the US probe. Connect the two pairs of skin marks to form two lines that intersect at a right angle (**Figure 115-14**). Their intersection marks the site of needle entry (**Figure 115-14**). Clean and prep the patient's skin and perform the LP as described previously.



FIGURE 115-12. The US probe is oriented transversely across the lumbar spine. A mark is placed on each side of the US probe's midpoint.



FIGURE 115-13. The US probe is oriented longitudinally along lumbar spine. A mark is placed on each side of the US probe's midpoint.



FIGURE 115-14. Two pairs of marks are obtained. Their intersection (purple dot) marks the spot for the spinal needle entry.

RISK FACTORS FOR TRAUMATIC OR UNSUCCESSFUL LP

There are numerous risk factors for obtaining a traumatic or unsuccessful LP.[60,80] It is important to recognize these, as traumatic or unsuccessful attempts may cause diagnostic ambiguity and lead to unnecessary antibiotic use, hospitalization, and patient discomfort. In the setting of a high likelihood of a difficult LP, steps may be taken to minimize patient discomfort and maximize the chance of a successful LP. Have the most experienced Emergency Physician perform the procedure. If there is a high likelihood of a traumatic LP and there is a high suspicion of a SAH, consider the use of US or fluoroscopic guidance. **Emergency Physicians should never delay administering antibiotics, or other potentially lifesaving treatment, because an LP may appear difficult.**

In adults, the inability to either visualize or palpate the spinous processes is predictive of a difficult LP. The inability to visualize the spinous processes is associated with an increased risk of a traumatic LP.[80] As described previously, the use of bedside US can assist in the identification of the spinous processes.

There are several risk factors in children associated with an unsuccessful or traumatic LP.[60] These include patient-related factors such as young age and inability to visualize the spinous processes, physician factors such as less experience performing LP, and procedural factors such as no local anesthetic use, patient movement, and advancement of the spinal needle with the stylet in place.[60]

Physicians have traditionally been taught to keep the stylet in place as the spinal needle is advanced into the subarachnoid space as this will avoid the introduction of epidermal cells into the subarachnoid space and the subsequent development of an epidermoid spinal canal tumor. However, the stylet-out technique has not been linked to this complication as long as the stylet is used as the needle penetrates the skin.[60] The greatest benefit of stylet removal appears to occur in young infants when the Emergency Physician is less likely to feel the spinal needle penetrate the dura. The stylet-out technique allows for continuous monitoring of penetration into the subarachnoid space by direct visualization for CSF return.

AFTERCARE

Clean the excess povidone iodine or chlorhexidine from the patient's back and apply a dressing or bandage to the puncture site. Immediately place the patient supine to decrease the potential for a postdural puncture headache (PDPH) and decrease the risk of local bleeding. Recumbent positioning will decrease the postural headache that sometimes follows LP, but it has not been shown to decrease the incidence of PDPH.

COMPLICATIONS

The use of proper technique is essential when performing an LP. It is also important that the Emergency Physician is aware of potential complications, how to recognize them, and how to manage the complications that can result from an LP. Refer to the article by Evans for a complete review of LP complications.[81] The PDPH is the most common complication and cerebral herniation is the most immediately life-threatening complication. Localized cellulitis, dural abscesses, discitis, and localized bleeding are also potential complications.

CEREBRAL HERNIATION

The most serious complication that may result from an LP is brain herniation or coning.[14] Theoretically, if a large pressure gradient exists between the cranial and lumbar compartments, herniation across the tentorial incisura or foramen magnum may occur after removal of CSF from the lumbar area. Patients with increased ICP secondary to intracranial mass lesions, cerebral edema, and acute hydrocephalus are at greater risk for cerebral herniation or coning. Herniation has also been known to occur in patients with meningitis. For many years, the role of LP in precipitating brain herniation has been the subject of debate. Several studies suggest that an LP is relatively safe in the patient with increased ICP.[82–84] However, each individual patient's risks and benefits must be considered before proceeding.

Herniation has resulted from an LP in patients with meningitis and SAH.[85–87] The actual role that an LP has in precipitating or facilitating the process of herniation is not known.[85] **Patients with decorticate or decerebrate posture, focal neurologic signs, or no response to pain should receive antibiotics but not a LP; this is true even in the face of a normal CT in suspected cases of meningitis.**[85,87] Deterioration after an LP has been reported in patients with a SAH. Fortunately, it is a rare outcome as a result of an LP. **A CT scan should be obtained before performing an LP if there is a suspicion for a SAH.**[88,89]

POSTDURAL PUNCTURE HEADACHE

The PDPH is the most common complication of an LP. It is thought to be the result of continued CSF leakage at the puncture site. The reason why this causes a headache is unclear.[90] It is thought that the lower CSF pressure induced by the leakage causes the brain to "sag." This leads to traction on pain-sensitive structures in the brain such as the dura, nerves, and bridging veins. Intracranial venous dilation and increased brain volume may lead to a neurohumoral response identified as pain.

The headache begins within 24 hours of the procedure in 65% of cases and within 48 hours in 90% of cases.[91] Delayed development of a PDPH 5 to 14 days after the procedure has been reported. The headache typically resolves within 7 days. It has been reported to last several months in rare individuals. The headache is usually located in the frontal or occipital area. It may vary in intensity. The PDPH is usually described as bilateral pressure that is throbbing or achy and improves with supine positioning. Associated symptoms may include nausea, vomiting, neck stiffness, auditory symptoms, and vestibular symptoms.[91]

The incidence of PDPH has been reported to be anywhere from 1% to 70%. The wide range is most likely due to the fact there are several identifiable risk factors that influence its development. Age and gender play a significant role.[91–93] The highest incidence occurs in 18 to 30 year olds. There seems to be a decreased incidence after the age of 60, the reason for which is unknown.

The type of needle and its diameter also influence the development of a PDPH.[34–38] This is based upon the amount of trauma and the size of the rent it makes in the dura. Smaller diameter needles and atraumatic needles lower the incidence of PDPH. However, a 22 or larger gauge needle must be used to determine the opening pressure and to collect samples in a timely fashion when performing a diagnostic LP.[94] The bevel orientation should be parallel to the longitudinal dural fibers when using a Quincke needle. This significantly reduces the incidence of PDPH.[58,95–97] The use of an atraumatic needle may also decrease the incidence of PDPH.[98,99] These needles are designed to separate rather than shear the dural fibers. Replacement of the stylet before removing the spinal needle has been shown to decrease the incidence of PDPH.[100] Repeated dural punctures have been associated with an increase in the incidence of PDPH.[101]

Other nonproven risk factors for a PDPH include psychogenic factors, the rapidity of CSF withdrawal, race, patient positioning, and hydration status. Bed rest for 24 hours was often widely

recommended. However, it has not been shown to decrease the incidence of PDPH.[102–104] Other studies have shown bed rest to increase the risk of PDPH.[105,106] Early ambulation does not increase the incidence of PDPH.[107] Dehydration was once felt to impair the patient's ability to produce CSF to compensate for the leaking CSF. Dieterich and Brandt found that the incidence of PDPH was independent of daily fluid intake.[108] They postulated that it is the closure of the dural defect and not the CSF loss that is the critical factor in the termination of the PDPH.

Supine positioning can provide some symptomatic relief for initial or mild PDPHs. A single 300 mg dose of oral caffeine may provide transient relief.[109] While offering no advantage over caffeine, an oral dose of theophylline can also be given. Administer 500 mg of intravenous caffeine, or 5 to 6 mg/kg of intravenous aminophylline, for more severe headaches. In the only study to date describing the use of intravenous caffeine, Sechzer and Abel reported an approximately 70% success rate in treating PDPH.[110] A more recent study suggests that intravenous caffeine administered prophylactically may minimize the incidence of PDPH.[111] There is some promise in the use of triptans.[112,113] The use of cosyntropin, an ACTH analog, has shown promise in the treatment of PDPH.[114,115] An occipital nerve block may resolve a PDPH.[116,117]

A more definitive but invasive treatment for the PDPH is the epidural blood patch.[118] This procedure is to be performed by an Anesthesiologist. It involves injecting 10 to 20 mL of autologous blood into the epidural space at the level of the previous LP. The blood acts to tamponade any further CSF leakage and allows healing of the dural rent. Epidural blood patching is successful in 85% of patients after one injection and about 98% of patients if a second blood patch is required.[119–121] Epidural blood patching should be performed no sooner than 24 hours after the LP. Complications of the blood patch include back pain, paresthesias, radiculopathies, and weakness; all of which are transient. A rare complication is the spinal subdural hematoma.[122] Other modalities for PDPH relief that have been used but not widely studied are epidural saline injections, dextrose injections, gelatin injections, and epidural morphine.

INFECTIONS

Local infections including cellulitis, abscesses (lumbar epidural or spinal cord), and discitis can result from an LP. Performing an LP through an area with a local infection, such as a cellulitis or an abscess, can introduce bacteria into the CSF and lead to meningitis. Contamination of the needle by airborne pathogens can also occur. **Always wear a sterile gown and gloves, a mask, and a cap while performing an LP.**[50] It is possible for the Physician's oral flora to contaminate the field and equipment, resulting in an iatrogenic meningitis.[50–52]

It was once thought that an LP could induce meningitis in a bacteremic patient. Further studies have shown this idea to be unfounded.[123–125] **Bacteremia is not a contraindication to performing an LP.** Proper cleaning and disinfecting of the skin, avoiding infected areas with the spinal needle, and using aseptic technique will minimize but not eliminate any risk of infection.

HEMORRHAGE

A traumatic LP is a common occurrence. Up to 72% of LPs have anywhere from 1 to over 50 red blood cells.[126] This is a common and usually uncomplicated occurrence in patients with a normal coagulation profile. Traumatic LPs can result in a spinal epidural or spinal subdural hematoma in patients with or without coagulation abnormalities.[127–131] Epidural hematomas most likely result from needle trauma to the internal vertebral plexus or radicular vessels (**Figure 115-15**).[126] The radicular vessels course down the length of each nerve root. It has been suggested that the bevel of the spinal

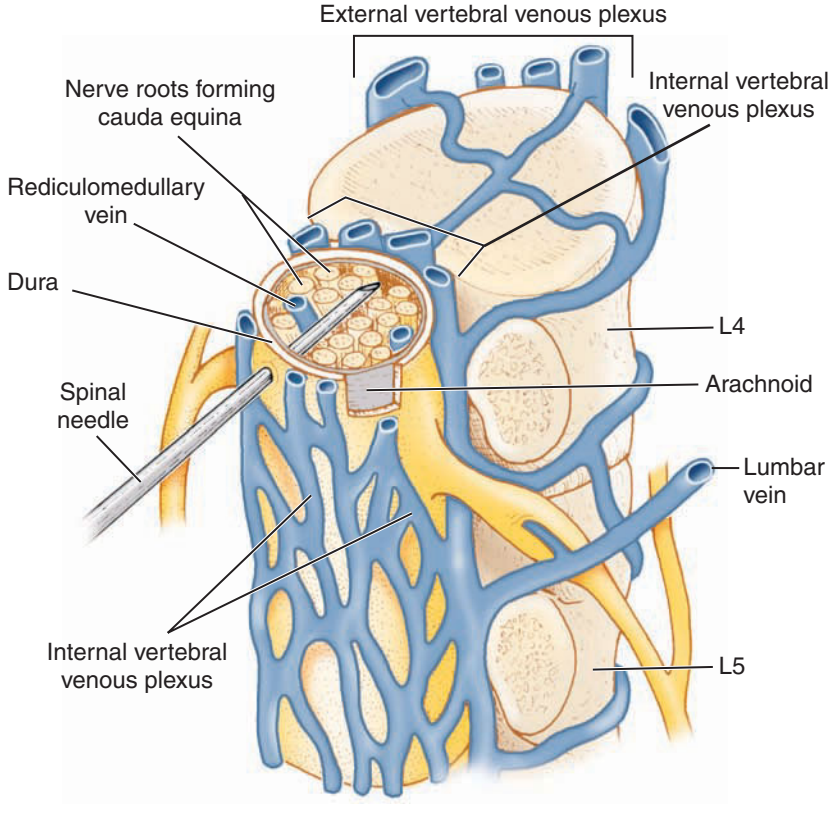


FIGURE 115-15. Illustration of the spinal cord and the potential sources of spinal needle-induced bleeding. Note, however, that the correct path of the spinal needle should usually avoid the internal vertebral venous plexus.

needle can induce trauma and bleeding to these vessels much like they produce paresthesias when touching the nerve roots. Spinal epidural hematomas, if large enough, can result in a cauda equina syndrome.[132]

Subdural or SAH is a rare but catastrophic complication in patients with or without a coagulopathy.[130] Edelson et al. recommend that the procedure be performed only if absolutely necessary in patients with a thrombocytopenia.[133] Platelets should be transfused prior to an LP in patients with platelet counts less than 20,000 or if platelet counts are dropping rapidly. The most skilled Emergency Physician should perform the LP using a 22 gauge (or smaller) needle.[133] Patients should be observed after the procedure for the development of neurological signs suggesting a hematoma. Such signs include paraplegia, lower extremity weakness, sensory deficits, or incontinence.

Another rare bleeding complication is an intracranial subdural hematoma.[134,135] This may result from the same mechanism causing a PDPH, namely the downward displacement of the brain from decreased CSF volume and persistent leakage after an LP. This may occasionally cause tearing of the bridging veins and lead to a unilateral or bilateral subdural hematoma. Suspect this diagnosis when a headache sounding like a PDPH lasts for more than a week, is no longer postural in nature, or returns after initially improving.[136]

MISCELLANEOUS COMPLICATIONS

Neuropathies involving cranial nerves III, IV, V, VI, VII, and VIII have been reported. They most likely result from traction on the nerves caused by low ICP after the LP. Typical complaints may include visual and auditory symptoms. Epidural fluid collections of CSF after an LP can be significant.[137] They usually resolve spontaneously with time but can compromise the thecal sac if large enough.

Mild low back pain is a common complaint that results from the local trauma of the needle tract. Transient dysesthesias are fairly common, resulting from spinal needle contact with the nerve roots. A spinal needle that passes beyond the subarachnoid space into the annulus fibrosis can cause disc herniation. This can also result in a discitis and vertebral collapse.[138]

Intraspinal epidermoid tumors are composed of well-differentiated stratified squamous epithelium surrounding a mass of caseous substance formed by the desquamation of epidermal tissue. They are often congenital but may result from the introduction of epidermal fragments into the spinal canal. This may occur if the stylet of the needle is not used. Spinal epidermoid tumors may present months to years after an LP.[139–142]

A dry tap is often the result of lateral displacement of the spinal needle. Maintain the spinal needle in the midline while it is being advanced. Not penetrating deep enough with the spinal needle can also result in a dry tap. This is especially true in obese patients that may require long, 7 to 10 in., spinal needles to gain access to the subarachnoid space. It has been suggested that the standard 3.5 in. spinal needle is adequate for 97% of patients.[143]

Prevent secondary injury by always inserting the stylet into the spinal needle before removing it.[61] Withdrawing the spinal needle without the stylet can result in the aspiration of a lumbar nerve root or arachnoid tissue into the epidural space. If this occurs, the patient may require a laminectomy to replace the nerve root or arachnoid tissue. The reinsertion of the stylet will also decrease the incidence of post-LP symptoms (e.g., dizziness, headache, nausea, and tinnitus).[61]

It is now common for adolescents and adults to have tattoos on their lower back. It is recommended to perform an LP in an area void of tattoo ink, at a higher or lower interspace, or nicking the skin with a needle or scalpel prior to inserting the spinal needle.[144,145] All these techniques avoid the spinal needle penetrating through the tattoo ink. The tattoo ink may contain substances that can be irritating or toxic if introduced into the spinal canal.

CSF INTERPRETATION

Proper interpretation of the CSF is an important skill for the Emergency Physician who performs the LP. **Tables 115-1** and **115-2** list the normal CSF values and the CSF values in a variety of different medical conditions.[146,147]

CSF PRESSURE

Normal CSF pressure ranges from 70 to 180 mmH_2O in adults and from 50 to 80 mmH_2O in infants and children. Note that many manometer kits use cmH_2O on the demarcations whereas results are commonly interpreted in mmH_2O. Elevated CSF pressure may be seen in bacterial meningitis, viral meningitis, brain abscesses, tuberculous meningitis, fungal meningitis, encephalitis, meningeal carcinomatosis, SAH, pseudotumor cerebri, and Guillain–Barré syndrome. It may be falsely elevated when the patient is tense or creating a lot of intraabdominal pressure by flexing their knees into the abdomen. The pressure will also be falsely elevated if the patient is in a sitting position. Although CSF pressure is not routinely recorded in infants and children (most likely because they are often crying, struggling, or difficult to hold), it should be recorded whenever possible. Low CSF pressure may be the result of a spinal root obstructing the flow of CSF into the needle or obstruction of flow from a spinal mass.

A novel device to measure pressure is the Compass LP (Mirador Biomed, Seattle, WA). This device is a single patient use and disposable unit that attaches to the spinal needle. It provides a digital readout of the CSF pressure. Further research is required before this device replaces the standard manometer.

CELL COUNTS AND DIFFERENTIAL

A variable amount of white blood cells (WBCs) may be normally present in the CSF depending upon the age of the patient.[148] Neonates may have up to 32 WBCs/mm^3 with 60% polymorphonuclear leukocytes (PMNs). Infants 4 to 8 weeks of age may

TABLE 115-1 Normal CSF Values

	Preterm infant	Term infant	Child	Adult
White blood cell count (WBC/mm^3)	9 (range 0–32) 57% PMNs	8 (range 0–22) 61% PMNs	0–7 0% PMNs	0–5 0% PMNs
Glucose (mg/dL)	24–63 (mean 50)	34–119 (mean 52)	40–80	50–80
CSF/blood glucose ratio				
Normal ratio	55%–105%	44%–128%	50%	60%–70%
Abnormal ratio	<0.5–0.6	<0.5–0.6	<0.4–0.5	<0.4–0.5
Protein (mg/dL)	65–150 (mean 115)	20–170 (mean 90)	5–40	15–45

TABLE 115-2 CSF Values in Various Neurological Conditions

Condition	Appearance	Pressure	Cell count (mm^3)	Glucose (mg/dL)	Protein (mg/dL)
Bacterial meningitis	Clear, cloudy, or purulent	Elevated	500–10,000 + cells with 90%–95% PMNs	0–40	>50
Partially treated bacterial meningitis	Possibly cloudy	Normal or elevated	1–500 cells, lymphs, or monos may predominate	Low or normal	>50 and <500
Brain abscess	Clear, cloudy, or purulent	Elevated	Possibly >100,000 cells if abscess ruptures. PMNs predominate	Normal	<200
Tuberculous meningitis	Clear, opalescent, or ground glass	Elevated	25–500 WBCs, PMNs early but usually lymphs predominate	10–40	50–500
Fungal meningitis	Clear or cloudy	Elevated	10–500 WBCs, lymphs predominate. PMNs early	<40	<600
Viral meningitis or encephalitis	Clear, may have faint opalescence	Normal or elevated	6–1000 cells, predominance of lymphs. PMNs early	Normal but may be low with herpes or mumps	<200
Acute syphilitic meningitis	Clear or turbid	Elevated	100–500 WBCs, usually lymphs	Normal or decreased	<200
Meningeal carcinomatosis	Clear or mucinous	Elevated	10–500 WBCs, lymphs predominate	<40	<500
Subarachnoid hemorrhage	Bloody, xanthochromia, clear	Elevated	1000–3.5 × 10^6 RBCs	Normal, but can be decreased in 10%–15% of cases	Increased
Multiple sclerosis	Clear	Normal	0–20 lymphocytes, >50 rare	Normal	45–75
Progressive multifocal leukoencephalopathy	Clear	Normal	<10 monos	Normal	Normal
Guillain–Barré syndrome	Clear or xanthochromic	Normal or elevated	Normal, but 10–200 WBCs, predominantly lymphs	Normal	May be as high as 1000
Pseudotumor cerebri	Clear	Elevated	Normal	Normal	Normal
Subacute sclerosing panencephalitis	Clear	Normal	Usually normal	Normal	Increased, check CSF measles titers and CSF gamma-globulin
Neuro-Behçet's syndrome	Clear	Normal or elevated	Up to 3000 WBCs, PMNs predominate	Normal	Increased

have up to 22 WBCs/mm^3. However, most sources consider anything greater than 8 to 10 WBCs/mm^3 to be abnormal.[149,150] Normal adult CSF should contain no more than 5 WBCs/mm^3 with a differential of mononuclear cells or lymphocytes. The presence of more than one PMN should be considered abnormal.

In cases of bacterial meningitis, cell counts are usually greater than 500 WBCs/mm^3 with a predominance of PMNs; though lymphocytosis can uncommonly occur.[151] The CSF will usually contain less than 1000 WBCs/mm^3 in patients with viral meningitis and have a differential of 100% lymphocytes. Early in the course of viral meningitis (the first 48 hours), 20% to 75% of patients will have a predominance of PMNs in the CSF, making it difficult to distinguish it from bacterial meningitis.[152,153] Within 8 to 12 hours, approximately 90% of patients will show a switch to a mononuclear pleocytosis on repeat LP.[154]

Normal cell counts and differentials do not always exclude meningitis. Approximately 95% of the population does not normally have any PMNs in their CSF. The presence of one PMN could represent an abnormality. One PMN may be seen in approximately 5% of normal children. Bonadio and colleagues reviewed 424 LPs of which 106 had PMNs but no pleocytosis.[155] All 106 patients had negative Gram's stains and cultures. The authors concluded that the older child without pleocytosis or abnormal CSF chemistries can be considered at very low risk for meningitis. If meningitis is suspected and the CSF is normal or has PMNs, close clinical observation and hospitalization for treatment and repeat LP should be considered until CSF culture results are negative.

A traumatic LP can often make the interpretation of the CSF difficult as peripheral WBCs can be introduced into the CSF. Clearing of the red hue of the CSF from the first to last tube suggests that the tap was traumatic. However, this is not always a reliable sign. Traditionally, the ratio of the RBCs to the WBCs in the blood is compared to the ratio in the CSF. This is based upon the assumption that when blood is introduced into the CSF, the ratio of RBCs to WBCs should stay the same. Some use a set RBC to WBC ratio of 750:1 or 500:1. This is not always accurate as a peripheral leukocytosis may often be present. By comparing the ratios, a predicted WBC count for the CSF can be obtained (predicted CSF WBC = CSF RBC × blood WBC ÷ blood RBC). The actual WBC count will then be the predicted WBC subtracted from the observed or measured WBC (actual CSF WBC = observed CSF WBC – predicted CSF WBC).

Most studies on patients with traumatic taps that did not have meningitis have shown that these formulae are often inaccurate.[156] Oftentimes, the observed CSF WBC count is less than the predicted CSF WBC count.[157] This raises concerns that in the presence of meningitis, the diagnosis could be missed. Mayefsky and Roghmann studied the use of the formula in patients that had meningitis and found that it led to many false-positive and false-negative results.[158] They investigated the value of an O:P ratio (observed CSF WBC/predicted CSF WBC) in predicting the presence of meningitis. They found that a ratio greater than 10 had a sensitivity of 88% and a specificity of 90% in predicting culture positive meningitis. They concluded, along with others, that pleocytosis in bacterial meningitis is rarely masked by a traumatic tap.[158,159] The O:P ratio of ≤0.01 can be used to identify patients with traumatic LPs that do not have meningitis.[160]

GLUCOSE

Normal values for CSF glucose are listed in **Table 115-1**. Compare the ratio of CSF glucose to a simultaneously determined blood glucose level to determine if low CSF glucose (hypoglycorrhachia) exists. The ratio is abnormal in preterm infants if it is lower than

0.5 to 0.6. A ratio of less than 0.4 to 0.5 in children and adults is abnormal. Approximately 58% of patients with bacterial meningitis will have a glucose of <40 mg/dL. The sensitivity for detecting bacterial meningitis increases to about 70% if a CSF-to-serum glucose ratio of <0.31 is used.[161] The normal steady state of 0.6 tends to decrease as serum glucose increases. Ratios of less than 0.3 should be considered abnormal in cases of severe hyperglycemia. The CSF-to-serum glucose ratio is less accurate when there are rapid changes in the serum glucose. **A low CSF-to-serum glucose ratio should always raise the concern of bacterial or fungal meningitis.** Other conditions such as tuberculous or syphilitic meningitis, meningeal carcinomatosis, or SAH can also be the etiology. Approximately 15% to 20% of patients with a SAH will have hypoglycorrhachia.[162,163] Normal CSF-to-serum glucose ratios are usually seen with aseptic meningitis, encephalitis, brain abscesses, and subdural empyemas.

PROTEIN

The normal CSF protein levels are listed in **Table 115-1**. Elevated CSF protein levels, often greater than 150 mg/dL, are seen in acute bacterial meningitis. Others causes of increased CSF protein include any type of meningitis, encephalitis, CNS tumors, SAH, demyelinating syndromes, and a traumatic LP.[164] Correct the CSF protein by subtracting 1 mg/dL of protein for each 1000 RBCs in traumatic LPs.

GRAM'S STAIN

The Gram's stain is a very reliable test when performed by properly trained individuals. In general, it is positive in identifying approximately 80% of bacterial CNS infections.[165] The probability of detecting bacteria on a Gram's stain depends upon the number of bacteria present in the CSF.[166] Approximately 25% of smears are positive with $\leq 10^3$ colony-forming units (CFU)/mL, 60% with 10^3 to 10^5 CFU/mL, and 97% with $>10^5$ CFU/mL. False negatives can result from partially treated meningitis where the sensitivity decreases to about 60%.[167] False positives can result from the use of contaminated LP trays or reagents, or the use of an unoccluded spinal needle.[168]

CSF CULTURES

CSF cultures should be obtained in all patients suspected of having meningitis. Positive cultures are assumed to be 100% specific but may only occur in 80% of patients thought to have bacterial meningitis.[169] Transport the CSF specimens to the laboratory promptly, as *H. influenza* and meningococcus will not survive storage or variations in temperature. In general, antibiotics given prior to LP can sterilize the CSF. However, depending upon the amount of bacteria in the CSF and the elapsed time from initiation of antibiotics, there is probably a window of about 2 to 3 hours where antibiotics do not affect the culture results. The percentage of positive CSF cultures decreases from 33% to 4% and Gram's stains from 41% to 7% when antibiotics are given prior to LP.[170] Blazer et al. studied the effect of full intravenous antibiotic treatment on CSF cultures by performing an initial LP and then a repeat LP in 44 to 66 hours.[171] All but one of the cultures became negative whereas the cytology and biochemistry were not affected. They concluded that partial treatment with antibiotics may alter the culture results but does not distort the other characteristics of a "bacterial" CSF.

SUBARACHNOID HEMORRHAGE

It is imperative to interpret the CSF results correctly when an LP is performed after a negative head CT to rule out the possibility of a SAH. Most sources agree that the presence of xanthochromia, which results from lysis of red blood cells, confirms the presence of intracranial bleeding.[172,173] Xanthochromia, when measured by spectrophotometry, has a sensitivity that approaches 100% when performed between 12 hours and 2 weeks from the initial SAH. Do not accept gross xanthochromia as a positive finding.[174–176] Gross xanthochromia can be a false positive. Always rely on a spectrophotometric determination of xanthochromia. Xanthochromia can develop in specimens within a few hours if the tap was traumatic.[177] One cannot rely on the finding of xanthochromia if the WBC count is >10,000 or if the analysis of CSF samples is delayed.[177]

So how should patients that present within 12 hours of their symptom onset be managed? Delaying a LP for 12 hours would require holding patients in the Emergency Department or admitting everyone who required an LP for evaluation. This presents a legitimate logistical problem. Edlow et al. suggest that patients that have a negative CT should undergo immediate LP.[178] If the CSF is persistently bloody without xanthochromia, and clinical suspicion is high, vascular imaging should be the next step.

SUMMARY

Most LPs will be performed in suspected cases of meningitis or SAH after a negative head CT. The risks of performing an LP need to be weighed against the potential benefits of diagnosing these two potentially life-threatening illnesses promptly. Knowledge of the proper indications, contraindications, technique, and interpretation of the CSF findings will undoubtedly help the Emergency Physician to minimize the complications that can be associated with the procedure. Although most complications are rare, awareness of their existence, presentation, and proper treatment is imperative.

116 Burr Holes

Eric F. Reichman

INTRODUCTION

Burr holes in the Emergency Department setting are uncommonly performed for diagnostic and therapeutic purposes. Diagnosis and treatment of increased intracranial pressure (ICP) in a timely fashion can be a lifesaving measure. Increased ICP can be the result of congenital anomalies, hemorrhage, infection, trauma, and tumors. There has been less need to make exploratory burr holes in head-injured patients since CT scanning has become widely available.

Burr holes can be lifesaving on rare occasions when the patient is worsening neurologically or has blown a pupil and CT scan is unavailable. Suspect a space-occupying lesion when there is clinical evidence of tentorial herniation or upper brain stem dysfunction. This includes pupillary dilation with a decreased or absent light reflex, progressive deterioration in the patient's level of consciousness, and/or hemiparesis including posturing (decerebrate/decorticate) or flaccidity. The placement of a temporal burr hole on the side of the mydriatic pupil to decompress an epidural or subdural hematoma can be lifesaving. Up to 70% of patients with evidence of brain stem dysfunction soon after head trauma have significant intracranial mass lesions, most of which are extra-axial blood collections.[1]

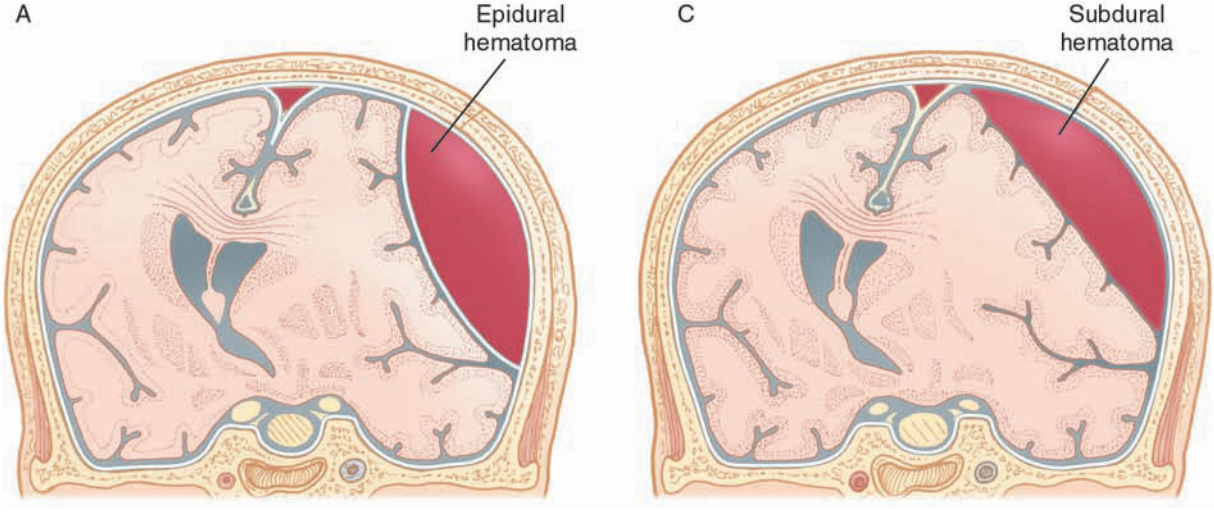
ANATOMY AND PATHOPHYSIOLOGY

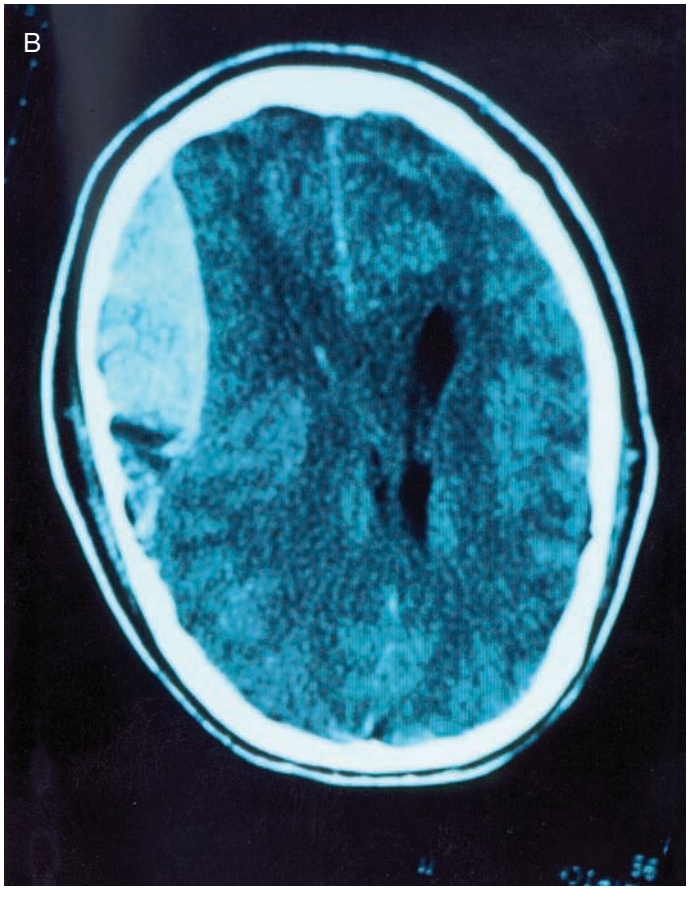
A significant proportion of patients with fatal head injuries die before reaching the hospital. The cause of death is usually a result of an expanding intracranial hemorrhage, extensive basilar skull fractures with associated injury to the venous sinuses, intracranial

carotid artery lacerations, and/or major cortical blood vessel lacerations. Skull fractures are present in up to 90% of adults who develop a traumatic intracranial hematoma. Children are less likely to suffer a skull fracture after head trauma than adults.

The middle meningeal artery is a branch of the maxillary artery and enters the cranium via the foramen spinosum. It is usually located between the periosteal and meningeal layers of the dura mater. Shortly after entering the skull, it divides into anterior and posterior branches. The larger branches of the middle meningeal artery lie within the dura and are accompanied by veins. Their superficial location in the dura produces grooves on the interior of the cranium. This location makes them vulnerable to injury, especially from fractures of the temporal bone. The bony vault of the skull is fairly thick, approximately 5 mm in thickness, and shows considerable individual and regional variation. The temporal bone, in particular the squamous temporal bone, is much thinner than other areas of the skull. This makes it more vulnerable to a fracture with an associated injury to the underlying middle meningeal vessels.

Posttraumatic epidural hematomas usually develop in the temporal or temporoparietal location as a result of an injury to the middle meningeal vessels (**Figures 116-1A & B**). More than 50% of all epidural hematomas result from an injury to the middle meningeal





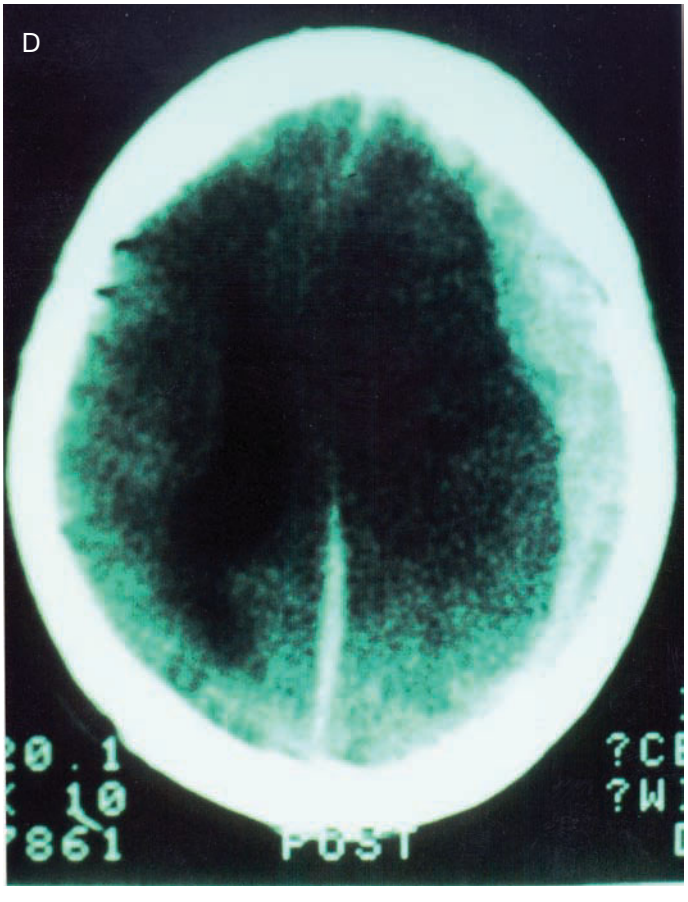


FIGURE 116-1. Hematomas requiring drainage through a burr hole. **A.** Illustration of an epidural hematoma. **B.** CT scan of an epidural hematoma. **C.** Illustration of a subdural hematoma. **D.** CT scan of a subdural hematoma.

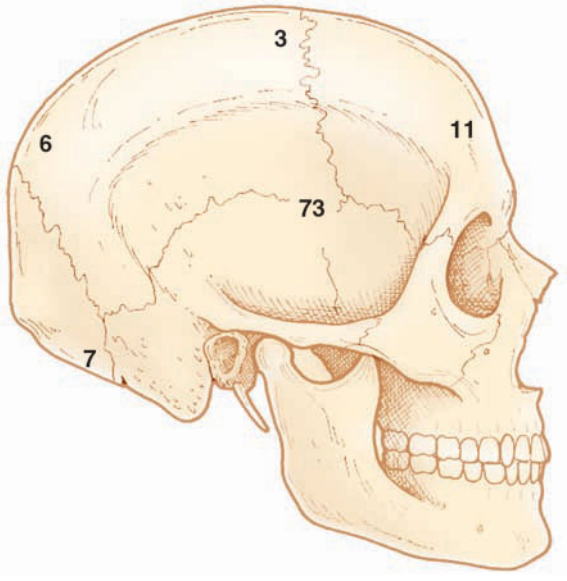


FIGURE 116-2. Percentages of epidural hematomas by anatomic location.

artery itself. Epidural hematomas occur laterally over the cerebral hemispheres with the epicenter at the pterion in approximately 70% of patients (**Figure 116-2**). The remaining epidural hematomas are distributed in the frontal area, occipitoparietal area, and the posterior fossa. Other sources of epidural hematomas include a torn venous sinus or an injury to the carotid artery before it enters the intracranial dural mater.

Subdural hematomas are collections of blood between the dura mater and the brain (**Figures 116-1C & D**). They usually are the result of blunt head trauma.[1] These result from the tearing of a bridging vein as the brain forcefully moves within the skull. The patient will present with an abnormal neurological examination minutes to hours after the acute injury.

Pupillary changes are not an early sign of an intracranial hematoma. However, when they do occur, they signify cerebral compression and transtentorial herniation. Other causes of acute pupillary changes need to be ruled out. Hematomas are usually found ipsilateral to the pupillary change in up to 85% of cases.

INDICATIONS

There are a few indications to emergently place a burr hole in the Emergency Department. These include monitoring of intracranial pressure, the emergent drainage of an intracranial hematoma, and the emergent cannulation of the ventricular system (Chapter 118). This procedure may be performed by trained Emergency Physicians if a Neurosurgeon has been consulted and is not immediately available.

CONTRAINDICATIONS

The only absolute contraindication is a patient who is coagulopathic. Otherwise, the available Emergency Physician with the most skill and experience in performing this technique should be the one to place the burr hole. Other contraindications include localized infections of the scalp and patients who are thrombocytopenic. This procedure should not be performed by those unfamiliar with the technique and its complications.

A coagulopathy or thrombocytopenia makes a burr hole dangerous to perform. The use of anticoagulants and antiplatelet agents by the patient increases their risk of hemorrhagic complications. Consider reversing these conditions by the administration of fresh frozen plasma and/or platelets prior to performing a burr hole. A mild elevation in the international normalized ratio (INR) up to 1.6 may be acceptable to place a burr hole.[3]

EQUIPMENT

- Sterile prep kit
- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Cap
- Povidone iodine or chlorhexidine solution
- Sterile drapes
- 1% or 2% lidocaine containing epinephrine
- 22 gauge needles
- 5 mL syringe
- #10 scalpel blades
- #11 scalpel blades
- #3 scalpel handle
- Bipolar cautery, optional
- Self-retaining mastoid retractors
- Hudson brace drill
- Skull perforator bits
- Conical burr bits
- Small hook
- Bone wax
- Thrombin-soaked Gelfoam
- Periosteal elevator
- Suction catheter kit
- Head covers, masks, and sterile gowns
- Ventriculostomy catheter (optional)
- Bone rongeur
- Mayo scissors
- 4-0 nylon suture
- Potts scissors

The required equipment is all contained within a prepared sterile tray that can be obtained from the Operating Room or hospital central supply (**Figure 116-3**). A completely disposable, sterile, and single patient use instrument set is also available (Spectrum Surgical Instruments Corp., Stow, Ohio). The Hudson brace drill is a handheld device (**Figure 116-4**). It has a stabilizing handle in series with a handle that rotates in circles. The distal end has a snap lock chuck that slides to allow easy insertion and removal of the bits. The bits come in a variety of shapes and sizes (**Figure 116-5**). The perforator bits have a sharp point. The tip of the perforator bit is designed to penetrate the inner table of the skull and lock without allowing it to puncture the dura or the brain (**Figure 116-6**). **However, exercise extreme caution as the bit may occasionally not lock when it penetrates the inner table of the skull.** The burr bits are rounded. They are used to enlarge the hole in the skull made by the perforator bit (**Figure 116-6**).

PATIENT PREPARATION

The patient should be fully monitored with a noninvasive blood pressure cuff, pulse oximetry, cardiac monitor, and end-tidal carbon dioxide monitor (if available). Obtain a CT scan of the head



FIGURE 116-3. The contents of the hospital-prepared burr hole tray.



FIGURE 116-5. Examples of perforator bits (left) and burr bits (right).

to determine the presence of an acute subdural or epidural hematoma, the location and extent of the hematoma, to rule out the presence of a mass, and to determine if there is any herniation. Obtain a complete blood count (hemoglobin, hematocrit, and platelet count) and a coagulation profile (PT, PTT, and INR) to ensure that the patient is not thrombocytopenic or coagulopathic. These may require reversal with the administration of fresh frozen plasma and/or platelets.

Explain the risks, benefits, and complications of the procedure to the patient and/or their representative. Obtain an informed consent. However, in the patient who is deteriorating neurologically with tentorial herniation, consciousness is usually lost and time is of the essence.

Determine the site for the skin incision and the burr hole (**Figure 116-7**). A frontal or anterior burr hole is made just anterior to the coronal suture and 3 cm lateral to the midline, approximately along the midpupillary line (**Figure 116-7A**). The coronal suture is often palpable. If not, draw a perpendicular line midway between the lateral canthus of the orbit and the external auditory meatus. The frontal burr hole can be used to drain an intracranial hematoma or to perform a ventriculostomy. The temporal burr hole is made two



FIGURE 116-4. The Hudson brace drill.

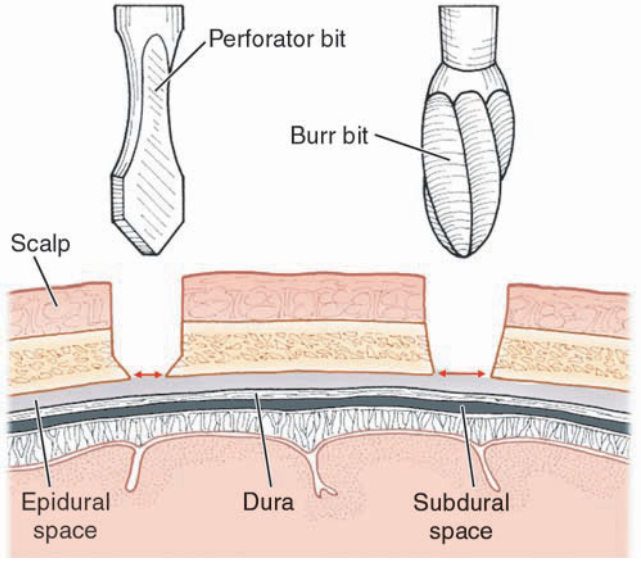


FIGURE 116-6. The perforator bit is used to make a hole through the skull and just penetrate the inner table of bone. The burr bit is used to enlarge the hole.

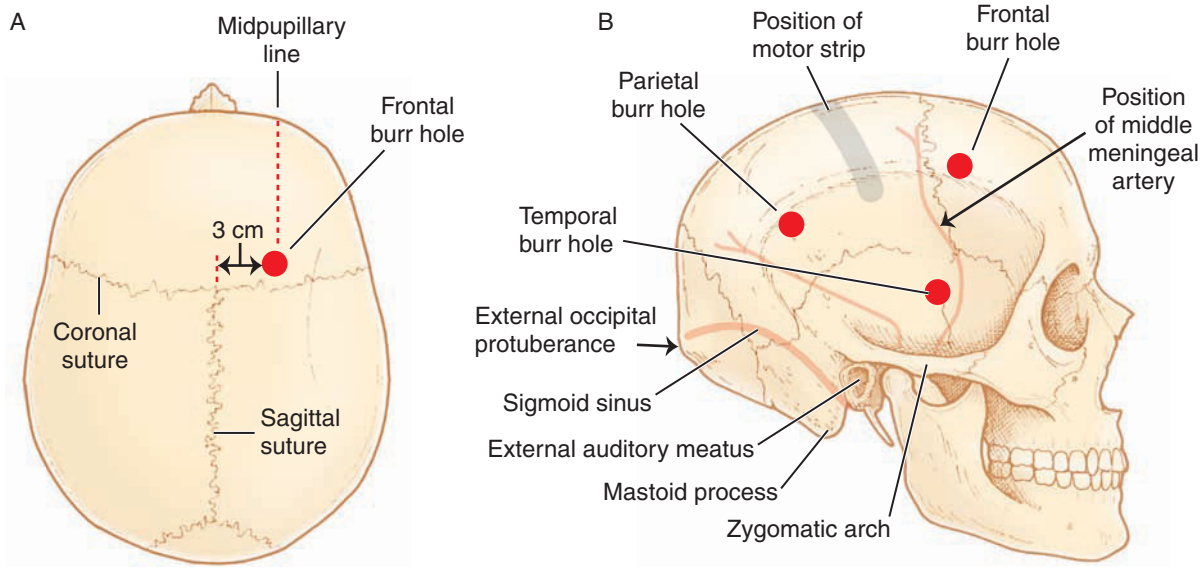


FIGURE 116-7. Typical locations for burr holes. **A.** Superior view of the skull. **B.** Lateral view of the skull.

finger breadths above the zygomatic arch and two finger breadths anterior to the external auditory meatus (**Figure 116-7B**). The parietal or posterior burr hole is made two finger breadths behind the external auditory meatus and three finger breadths above the mastoid process (**Figure 116-7B**).

Prepare the patient. Orotracheally intubate the patient to protect and secure the airway. Insert a nasogastric tube to decompress the stomach. Shave the scalp at least 5 cm in all directions from the proposed skin incision. **This procedure requires strict aseptic technique.** Clean the skin of any dirt or debris. Cleanse the skin first using 70% alcohol followed by povidone iodine or chlorhexidine solution. Allow the povidone iodine or chlorhexidine solution to dry. The Emergency Physician should don full sterile and personal protective equipment at this point. This should include sterile gloves, a sterile gown, a face mask with an eye shield or goggles, and a cap. Isolate the surgical field by using sterile drapes. Prophylactic intravenous antibiotic coverage is recommended if time permits. Administer a broad-spectrum antibiotic that covers gram-positive skin flora. Position the patient so that the proposed incision site is visible and easily accessible. Place the patient supine with a folded blanket or towel under the ipsilateral shoulder. Turn the head to the contralateral side if the cervical spine has been cleared. Instruct an assistant to hold and steady the patient's head.

TECHNIQUES

BURR HOLES

Identify the site to make the burr hole. Infiltrate 5 mL of lidocaine containing epinephrine along the proposed incision site and down to the level of the periosteum on the skull. This will result in analgesia and vasoconstriction that may aid in hemostasis. Make a 2 cm long skin incision centered about the site to make the burr hole. Carry the incision down to the bone of the skull. The incision must traverse all layers of the scalp including the skin, the subcutaneous tissue, the temporalis muscle (if present), and the periosteum. Remove the periosteum overlying the skull by scraping it away with a periosteal elevator. The periosteum will otherwise get caught in the perforator bit and make it difficult to turn. Insert a small self-retaining retractor into the wound (**Figure 116-8A**). Hemostasis can often be obtained with the use of the retractor. However, having cautery available can be helpful. Small bleeding vessels may be tied off with absorbable suture (**Figure 116-8A**).

Fit the Hudson brace drill with a perforator bit. Grasp the stabilizing handle of the Hudson brace with the nondominant hand. Grasp the rotating handle with the dominant hand. Place the tip of the perforator bit against the skull (**Figure 116-8B**). Turn the rotating handle clockwise with the dominant hand using a smooth and slow motion. **Always maintain the drill perpendicular to the skull. Maintain controlled pressure on the Hudson brace drill.** Watch as the perforator bit cuts through the skull. Frequently remove the perforator bit to examine the hole. Irrigate the area. Use suction to remove the bone fragments and the irrigation fluid. Gently probe the hole to determine if the inner table has been penetrated. Continue to drill until the inner table has been penetrated or the perforator bit locks (**Figure 116-8C**). **Do not apply too much downward pressure on the brace to prevent it from plunging into the brain. Exercise extreme caution as the bit does not always lock when the inner table is perforated.**

Remove the perforator bit from the Hudson brace drill. Place the burr bit on the Hudson brace drill. Place the burr bit into the hole in the skull. Hold the Hudson brace drill as described above. Rotate the handle clockwise to enlarge the hole in the skull (**Figure 116-8D**). Frequently remove the burr bit to examine the hole. Irrigate the area. Use suction to remove the bone fragments and the irrigation fluid. Continue to drill until the hole in the inner table is enlarged enough to accept the tip of the bone rongeur. **Do not apply too much downward pressure on the Hudson brace drill to prevent it from plunging into the brain.**

Control bleeding from the bone with bone wax and from the epidural space with Gelfoam. The clot of an epidural hematoma will be obvious as it separates the inner table of the skull from the dura. This clot will be gelatinous in consistency and drainage through a single burr hole can be difficult. Free the underlying dura from the bone edge with a Penfield elevator. **Gently insert the elevator between the inner table of the skull and the dura. Gently separate the dura from the skull.** Enlarge the burr hole in order to facilitate aspiration of the blood clot. Insert a bone

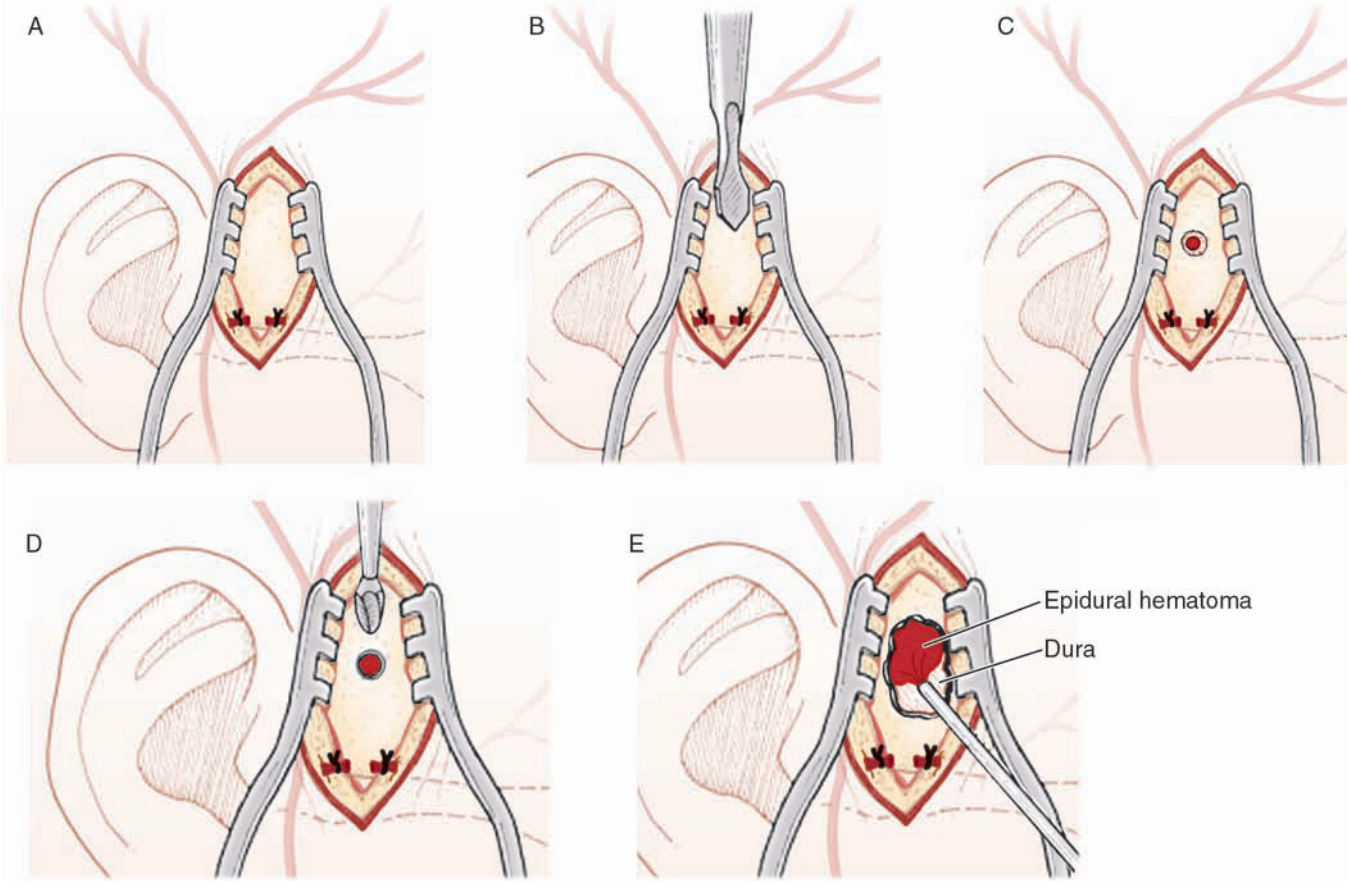


FIGURE 116-8. Drainage of an epidural hematoma. **A.** An incision is made through the skin, subcutaneous tissue, temporalis muscle, and galea aponeurotica. The incision is held open with a self-retaining retractor. **B.** A Hudson brace drill fitted with a perforator bit is used to penetrate the skull to the inner table. **C.** A hole has been made with the perforator bit. **D.** The hole is enlarged with a burr bit on the Hudson brace drill. **E.** The bone edges have been removed with a rongeur to expose the epidural hematoma. The hematoma is gently removed by suction.

rongeur into the hole. Take small bites of the skull to enlarge the hole (**Figure 116-8E**). Do not concern yourself with making the hole smooth or symmetric. The Neurosurgeon will later trim and repair the bony defect.

HEMATOMA DRAINAGE

An epidural hematoma is aspirated by gentle suction and irrigation with normal saline through an adequate bone opening (**Figure 116-8E**). **Pay close attention to the temperature of the irrigation solution. It should ideally be body temperature.** Use wall suction with a #9 or #11 French aspirator.

Epidural and subdural hemorrhages are usually clotted in the acute stages. In the event that an epidural hematoma is not identified after placement of the burr hole, inspect the underlying dura for a possible subdural hematoma. The presence of a subdural hematoma causes the dura to have a bluish hue or tinge (**Figure 116-9A**). Carefully place a traction suture in the middle of the exposed dura using 4-0 nylon (**Figure 116-9B**). Apply traction on the suture to elevate the dura. Incise the dura with a fine Mayo scissors or a #11 scalpel blade (**Figure 116-9B**). **Exercising extreme caution during the maneuver is mandatory to prevent lacerating the brain.** Open the dura in a cruciate fashion. Drain the subdural clot using suction and gentle irrigation. **At no time should any pressure be placed on the brain. Care should be taken not to irrigate with any force directly against the brain surface.**

VENTRICULOSTOMY

The burr hole can be made in order to place a ventriculostomy catheter. Make a nick in the dural with an 18 gauge needle or a #11 scalpel blade. Perform a ventriculostomy using an appropriate ventricular catheter. Anatomical landmarks suggestive for placement of the catheter within the ventricular system are to insert the catheter

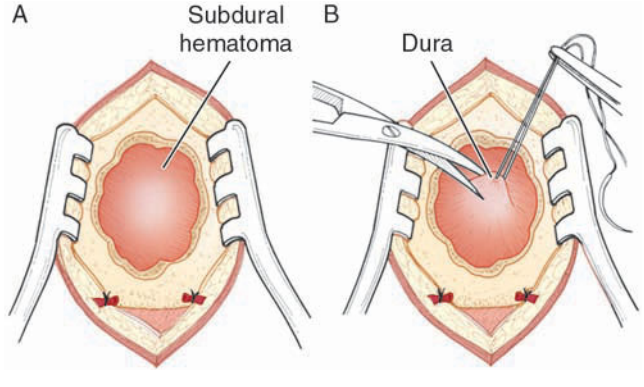


FIGURE 116-9. Drainage of a subdural hematoma. **A.** The dura is exposed and a hematoma is visible below it. **B.** Traction is placed on a suture that has been placed through the center of the exposed dura. The tented dura is carefully opened with a scissors or scalpel to expose the underlying hematoma.

perpendicular to the skull and directed toward the ipsilateral inner canthus.[2] Advance the catheter to a depth of approximately 5 to 6 cm. If unsuccessful after three attempts, place the parenchymal monitor or a subarachnoid bolt. Refer to Chapter 118 for the complete details of performing a ventriculostomy.

ASSESSMENT

Assessment and stabilization of the head injury victim prior to placement of the burr hole, during the procedure, and postprocedurally requires attention to securing the patient's airway, adequate and aggressive treatment of hemodynamic instability and shock, stabilization of the cervical and thoracolumbar spine, and concomitant treatment of any extracranial injuries. **Aggressive management of hypoxia and hypotension cannot be overemphasized. Hyperventilation in the first 24 hours after severe head injury should be avoided as it can reduce cerebral blood flow.** The assessment should include hemodynamic parameters, Glasgow Coma Score, and frequent neurological examinations. The neurological examination should include pupillary size and reaction, extraocular muscle function, and motor movements of the extremities. Intubation utilizing the rapid sequence technique often precedes burr hole placement in the patient with severe head injury. This precludes a detailed neurological examination as most patients will have received neuromuscular blockade.

Reduction in pupillary size can be appreciated postevacuation of the hematoma in patients who have had pupillary changes preceding the burr hole placement. Repeat the hemodynamic and neurological assessments often, every 5 minutes, and document these in the patient's record. Obtain a postprocedural CT scan of the head as early as possible to check the status of the hematoma. CT scanning also verifies catheter location and reduction in ventricular size in patients in which trephination has been completed for ventricular catheter placement.

AFTERCARE

Patients who have had burr hole placement because of neurological deterioration require further definitive management by a Neurosurgeon. A craniotomy is indicated for a more thorough evaluation, irrigation of the epidural or subdural space, and for hemostasis. Postprocedural CT scanning should not be performed if definitive management by a Neurosurgeon is available. It is an unnecessary waste of time and the patient should proceed directly to the Operating Room. Cranioplasty is often not completed initially after burr hole placement in order to minimize the infectious risk. Postprocedural treatment often requires airway protection with continued endotracheal intubation, adequate fluid resuscitation, management of hypoxia, management of hypotension, management of seizures, and management of any coagulopathy. Secondary injuries can evolve, even after adequate hematoma evacuation. They need to be anticipated, recognized, and treated aggressively.

A two-layer closure is recommended in the event a craniotomy is not to follow or will be delayed. The dura is usually not closed. Cover the dura with a small piece of thrombin-soaked Gelfoam. Close the galea with 3-0 absorbable suture. Close the scalp/skin with 3-0 nylon suture. Apply a dry dressing to the scalp wound. Alternatively, apply sterile saline-soaked gauze over the wound and cover this with a dry dressing.

COMPLICATIONS

Wound infections, abscesses, hemorrhage, and postoperative hematomas are major complications.[3] These can be avoided by using sterile precautions, antibiotic prophylaxis, and fine surgical technique. Other complications include plunging with the perforator bit or the burr bit resulting in a penetrating injury to the brain, cortical lacerations, cortical contusions, and seizures. Blunt or penetrating brain injuries can result in delayed stroke and hemorrhage. At times, this can be produced by a post-traumatic aneurysm or arteriovenous fistula. In the severely head-injured patient, a multitude of coagulopathic abnormalities can occur including hypercoagulable and fibrinolytic states as well as disseminated intravascular coagulation (DIC).

Significant bleeding complications can occur from this procedure.[3] Penetration of the sagittal sinus can result in significant hemorrhage and possible exsanguination. Prevent this by staying at least 2 cm from the midline and properly identifying the landmarks before drilling into the skull. Avoid lacerating the middle meningeal artery or its branches. Prevent injuries to these arteries by not drilling beyond the inner table and carefully separating the dura from the skull before using the bone rongeur. Another option is to obtain a lateral plain radiograph of the skull. Note the position of the grooves in relation to the external auditory meatus. Avoid these grooves, and thus the branches of the middle meningeal artery, when determining the exact site to place the burr hole.

SUMMARY

The prognosis for the severely head-injured patient with clinical evidence of tentorial herniation and brainstem compression is poor. Rapid evacuation of an intracranial hematoma may help to improve the outcome. Ideally, these patients are resuscitated and a CT scan of the head is completed in order to determine the presence of an intracranial hematoma. Patients may at times undergo rapid neurological deterioration prior to CT scanning or CT scanning may not be readily available. Diagnostic burr hole exploration and evacuation of an extra-axial hematoma can be a lifesaving measure. The author does not wish to suggest that exploratory surgery should replace CT scanning in the management of patients with a severe head injury. The CT scan is invaluable in assessing and identifying accurately the location of any mass lesion intracranially. Burr hole evacuation in a trauma setting should be considered only in the presence of rapid neurological deterioration with evidence of herniation and brainstem compression and the unavailability of a Neurosurgeon to perform the procedure.

117 Lateral Cervical Puncture

Eric F. Reichman

INTRODUCTION

The safest procedure to obtain cerebrospinal fluid (CSF) is lumbar puncture. However, there are situations where lumbar puncture is either contraindicated or technically not feasible. This includes infections in the lumbar area, obesity, previous spinal surgery, previous spinal fusion, a history of arachnoiditis, and the previous injection of chemotherapeutics. The usual and safe alternative method is a lateral cervical puncture under such circumstances. Cisternal puncture describes the suboccipital access to cisterna magna, a CSF containing space. It is a less frequently used procedure due to the high incidence of complications. As a result, cisternal puncture should be performed by a Neurosurgeon for patients whose CSF cannot be accessed by lumbar puncture or lateral cervical puncture.[1]

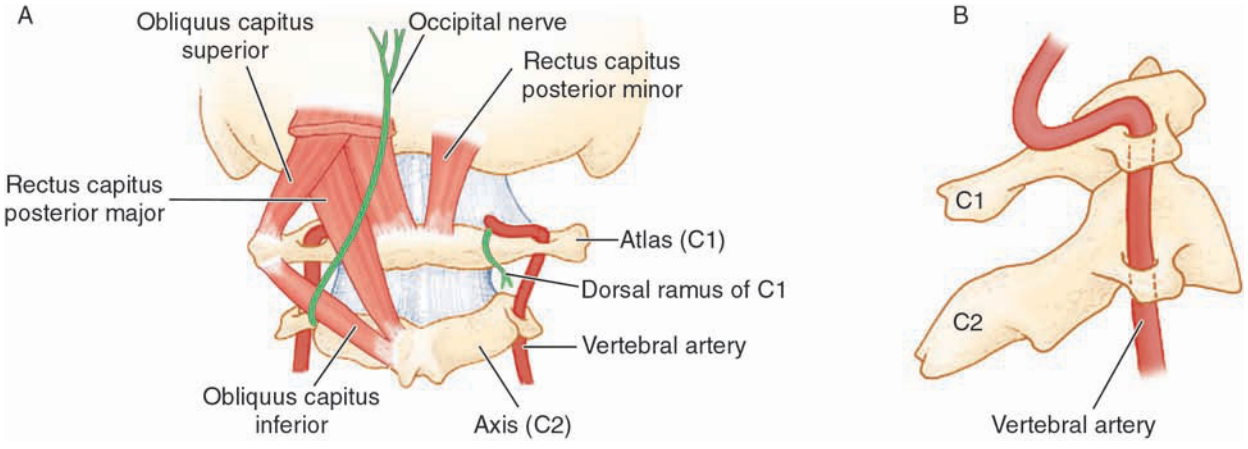


FIGURE 117-1. The course of the vertebral artery at the level of C1-C2. **A.** Posterior view. **B.** Lateral view.

Dr. Mullan introduced a method for performing a percutaneous cordotomy using a lateral cervical puncture in the early 1960s.[2] He introduced a strontium-90 needle through the C1-C2 interspace and into the subarachnoid space under fluoroscopic guidance. He then directed the needle anteriorly toward the anterior dura mater to interrupt the spinal thalamic fibers in an attempt to control intractable pain. The lateral cervical puncture is a direct derivative of this technique.

ANATOMY AND PATHOPHYSIOLOGY

Lateral cervical puncture involves the placement of a spinal needle into the C1-C2 interspace, posterior and inferior to the vertebral artery. The vertebral artery ascends through the foramina in the transverse processes of the cervical vertebrae beginning at the sixth cervical vertebra. It winds behind the lateral mass of the atlas (C1) to enter the skull through the foramen magnum (**Figure 117-1**). Inserting the needle 1 cm inferior to the tip of the mastoid process and 1 cm posterior from that point will avoid puncturing the vertebral artery (**Figure 117-2**).

The spinal canal is formed by sequential vertebral foramina and is triangular in shape. Its lateral width is greater than the anteroposterior width. The spinal canal is more spacious in the upper cervical spine allowing for safe placement of a needle into the C1-C2 interspace. The sagittal diameter of the spinal canal is approximately 23 mm at C1 and 20 mm at C2. The cross-sectional area of the cervical spinal canal is greatest at C2 and progressively decreases. It is smallest at the level of C7. The vertebral canal is narrower in women than in men. The spinal canal at the level of C1-C2 can be divided into three parts. The anterior third is occupied by the odontoid process. The middle third is occupied by the spinal cord itself. The posterior third is occupied by the subarachnoid space. The spinal cord is suspended and cushioned within the subarachnoid space by cerebral spinal fluid. The anterior boundary of the spinal canal is formed by the posterior aspect of the vertebral bodies and the intervertebral disks. The lateral wall of the spinal canal is formed by the pedicles and the intervertebral foramen. The posterior wall of the spinal canal is formed by the lamina, the ligamentum flavum, and the lateral masses or articular processes.

The morphology of the spinal cord demonstrates considerable individual variation in size and shape. The spinal cord changes in morphology throughout the entire spinal canal. It is cylindrical in shape and larger in transverse diameter than anteroposterior diameter. The spinal cord is largest from C3 to C6, obtaining approximately 13 to 14 mm in maximal transverse diameter. The average sagittal diameter of the cervical spinal cord is approximately 11 mm at C1 and 10 mm at C2.

The cervical nerve roots usually occupy the inferior one-third of the neural foramen. The first cervical spinal nerve root exits between the occiput and C1. The C2 through C7 spinal nerves exit above their corresponding numbered vertebra. Each nerve root innervates a specific dermatome and myotome, with considerable anatomical variation and overlap. The C1-C2 interspace is guarded laterally by the ligamentum flavum. The ligamentum flavum is composed of a yellow elastic tissue, the fibers of which are almost perpendicular in direction. It is attached to the lower part of the anterior surface of the lamina above and the posterior surface of the upper margin of the lamina below.

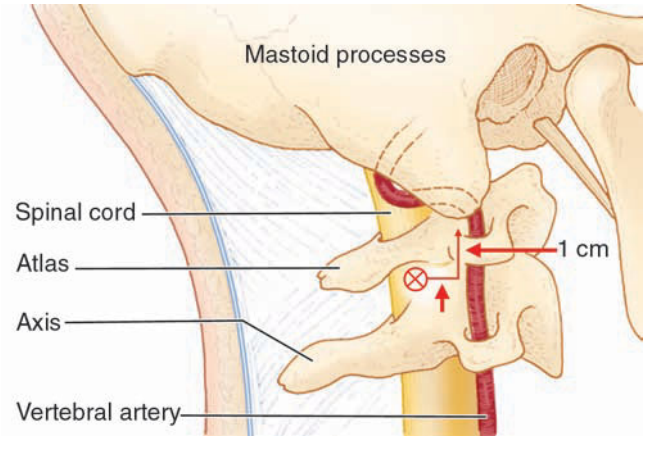


FIGURE 117-2. Anatomic landmarks for the lateral cervical puncture. The site for insertion of the needle is represented by an ⊗.

INDICATIONS

The lateral cervical puncture is an alternative method for obtaining CSF when lumbar puncture is not feasible or successful. Conditions that make lumbar puncture difficult are considered contraindications such as lumbar arachnoiditis, marked obesity, infections in the lumbar area, prior lumbar spine surgery, prior administration of lumbar intrathecal chemotherapeutics, and known congenital anomalies of the lumbar area (e.g., meningocele and myelomeningocele). The lateral cervical puncture is performed, like the lumbar

puncture, in order to obtain CSF for analysis. CSF analysis is indicated in patients suspected of having a central nervous system infection or a subarachnoid hemorrhage. Other indications for lateral cervical puncture include the installation of antineoplastic or antimicrobial agents. Lateral cervical puncture may also be necessary for the introduction of dye for radiographic studies.

CONTRAINDICATIONS

Contraindications for a lateral cervical puncture include brain abscesses, brain tumors, cervical spine anomalies and deformities, coagulopathy, increased intracranial pressure, inflammatory adhesions, local infections, posterior fossa abscesses, posterior fossa tumors, thrombocytopenia, and vertebral artery anomalies (course or location). Arnold-Chiari malformations and other congenital abnormalities in the region of the foramen magnum are also a relative contraindication. These include achondroplasia, basilar impression, Dandy-Walker malformation, Klippel–Feil syndrome, and syringomyelia.

EQUIPMENT

- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Cap
- 20 gauge spinal needle with a stylet
- 23 gauge spinal needle with a stylet
- 3 mL syringe
- 20 gauge needles
- 22 gauge needles
- Three-way stopcock
- Manometer
- Extension tubing, optional
- Four specimen vials with caps
- Gauze pads
- Sterile towels
- Fenestrated sterile drape
- Lidocaine hydrochloride, 1%
- Sterile gloves
- Povidone iodine or chlorhexidine solution
- Fluoroscopy unit, optional

All of the basic equipment can be found in commercially available lumbar puncture kits. The kit needs to be supplemented with personal protective equipment and skin antiseptic.

PATIENT PREPARATION

The patient should be fully monitored with a noninvasive blood pressure cuff, pulse oximetry, cardiac monitor, and end-tidal carbon dioxide monitor (if available). Obtain a CT scan of the head if a complete neurological examination cannot be performed or if it is abnormal in any way, the patient has a history of malignancy, of the patient may have a potential mass occupying lesion (e.g., the HIV patient). Obtain a complete blood count (hemoglobin, hematocrit, and platelet count) and a coagulation profile (PT, PTT, and INR) to ensure that the patient is not thrombocytopenic or coagulopathic. Do not delay the administration of intravenous antibiotics pending these studies if meningitis is in the differential diagnosis and the reason for the lateral cervical puncture.

Explain the procedure, its risks, and benefits to the patient and/or their representative. Explain the postprocedural care. Obtain an informed consent for the procedure. Place the patient supine on the gurney, without a pillow, and the neck as straight as possible. Limit any head rotation from the true supine position. The landmark for needle insertion is 1 cm caudal and 1 cm posterior to the tip of the mastoid process (**Figure 117-2**).

This procedure requires strict aseptic technique. Clean the skin of any dirt and debris. Swab the area with alcohol pads. Shave the area so that the mastoid tip is contained within the sterile field. The Emergency Physician should don full sterile and personal protective equipment at this point. This should include sterile gloves, a sterile gown, a face mask with an eye shield or goggles, and a cap. Apply povidone iodine or chlorhexidine solution to the skin and allow it to dry. Apply sterile towels and drapes to delineate a sterile field. Inject local anesthetic solution subcutaneously at the above identified landmark. Consider the administration of intravenous diazepam or midazolam, if not contraindicated, to relax the patient. Some patients may require the administration of procedural sedation. The aid of an assistant to hold the patient's head straight and upright is recommended.

TECHNIQUE

Maintain the patient in the supine position with absolutely no head movement. An assistant should stabilize the patient's head. Introduce a 21 or 22 gauge spinal needle perfectly horizontal, parallel to the plane of the bed, and perpendicular to the neck (**Figure 117-3**). The needle will cross a number of tissue planes including the skin, subcutaneous tissue, trapezius muscle, suboccipital muscles, and the meninges. Advance the needle slowly and in 2 to 3 mm increments. Remove the stylette frequently to check for CSF. The subarachnoid space is approximately 6 cm from the skin surface in most adults. Puncture of the dura is often felt as a "pop" or loss of resistance. Frequent checks for CSF prevent excessive penetration of the needle

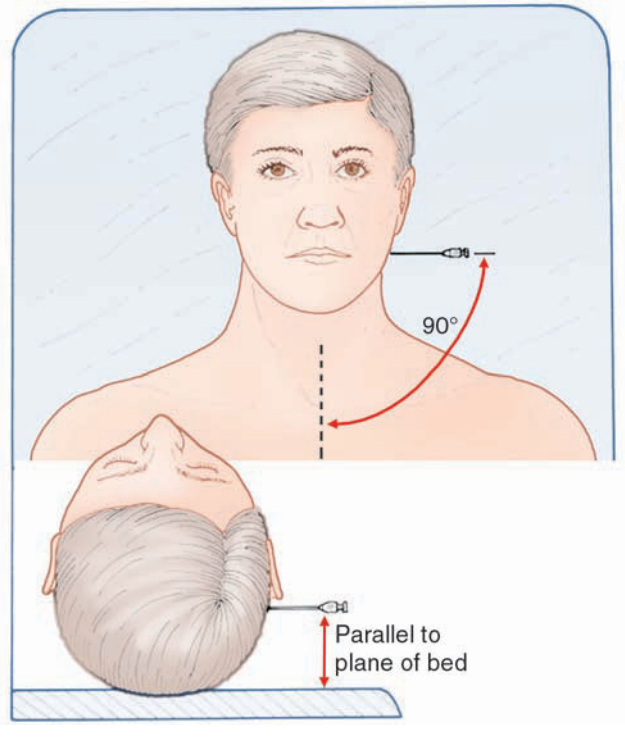


FIGURE 117-3. Proper needle trajectory for a lateral cervical puncture.

through subarachnoid space, overshooting the spinal canal, or inadvertent puncture of the spinal cord or vertebral artery. **Immediately remove the spinal needle if the patient develops any neurological symptoms.**

CSF flow through the needle signifies that the tip is within the subarachnoid space. If CSF is not draining after puncture of the dura and removal of the stylet, rotate the needle 30°. The use of a portable fluoroscopic unit can confirm the needle's trajectory and exact position. Carefully apply the three-way stopcock and manometer to the spinal needle to measure the pressure of the CSF. Carefully remove the stopcock and the manometer from the spinal needle. **Do not allow the spinal needle to move while applying and removing the stopcock and manometer. Keep in mind that the needle is not very well supported by the soft tissue as in the lumbar puncture. Hence, the needle must be supported more carefully.** Collect 1 to 2 mL of CSF in each specimen tube. Insert the stylet into the spinal needle. Remove the spinal needle and stylet as a unit. Apply a bandage to the skin puncture site.

Encountering arterial blood from the spinal needle usually indicates that it was pointing too far anteriorly and that the vertebral artery was penetrated. The venous plexus surrounding the vertebral artery may also be penetrated. Remove the spinal needle and apply manual pressure if the vertebral artery is inadvertently entered. Reattempt the procedure with the tip of the spinal needle directed slightly more posteriorly. Directing the spinal needle too far posteriorly causes it to enter the spinal musculature and miss the spinal canal. In the event that bone is encountered, meaning that either the lateral arch of C1 or C2 is encountered, redirect the spinal needle slightly rostrally or caudally and advance it into the subarachnoid space.

AFTERCARE

Maintain the patient in a supine position after the procedure. A small bandage is usually sufficient to control any soft tissue bleeding or continued CSF leakage. Postdural puncture headaches can be minimized by utilizing a small-gauged spinal needle inserted with the bevel parallel to the fibers of the dura. Resting in the supine position for 24 hours also reduces the incidence of postdural puncture headaches. Monitor the patient's neurological status. Any change in patient's baseline neurological examination requires a CT scan of the brain, posterior fossa, and occipital-cervical junction in order to rule out a herniation, epidural hematoma, or intradural hemorrhage.

Send the aspirated fluid for the appropriate laboratory analysis if an etiology other than an acute traumatic hemorrhage is suspected.[3] This can include a biochemistry analysis (glucose and protein level), cell count and differential, culture (bacterial, fungal, viral, etc.), cytology, and gram stain.

COMPLICATIONS

The complications associated with lumbar puncture are also possible during the lateral cervical puncture. Specific complications from lateral cervical puncture include penetration of the vertebral artery with subsequent hematoma formation and puncture of the spinal cord with resultant neurological deficits.[3–8] Minimize complications by utilizing a small gauge spinal needle. These complications should result in no serious consequences if unilateral and recognized.[3] Approximately 0.4% of the population has an anomalously positioned vertebral artery. There has been a single case report of a death from a subdural hematoma due to puncture of this vessel.[4] A nerve root may be irritated with passage of the needle resulting in local pain or possibly a headache. Other complications include infection, herniation syndromes, neck pain, and headache. The incidence of postdural puncture headache is less with the lateral cervical puncture than with a lumbar puncture. Refer to Chapter 115 for the complete details regarding the complications associated with a lumbar puncture.

SUMMARY

A lumbar puncture is still the preferred technique to obtain cerebrospinal fluid for analysis as well as for injection of contrast material. The lateral cervical puncture is a safe alternative method. One can avoid the complications of puncturing the vertebral artery or the spinal cord by observing maximum attention to detail. The lateral cervical puncture can be performed at the bedside. However, the availability of a portable fluoroscopy unit can facilitate the procedure.

118 Ventriculostomy

Eric F. Reichman

INTRODUCTION

Performing an emergent ventriculostomy may be lifesaving when faced with a patient who is deteriorating rapidly from a neurologic perspective and all other therapeutic options have been employed.[1] This chapter will discuss some of the situations when this procedure may be considered, other therapeutic options, and an explanation of how to perform an emergent ventriculostomy.

ANATOMY AND PATHOPHYSIOLOGY

The cranium is a fixed space after infancy that has little capacity for added volume or mass. Pathologic conditions such as tumors, intracranial hemorrhage, infection, massive cerebral infarctions, and edema can exert direct pressure on the brain or interrupt flow of the cerebrospinal fluid (CSF). These processes can all result in fluid accumulation and increased intracranial pressure (ICP).

The patient with increased ICP may display the classic clinical signs of headache, vomiting, and papilledema.[1] Vomiting is particularly associated with acute increases in ICP. Other signs include an abducens nerve palsy (cranial nerve VI) that causes diplopia, decreased consciousness, and an elevated blood pressure with bradycardia (Cushing's phenomenon). An increase in ICP may eventually progress to brain herniation.

Herniation occurs when there exists a force in part of the brain great enough to push other parts of the brain into different compartments. The cranial contents are divided into compartments by invaginations of the dura mater (**Figure 118-1**).[2] The supratentorial space is separated from the infratentorial space by the tentorium cerebelli. The right and left hemispheres are separated by the falx cerebri.

When a unilateral supratentorial mass exerts enough force, the ipsilateral cerebral hemisphere is pushed medially toward the opposite hemisphere (**Figure 118-2A**). The medial aspect of the temporal lobe is pushed down toward the brainstem and over the edge of the tentorium cerebelli (**Figure 118-2B**). This process is known as tentorial herniation. Symptoms of tentorial herniation include a worsening of any headache with vomiting, progressively decreasing consciousness, anisocoria, hemiparesis, and Parinaud's syndrome (an upward gaze paresis). Compression of the oculomotor nerve results in a sluggish and dilated pupil, usually on the same side as

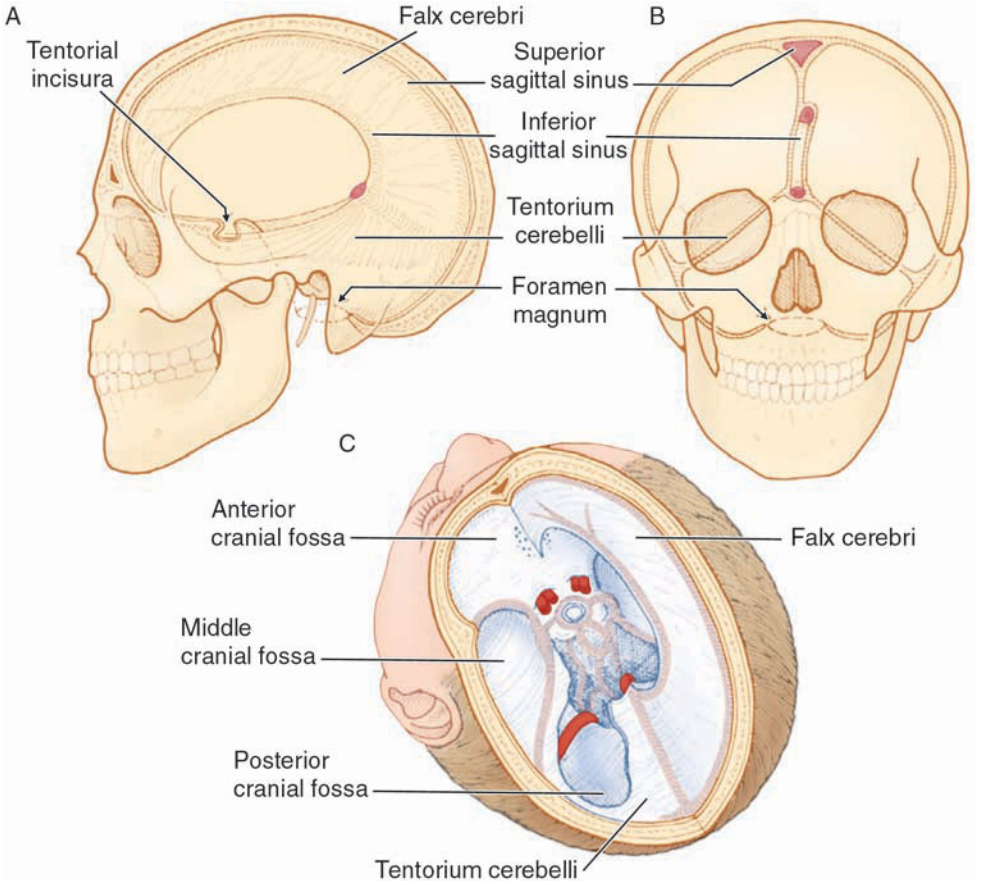


FIGURE 118-1. The falx cerebri and tentorium cerebelli divide the skull into compartments. **A.** Sagittal view. **B.** Coronal view. **C.** Top of the skull removed with a section of tentorium cerebelli also removed.

the mass lesion. A progression to a fixed and dilated pupil, with decerebrate rigidity (extensor posturing), is an ominous sign of increased ICP.

Mass effect in the infratentorial compartment of the skull may produce downward pressure of the cerebellum into the foramen magnum (**Figure 118-3A**) or upward pressure of the midbrain into the supratentorial compartment (**Figure 118-3B**), the former being more common. The downward pressure is known as tonsillar or cerebellar herniation (**Figure 118-3A**) and the terminal events surrounding this condition may occur more urgently and fatally than a supratentorial herniation. For example, an acute respiratory arrest may occur from compression of the medulla. Other important signs of tonsillar herniation include profuse vomiting, irregular respirations (ataxic breathing), neck pain, and neck stiffness. The patient may not necessarily lose consciousness or have pupillary changes prior to the terminal events of tonsillar herniation. Upward herniation forces the cerebellum and upper brainstem through the tentorial notch (**Figure 118-3B**). The patient is usually obtunded or comatose with small or anisocoric pupils that may, at first, be reactive. There may be an associated paresis of the extremities that progresses to decorticate posturing.

Any patient with these potentially life-threatening neurologic findings should be considered unstable and worked up accordingly. An emergent head CT scan, if available, is the diagnostic test

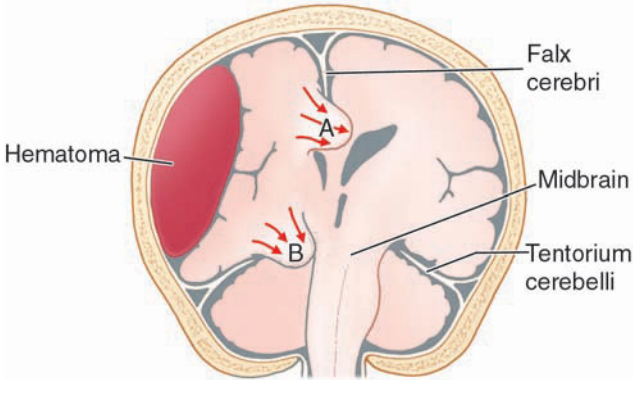


FIGURE 118-2. Supratentorial herniation of the brain. **A.** Tentorial herniation. **B.** Subfalcial herniation.

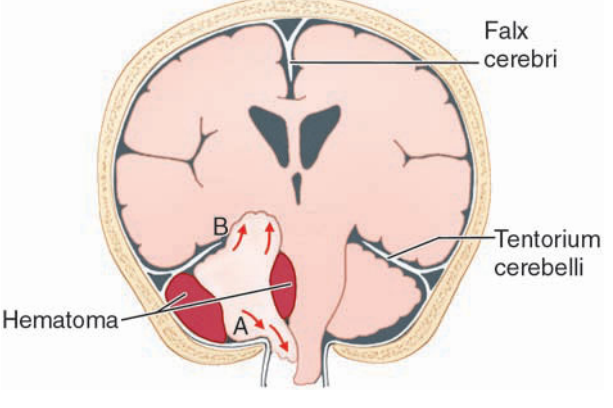


FIGURE 118-3. Infratentorial herniation of the brain. **A.** Downward tonsillar herniation through the foramen magnum. **B.** Upward herniation into the supratentorial compartment.

of choice after the patient's airway, breathing, and circulation have been stabilized. Signs of herniation on the head CT include an anterior midline shift with brain tissue from one side pushed under the falx and into the opposite side of the brain (subfalcial herniation; **Figure 118-2A**). Other signs include generalized cerebral edema with effacement of the sulci, the ventricles, the basilar cisterns, and the fourth ventricle.

There are several clinical interventions that should be implemented immediately once increased ICP, hydrocephalus, or herniation is suspected and the patient's condition is declining. The airway must be stabilized and rapid-sequence intubation is the procedure of choice. Pretreatment with lidocaine is useful in diminishing the elevation in ICP that occurs during direct laryngoscopy. Thiopental, etomidate, and propofol are the induction agents of choice as they decrease the ICP.

Neuromuscular blockade is accomplished with succinylcholine after administering a defasciculating dose of a nondepolarizing neuromuscular blocking agent. Paralytics may only be necessary for a brief period during intubation. **It is preferable to avoid paralysis for any length of time when the patient's neurologic status needs to be followed closely and any changes readily identified.** However, the need to follow the patient's neurologic course should be balanced by the need to reduce elevated ICP that may be accomplished, in part, with sedatives and paralytics. The potential for succinylcholine increasing ICP is most prevalent in patients with neoplasms of the central nervous system and may not be significant for acute trauma or bleeds.[3] Maintain the patient's oxygen saturation at 100%. Elevate the head of the bed to 30°. Place the patient in the reverse Trendelenburg position if a cervical spine injury is suspected.

It is desirable for the mean arterial pressure to be 90 mmHg or higher in order to maintain an adequate cerebral perfusion pressure and diminish the risk of cerebral ischemia. The commonly employed modalities of hyperventilation and osmotic diuresis are still used in the acutely deteriorating patient but their value is limited because of the ischemic and metabolic complications related to their use. Reducing the pCO_2 to 25 mmHg via hyperventilation can reduce the ICP in the acute resuscitation phase. The pCO_2 should not be maintained below 35 mmHg during the immediate postresuscitation period. The use of osmotic diuretics, such as mannitol, can also reduce ICP quickly. Unfortunately, any extended duration of use of osmotic diuretics places the patient at an increased risk for cerebral ischemia. Other methods to consider include the use of dexamethasone in patients with edema surrounding a neoplastic mass or abscess. Pentobarbital can be used to induce a coma and reduce the ICP, but it can also cause hypotension. An ICP monitoring device must be put into place since the ability to do sequential neurological checks is lost.

INDICATIONS

It is preferable to treat an identifiable pathologic process as soon as possible. This usually requires intervention by a Neurosurgeon. The Neurosurgeon may be able to take the patient to the Operating Room to place an indwelling ventricular shunt system in an expedited fashion. The ICP can be monitored and reduced by draining CSF via a ventriculostomy in the Emergency Department if the patient continues to deteriorate and a definitive procedure cannot be immediately arranged.

The primary indication for a ventriculostomy is cerebral herniation unresponsive to less invasive management methods. A ventriculostomy can also be performed to drain CSF to treat hydrocephalus, decrease ICP from any cause, measure ICP, introduce contrast for radiographic studies, or to collect CSF from the ventricular system.[4]

CONTRAINDICATIONS

Performing a ventriculostomy could precipitate or worsen herniation and hasten the patient's mortality if an infratentorial mass has been identified and it appears to be inducing upward pressure into the supratentorial compartment. A coagulopathy or thrombocytopenia makes a ventriculostomy dangerous to perform. The use of anticoagulants and antiplatelet agents by the patient increases their risk of hemorrhagic complications. Consider reversing these conditions by the administration of fresh frozen plasma and/or platelets prior to performing a ventriculostomy. A mild elevation in the international normalized ratio (INR) up to 1.6 may be acceptable to place a ventriculostomy.[5]

EQUIPMENT

- Skin razor
- Skin prep kit
- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Cap
- Povidone iodine or chlorhexidine solution
- Skin marker
- Ventricular catheter with stylet
- Drainage tubing and collection system
- Measuring implement
- Scalpel handle
- #15 scalpel blade
- 10 mL syringe
- 25 gauge needle
- Lidocaine with epinephrine, 1%
- Self-retaining retractor
- Twist drill with a ¼ in. bit
- Sterile towels
- Bipolar cautery
- Needle driver
- 3-0 nylon suture
- Suction source
- Suction tubing
- Suction catheters
- Headlight, optional
- Curette, optional
- Three-way stopcock, optional

It is most useful to have either a commercially available ventriculostomy kit or assemble one to have available in the resuscitation area. Complete, disposable, and single-patient use kits are convenient and cost-effective (**Figure 118-4**).

PATIENT PREPARATION

The patient should be fully monitored with a noninvasive blood pressure cuff, pulse oximetry, cardiac monitor, and end-tidal carbon dioxide monitor (if available). Obtain a CT scan of the head to determine the presence of an acute subdural or epidural hematoma, the location and extent of the hematoma, to rule out the presence of a mass, and to determine if there is any herniation. Obtain a complete blood count (hemoglobin, hematocrit, and platelet count) and



FIGURE 118-4. An example of the contents of a commercially available ventriculostomy kit.

a coagulation profile (PT, PTT, and INR) to ensure that the patient is not thrombocytopenic or coagulopathic. These may require reversal with the administration of fresh frozen plasma and/or platelets.

This procedure is often performed emergently. Explain the procedure, its risks, and benefits to the patient and/or their representative. If it will not unduly delay the treatment, obtain an informed consent to perform the procedure.

This procedure requires strict aseptic technique. Place the patient supine on a gurney with the head elevated 30°. Identify the burr hole entry site. This is located 3 cm to the right of midline and 10 cm behind the glabella in the midpupillary line or 1 cm anterior to the coronal suture in the midpupillary line (**Figure 118-5**). Shave the right side of the head, the nondominant side in most people, for 4 to 5 cm surrounding the burr hole entry point. The hair from the entire frontal area back to the ear may be shaved, but it is probably unnecessary to do so. Clean the scalp of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. The Emergency Physician should don full sterile and personal protective equipment at this point. This should include sterile gloves, a sterile gown, a face mask with an eye shield or goggles, and a cap. Denote the landmark on the skin with a sterile skin marker. Apply sterile drapes to the head so that the medial canthus of the right eye can be visualized. Note the premade markings on the ventricular catheter or mark 4, 5, and 7 cm on the catheter prior to its insertion.

Consider the administration of prophylactic intravenous broad spectrum antibiotics immediately prior to the procedure. The usual infecting organisms are *Staphylococcus epidermidis* and *Staphylococcus aureus.* Appropriate antibiotic coverage includes third-generation cephalosporins and penicillinase-resistant penicillins.

TECHNIQUE

Infiltrate the marked area with 3 to 5 mL of lidocaine with epinephrine. Make a 1 to 2 cm incision with a #15 scalpel blade. Carry the incision from the skin surface down to and through the periosteum of the skull. Tie off or cauterize any bleeding vessels. Insert the self-retaining retractor into the incision to provide adequate exposure.

Prepare the hand drill. Choose the appropriate drill bit and insert it into the drill. Adjust the safety stop on the drill bit to the estimated skull thickness. Secure the safety stop on the drill bit firmly with an Allen wrench. Carefully and slowly drill through the outer and inner tables of the skull. **Take care not to penetrate the dura. Do not apply too much force against the drill to prevent plunging the drill bit into the brain. Stop drilling when a loss of resistance is felt.** Flush the hole with warm sterile saline to remove any debris. Carefully make an opening in the dura with an 18 gauge needle or a #11 scalpel blade.

A simple ventricular catheter or a fiberoptic catheter with a screw-in mechanism should be available. Apply gentle pressure while inserting the catheter into the brain matter and aiming for the medial canthus of the ipsilateral eye (**Figure 118-5A**). A loss of resistance or a "give" will often be felt as the catheter enters the ventricle. There should be a return of CSF at a depth of 4 to 5 cm of catheter penetration. Withdraw the stylet and advance the catheter 1 cm farther. **Do not insert the catheter more than 7 cm deep.**

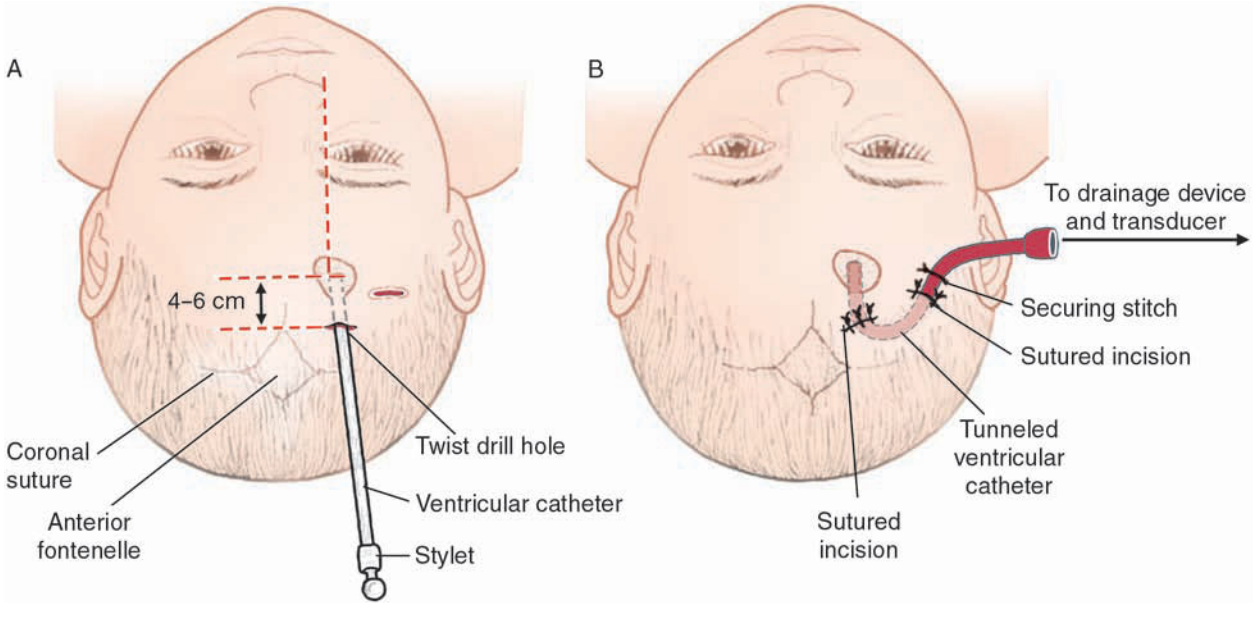


FIGURE 118-5. Placement of a ventriculostomy catheter. **A.** Insertion of the ventricular catheter. **B.** The catheter is tunneled and the skin closed.

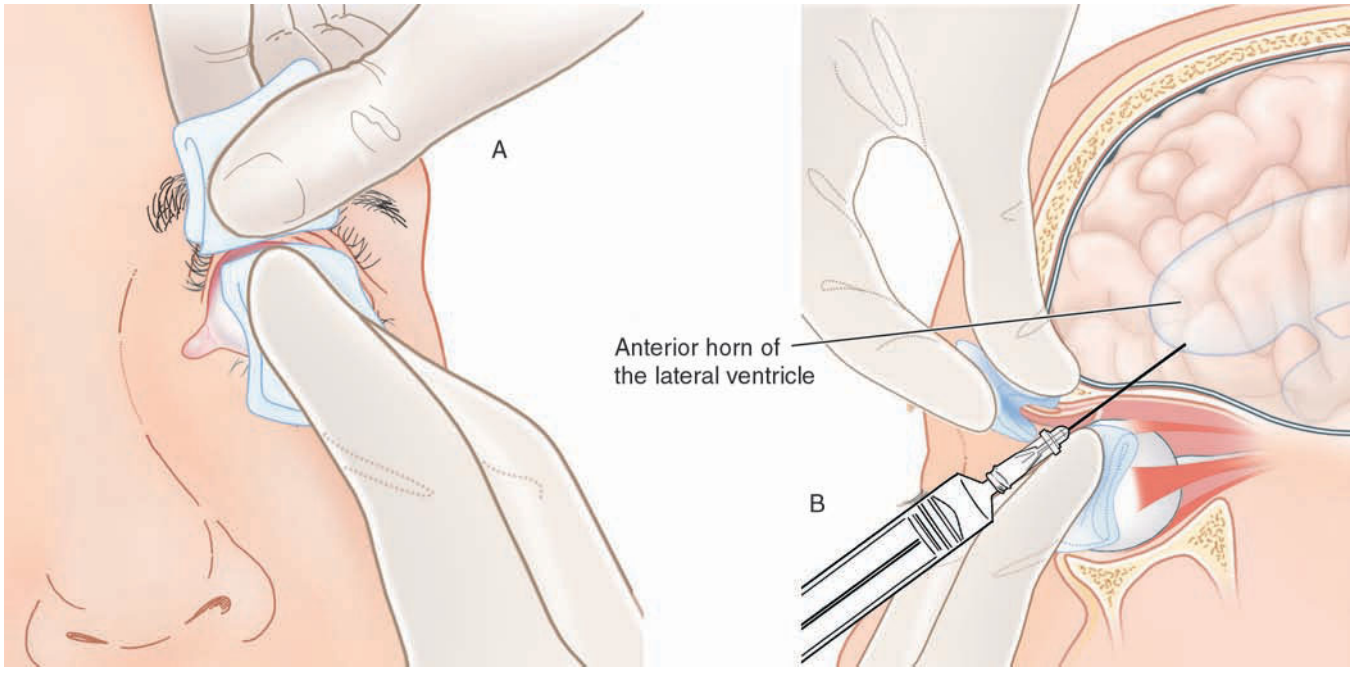


FIGURE 118-6. Transorbital ventricular decompression. **A.** The upper eyelid is retracted and the globe is displaced downward. **B.** Insertion of the needle.

If no CSF is obtained, withdraw the catheter and reinsert it while aiming slightly more medially and posteriorly, as the position of the ventricles may be distorted by the underlying pathologic process. Attach the pressure transducer to measure ICP.

ALTERNATIVE TECHNIQUE

The gathering of equipment, making the burr hole, and the insertion of the ventriculostomy catheter can take significant time and experience. The required equipment may not be readily available. An easier, quicker, and simpler technique is to perform a transorbital decompression.[9,10] This technique is adapted from the old frontal lobotomy of years ago. Clean and prep the skin of the eyelids and periorbital area. Moisten sterile gauze with sterile saline. Instruct an assistant to grasp the upper eyelid with a piece of saline-moistened gauze. Instruct the assistant to retract the upper eyelid outward then upward and maintain this position (**Figure 118-6A**). Grasp a piece of saline-moistened gauze in the nondominant hand. Apply this to the sclera at the 12 o'clock position and displace the globe downward (**Figures 118-6A & B**). **Be sure to not place the gauze on the cornea as this can cause a significant corneal abrasion.** Apply an 18 gauge, 1.5 to 2.5 in. angiocatheter or spinal needle on a syringe. Insert the needle through the orbital roof, 1 cm posterior to the superciliary arch (**Figure 118-6B**). Aim the needle toward the coronal suture at the midline or vertex of the skull. Advance the needle approximately 3 cm so that its tip enters the anterior horn of the lateral ventricle. Gently aspirate after the needle is inserted to a depth of 3 cm and CSF is aspirated. If using an angiocatheter, the soft plastic catheter can be secured to the orbital roof with a suture and the ICP monitored through the pressure transducer.

AFTERCARE

It is desirable to tunnel the drainage tubing subcutaneously for several centimeters to reduce the risk of infection (**Figure 118-5B**).[1,6] Suture the ventricular catheter and tubing to the skin so that it remains in place (**Figure 118-5B**). Close the skin around the ventricular catheter. If a pressure transducer is being utilized, obtain a measurement prior to allowing any quantity of CSF to drain. Attach the sterile fluid collection system. If a simple drainage bag is being used, ensure that it is kept at the level of the ventricle to avoid overdrainage. **Frequently recheck and document the patient's neurologic status.** It is useful to send a baseline sample of CSF for culture, cell count, chemistry, and cytology (if applicable) after ventriculostomy placement.

PEDIATRIC CONSIDERATIONS

Young children have an open anterior fontanelle. This large area devoid of bone is ideal for the introduction of a needle to drain CSF from the ventricular system. This procedure may be required in cases of acute patient decompensation due to an acute nonobstructing hydrocephalus (e.g., meningitis), an acute obstructing hydrocephalus (e.g., brain abscess, brain tumor, epidural hematoma, intracranial hemorrhage, or subdural hematoma), or the acute decompensation of a chronic hydrocephalus (e.g., aqueductal stenosis, posterior fossa tumors, or other congenital malformations).[4]

The ventriculostomy procedure in a young child is similar to that in an older child, adolescent, and adult with a few exceptions. A burr hole is not required as the anterior fontanelle allows an easy access point. Use an 18 or 20 gauge, 1.5 in. long angiocatheter instead of the spinal needle. The procedure is similar to inserting an intravenous catheter. Insert the angiocatheter perpendicular to the skin and at the most lateral aspect of the anterior fontanelle or the coronal suture to avoid the midline sagittal sinus. Stop advancing the angiocatheter when CSF flows from the hub of the needle. Slightly advance the plastic catheter while withdrawing the needle. Apply the pressure transducer to the hub of the catheter to measure ICP. Remove enough CSF to decrease the ICP to an appropriate level or until the signs and symptoms of herniation are reversed.[6,7] Remove the catheter or secure it to the scalp with suture. The secured catheter can be capped or left attached to transducer to continue to monitor ICP.

COMPLICATIONS

The most common complication of placement of an emergent ventriculostomy is a CSF infection. The risk of infection increases the longer the drain is left in place. Fortunately, infections are rare for those in place for fewer than 4 days. Tunneling the drainage tubing, adhering to strict aseptic technique, and administering prophylactic antibiotics can reduce the incidence of infection.

Ventricular puncture can result in an acute bleed in the subdural, intraparenchymal, or ventricular spaces. This can occur from direct trauma to the vascular system or excessive CSF drainage that shrinks the brain and tears the bridging vessels to the subdural space. It is estimated that the risk of hemorrhage associated with a ventriculostomy is 5.7%, with 1% of ventriculostomy patients having a clinical significant hemorrhage.[8] **An emergent head CT is indicated if the patient's condition deteriorates further after ventriculostomy placement. Patients should always be tested for normal blood clotting function prior to performing a ventriculostomy.**

The most feared complication of this procedure is plunging with the drill bit uncontrollably into the brain substance. This procedure should not be performed by those unfamiliar and untrained in the technique. Apply the minimal amount of pressure to the drill so that the bit penetrates the bone. **Never use a hand twist drill without the safety stop.**

SUMMARY

The traumatically head-injured patient or the patient with chronic hydrocephalus who presents with a rapidly deteriorating neurologic status may have increased ICP or be in the process of brain herniation. There are several tools, in addition to emergent ventriculostomy placement, that can temporarily stabilize the patient's changing neurological status. This includes intubation, hyperventilation, osmotic diuresis, maintenance of cerebral perfusion pressure, dexamethasone administration, and barbiturate coma. While the ultimate goal is to treat the primary pathologic condition, this chapter was designed to describe the use of CSF drainage via a ventriculostomy and its use in the context of the other methods commonly used to reverse the life-threatening complications of an acutely increasing ICP.

119 Ventricular Shunt Evaluation and Aspiration

Eric F. Reichman

INTRODUCTION

Pediatric and adult patients with ventricular shunts frequently seek medical attention in acute care settings with complaints that may or may not be caused by a malfunction and/or infection of these indwelling devices. The challenge for the Emergency Physician is to determine if the shunt system is functioning properly and if it is a direct cause of the patient's acute problem. This chapter will discuss the complications of ventricular shunt malfunction including infection.

Complications in children with ventricular shunts are common whereas those in adults occur less frequently. Approximately 30% to 40% of infants will experience shunt complications during their first year following shunt placement.[1,2] Children who had shunts placed as infants will require two shunt revisions secondary to obstruction within their first 10 years.[1] The overall shunt infection rate is 10% to 20%.[1,3,4] Approximately 90% of these infections will present within 3 months of the shunt placement.[1] These statistics apply to the population with conventionally treated hydrocephalus using indwelling ventricular shunt devices. It is significant to note that with the wide application and development of neuroendoscopic techniques, many of the complications discussed in this chapter may be significantly reduced or possibly eliminated.

Complications resulting from ventricular shunts take many forms.[5] These include proximal obstruction (most common), distal obstruction, disconnection, wound and cerebrospinal fluid (CSF) infections, seizures, epidural hygromas, subdural hematomas, low (overdrainage) and high pressure (slit ventricle) syndromes, and cranial deformities. There are other unique complications experienced by the smaller number of patients who have ventriculoatrial (V-A) and ventriculopleural shunt systems and these will be discussed separately. Unless stated otherwise, the reader should assume that reference is being made to the more common ventriculoperitoneal (V-P) shunt device.

Patients with shunts may present with clinical entities as benign as a viral upper respiratory infection or with a life threat like hydrocephalus. The wide range of possibilities is a challenge to the Emergency Physician's diligence and clinical acumen. Common presenting symptoms include headache, fever, vomiting, decreased alertness, neck stiffness, visual changes, malaise, abdominal pain, abdominal distension, and surgical site problems.

ANATOMY AND PATHOPHYSIOLOGY

Hydrocephalus, a condition defined by an excessive quantity of CSF, is the condition most frequently associated with the initial need for a ventricular shunt or a shunt revision if it malfunctions. Most abnormal accumulations of CSF are identified in the ventricles, although it may also occur in the subarachnoid or subdural spaces.

Several types of hydrocephalus are cited in the literature. Communicating hydrocephalus occurs when there is unobstructed flow of CSF between the ventricular system of the brain and the spinal cord. It frequently occurs in patients who have had a hemorrhage or infectious process whereby particulate matter interferes with the normal circulation and absorption of CSF. A congenital problem such as aqueductal stenosis or a mass lesion in the posterior fossa may obstruct the flow of CSF between the brain and spinal cord causing obstructive hydrocephalus or noncommunicating hydrocephalus. Normal pressure hydrocephalus is usually a diagnosis made in older people who present with the clinical triad of dementia, ataxic gait, and urinary incontinence. The CSF is found to flow within a normal pressure range, but the patient accumulates excess CSF due to decreased absorption. Hydrocephalus ex vacuo is the result of excessive CSF and ventricular enlargement due to brain atrophy. It presents a challenge to the acute care practitioner who may need to decide if a patient with large ventricles on head CT has a pathologic condition or has so much brain atrophy that the fluid-filled spaces appear excessively large.[6]

The clinical presentation of hydrocephalus will vary depending upon its acuity and the age of the patient. The individual who experiences shunt failure may present in the same way as one who is presenting with hydrocephalus initially. Infants may have an enlarged head circumference, a bulging anterior fontanel, separation of the cranial sutures, bilateral or unilateral palsy of the abducens nerve (medial eye deviation), or Parinaud's syndrome.[7] Parinaud's syndrome is a paralysis of upward gaze (also known as "sunset eyes" or the setting sun sign), unequal pupils, and the loss of convergence.[7]

Within hours of an acute cause of hydrocephalus, the patient (past infancy) will commonly experience a headache with nausea

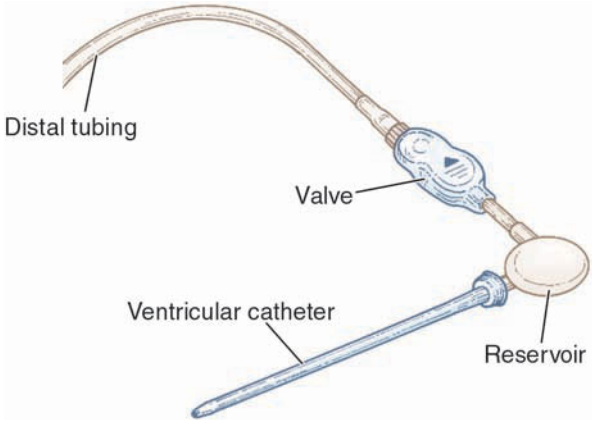


FIGURE 119-1. The components of a ventricular shunt.

and vomiting secondary to the quick increase in intracranial pressure (ICP). The patient may less commonly have a focal neurological deficit due to the pressure exerted by the brainstem from a dilated third ventricle. There may also be visual changes that include Parinaud's syndrome. A change in mental status may occur as the increase in ICP persists. Finally, the signs of herniation signify a terminal event. It will be observed with, for example, decorticate or decerebrate posturing, a third cranial nerve palsy, and the Cushing reflex (elevated blood pressure accompanied by bradycardia). The process of herniation is nearly completely reversible with immediate ventricular drainage through emergent revision of a malfunctioning shunt or the de novo placement of a ventricular drain.

Chronic hydrocephalus can present with a variety of signs and symptoms. The patient may complain of an isolated bifrontal headache, a generalized headache, vomiting, a change in behavior, a change in mentation, or a change in cognition. Ocular findings include papilledema, unilateral or bilateral abducens nerve palsy, Parinaud's syndrome, or even a bitemporal hemianopsia. The extremities may be involved with spasticity in the legs that is more pronounced than that found in the arms.

Once the diagnosis of hydrocephalus is made, the Neurosurgeon will be responsible for treating the primary causes (e.g., tumor, bleed, congenital abnormality) along with placement of an indwelling ventricular shunt. The components of a standard shunt system include a ventricular catheter, a one-way valve, and distal tubing that enters the cavity into which the fluid is being shunted (**Figure 119-1**). It is standard practice to enter the right lateral ventricle and tunnel the valve system and distal tubing subcutaneously along the right temporoparietal region of the skull, the lateral neck, the anterolateral chest wall, and finally into the peritoneal space just superior or lateral (right side) to the umbilicus (**Figure 119-2**). The shunt system may occasionally be found on the left side in some patients.

Much of the shunt pathway is palpable on physical examination (**Figure 119-2**). The entire system may be visualized on plain radiographs. The system is impregnated with radiopaque material either entirely or with intermittent markings.

The ventricular catheter is inserted through a burr hole and into the lateral ventricle. The distal end of the ventricular catheter is connected to one of many different types of valves currently available. Functionally, there are two main types. The differential pressure valve allows the Neurosurgeon to select a low, medium, or high pressure system whereby the CSF will flow out of the ventricle through a one-way system when the CSF pressure or CSF flow rate builds to

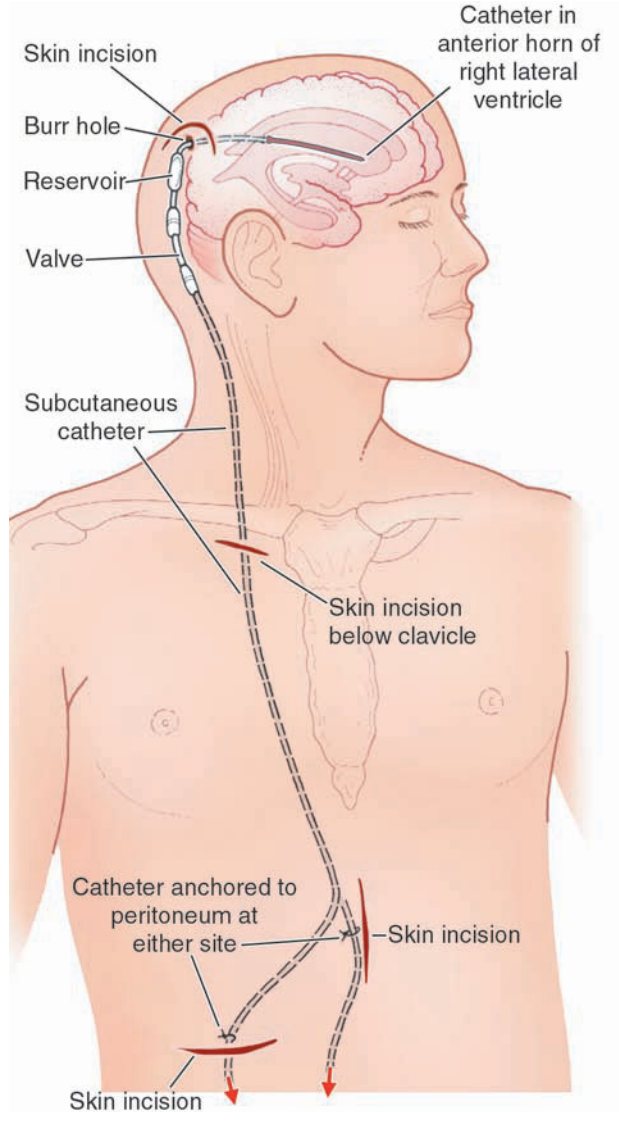


FIGURE 119-2. The anatomical pathway of a ventriculoperitoneal shunt.

a specified level. A variable resistance constant flow valve keeps CSF rates constant and, therefore, provides a more physiologic system by varying the resistance in the valve as the individual changes position. Some of these valves, although palpable on physical examination, do not allow access to the CSF for aspiration nor do they allow for any noninvasive assessment of CSF flow. A bubble-like reservoir (may be single or two bubbles in tandem) for the draining of CSF is a common addition to the standard three-part shunt system. While they can be inserted anywhere in the system, they are most frequently located adjacent to the valve mechanism on the lateral aspect of the skull (**Figure 119-2**).

The distal tubing is made of a flexible and soft synthetic rubber material that is attached to the reservoir or valve system and tunneled subcutaneously through the lateral neck, chest, and abdominal wall. A small incision is made in the skin and the peritoneum where the tubing is brought from the subcutaneous tissue into the peritoneal cavity. After securing the tubing to the peritoneum, a generous portion of tubing is left free floating inside the peritoneal cavity. This allows for the distal end to lengthen as the patient grows and lends further stability to its place within the abdominal cavity.

The distal tubing in ventriculoatrial and ventriculopleural shunt systems will terminate in the right atria and right pleural cavity,

respectively. However, these configurations are not used frequently. One may also come across a patient with a lumboperitoneal shunt that avoids any invasive procedures to the brain directly. This system is inserted into the lumbar subarachnoid space with the valve/reservoir system located above the iliac crest and the distal tubing tunneled subcutaneously in the abdominal wall and into the abdominal cavity.

The patient is subject to a host of complications due to mechanical malfunctioning that can occur anywhere along the path of the system. There is the risk of infection, as is the case with any indwelling medical device. The remainder of this chapter will guide the Emergency Physician through the process of identifying the various types of shunt problems.

INDICATIONS

The Emergency Physician is obliged to assess the patency, placement, and integrity of the shunt system when a patient presents with any symptoms even remotely related to hydrocephalus. The presence of systemic signs (e.g., fever, tachycardia, or hypotension) or local signs of infection (e.g., warmth, tenderness, bogginess, or redness along the shunt tract) is a reason to consider aspirating CSF from the system. This is not to say that every child with an upper respiratory infection requires that the shunt be tapped. It is not uncommon to have overlapping findings in that an infection may obstruct the system and therefore require both mechanical and infectious complications to be addressed. **The withdrawal of CSF from the shunt can be lifesaving and sustain the patient who is herniating, in extremis, or deteriorating neurologically until a Neurosurgeon can repair the shunt.**

CONTRAINDICATIONS

There are no contraindications to performing a thorough physical examination of the shunt system, obtaining a head CT, and obtaining plain radiographs to assess its integrity. There is some controversy, however, that surrounds the tapping of a shunt by personnel other than a Neurosurgeon.[8–10] It is possible to disrupt the pressure and valve mechanism by the manipulation of the needle that is required to perform the tap. The reservoir may develop a leak if the correct technique is not employed or if the shunt is tapped too frequently. There is the risk that bacteria will be introduced into the system. Many patients have had multiple complications related to both a primary disease and the shunt, with some already having undergone a number of shunt revisions. **It is prudent to assume a conservative approach with each of these patients and consult a Neurosurgeon prior to tapping the shunt.**

SHUNT ASSESSMENT

The technique of shunt evaluation begins with taking a complete history and performing a thorough physical examination. Palpate the entire system starting with the cranium. Examine the surrounding scalp carefully for any bogginess (indicating that CSF may have extravasated from the system), redness, tenderness, or warmth. The suture line should be examined as well if the shunt has been placed recently. Examine the scalp on the right side for a burr hole. This is where you may palpate a shunt reservoir that is placed subcutaneously. The reservoir feels like a firm fluid-filled bubble. Compress the bubble gently to assess if there is brisk refilling of the CSF. Quick filling of the reservoir is an indication that the proximal portion of the system may be patent, but this is by no means a perfect test. Resistance to compression indicates a distal malfunction. **Avoid pumping the reservoir repeatedly.**

A double bubble (reservoir system) may be occasionally palpated. Compress the proximal reservoir to empty it and fill the distal reservoir. While still compressing the proximal reservoir, compress the distal reservoir. Any resistance to compression indicates a distal malfunction. With both reservoirs compressed, release the proximal reservoir. It should refill very quickly. Any delay in filling of the proximal reservoir indicates a proximal malfunction.

Move down and palpate the temporal region of the scalp and the neck. Note any gaps in the system that could indicate a disconnection. The individual components of the shunt system are commonly joined by small connectors that may come apart. Continue to palpate the tubing along the neck and chest until you reach the abdomen. Perform a thorough abdominal examination, specifically noting the presence of any tenderness, masses, distension, or erythema of the abdominal wall.

The distal end of the shunt may not function for several reasons. The tip may have withdrawn out of the peritoneal cavity and into the preperitoneal fat or subcutaneous tissue of the abdominal wall where the CSF cannot be resorbed. This may have occurred simply because the patient had grown and used up the extra length of catheter that was originally left in the peritoneal cavity just for this reason. Intraperitoneal infections, particularly those caused by anaerobic organisms, may cause loculations around the catheter tip forming a pseudocyst. It is important to note that these patients may not have any signs of a systemic infection. Additional causes of distal catheter obstruction include kinking of the intraabdominal tubing, debris collection around the tube openings, and compression secondary to pregnancy or other processes that increase the intraabdominal pressure.

After completing the history and physical examination, including an assessment of the shunt system, the differential diagnoses will help initiate an appropriate work-up. One or more of the following studies may be indicated: plain radiograph shunt series, computerized tomography (CT) of the head, shunt aspiration of CSF, or a radioisotope shunt scan. **Stabilize the patient and arrange for an emergent head CT if any life-threatening signs of neurologic dysfunction appear.**

There are several important points to note. Findings consistent with hydrocephalus include enlargement or effacement of the ventricles, particularly looking for fullness of the temporal horns of the lateral ventricles (**Figure 119-3**). It can be difficult to determine if there is a change in the ventricular system because congenital or chronic abnormalities can give the CT scan an abnormal appearance. The best way to approach this situation is to compare the current scan to a previous one, preferably by comparing the two scans side by side. Brain atrophy causes the ventricles to appear abnormally full when, in fact, they appear large because of the relative loss of brain tissue.

Impending herniation may be a concern if the brain appears to be under increased pressure with a loss of the sulcal markings, loss of the differentiation between the gray and white matter, or an inability to visualize the fourth ventricle. The ventricles can appear unusually small which may be an indication of a shunt system that is draining CSF too vigorously. Overdrainage may be the problem if the patient complains of a positional headache that is worse in the upright position and less severe when supine. **If this is the case, it is important to carefully examine the CT scan for any subdural hematomas that can result from the brain shrinking away from the dura and tearing a bridging vein secondary to overdrainage of CSF.**

The patient's scan may reveal small ventricles accompanied by signs of increased ICP in the slit ventricle syndrome.[11,12] While the slit ventricle syndrome is poorly understood, it is theorized that ventricles with poor compliance (common in those with chronic hydrocephalus) will respond to small increases in CSF pressure with

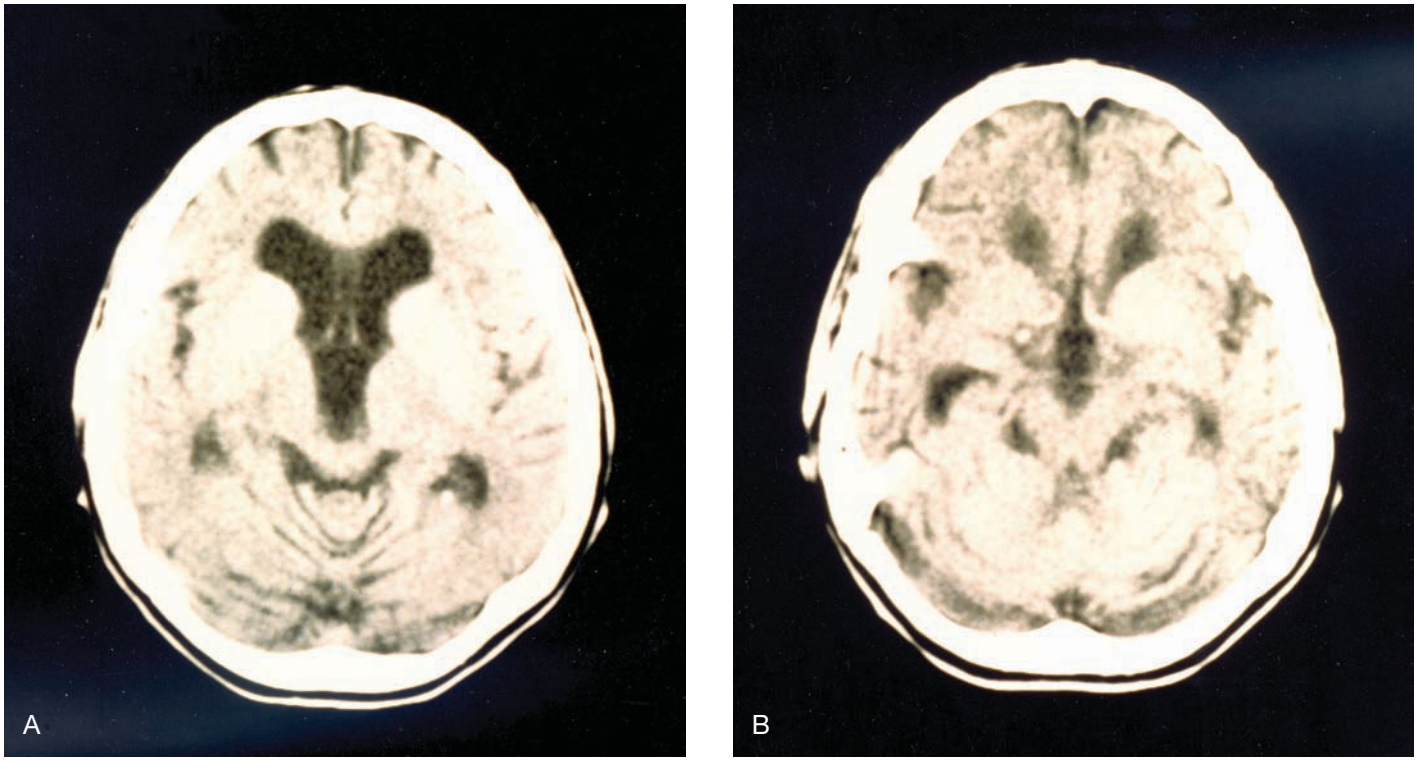


FIGURE 119-3. Head CT of a patient with hydrocephalus. **A.** The ventricles are enlarged with effacement. **B.** Pronounced temporal horns.

large increases in ICP. The management of the slit ventricle system can be medical, replacement of the valve with one of a higher resistance to flow, or the placement of a new shunt.[12,13]

Obtain a plain radiograph shunt series if there is the slightest suspicion of a shunt malfunction or infection. This study consists of anteroposterior and lateral plain radiographs of the skull, neck, chest, and abdomen. These films are useful for assessing placement and integrity of the connections within the shunt system.[14] Shunt materials are impregnated with a radiopaque substance either completely or in regularly placed markings so that the entire device can be visualized on plain radiographs. **It is important to obtain and review the lateral abdominal film as this view is frequently overlooked.** It is impossible to determine if the shunt tubing lies within the peritoneal cavity or not if the lateral abdominal film is excluded. The entire path of the shunt system should be visualized. Particular findings to note on this study include placement of the ventricular catheter inside of the ventricle, the integrity of the connections around the valve and/or reservoir, and the identification of the distal catheter within the peritoneal cavity. Examine the chest radiographs closely for a pleural effusion or a pneumothorax in a patient with a ventriculopleural shunt.[15]

SHUNT ASPIRATION

Tapping the ventricular shunt should be considered whenever there are signs of localized infection, systemic infection, or in some cases of suspected obstruction without an identifiable cause. It should also be performed if the patient is in extremis, deteriorating neurologically, or has signs of herniation on the CT scan. This can temporarily restore cerebral perfusion and sustain the patient until a Neurosurgeon can repair the shunt. **It is recommended that a Neurosurgeon be consulted and given the first option to perform the procedure.** The Neurosurgeon may have already manipulated the hardware multiple times and will ultimately be responsible for any shunt revisions and follow-up. Patients with ventriculoatrial shunts are a particular concern when there are any signs of an infection. The distal catheter sits at the intersection of the right atrium and the superior vena cava. This puts the patient at risk for life threats such as endocarditis and septic emboli. It may be possible to evaluate the majority of shunt malfunctions without tapping the device.[8]

Tapping a ventricular shunt is a quick and simple procedure. Palpate the lateral aspect of the skull (usually the right side of the patient) for the reservoir. Plain radiographs may be helpful if it is difficult to identify upon palpation. Prepare for the procedure by having the following equipment available: four sterile fluid specimen tubes with tight fitting tops (those supplied in the standard lumbar puncture kit are ideal), a 23 to 25 gauge butterfly needle, a 5 to 10 mL syringe, a shave-prep set, an antibacterial cleansing preparation (povidone iodine or chlorhexidine solution), a fenestrated drape, and personal protective equipment.

Local anesthetic is not required for this procedure. Place the patient in whatever position is mutually comfortable. Shave a small patch of hair overlying the reservoir. Clean the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. **This procedure requires strict aseptic technique.** The Emergency Physician should don full sterile and personal protective equipment at this point. This should include sterile gloves, a sterile gown, a face mask with an eye shield or goggles, and a cap. Place the drape over the patient's head so that the fenestration overlies the reservoir and prepped skin. Set up a bedside table with a sterile drape and all the supplies. A lumbar puncture tray supplemented with a butterfly needle is all that is required.

Insert the needle at approximately 45° from the vertex of the reservoir bubble with the tip pointed toward the center of the reservoir (**Figure 119-4**). This is where the greatest amount of CSF is located. **Avoid inserting the needle into any of the connections or internal pressure mechanisms that may be at either end of the reservoir.**

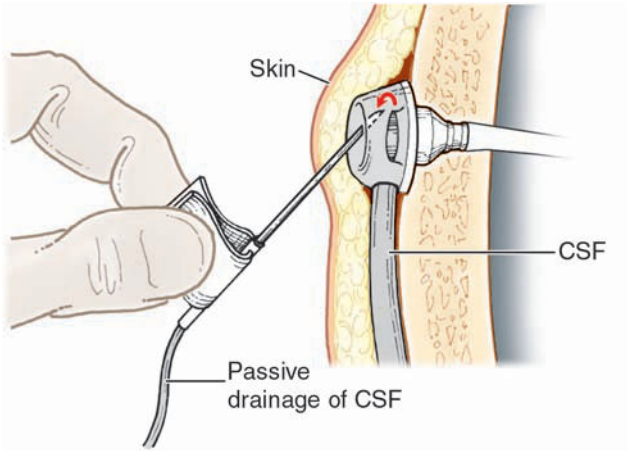


FIGURE 119-4. Tapping the shunt reservoir.

Allow the CSF to passively drain from the butterfly tubing into sterile tubes. It may be necessary to very gently aspirate 4 to 5 mL of CSF with a sterile syringe. The ventricular end of the shunt is usually obstructed if CSF cannot be aspirated.[10] Withdraw the needle from the shunt reservoir.

Label the tubes of CSF and have them transported to the laboratory for a cell count and differential, Gram's stain, culture (bacterial, viral and fungal), and chemistry (protein and glucose). Obtain a sample of the patient's serum glucose at the same time so as to more accurately determine what level of glucose in the CSF to call abnormal. A normal level of CSF glucose should not be any lower than 50% to 66% of the serum level.

It is possible to attach the end of the butterfly tubing to a manometer so that an opening pressure can be measured. This must be done, however, with the patient in the lateral decubitus position, reservoir side up, and the head level with the heart.

Obtain a nuclear medicine scan ("shunt-o-gram") if CSF cannot be aspirated to determine proximal patency of the system. A radioactive isotope (e.g., technetium) is injected into the reservoir after manually occluding the distal shunt tubing. The flow, or lack thereof, of the radioactive isotope is then imaged.[4] The addition of a nuclear medicine scan to the CT scan can increase the sensitivity of diagnosing a shunt malfunction.[16]

A lumbar puncture should never be performed in lieu of tapping the shunt. Obstruction of the shunt system can result in obstructive hydrocephalus. Lumbar puncture in a patient with obstructive hydrocephalus can cause a significant pressure differential and precipitate brain herniation.

CSF ASSESSMENT

The CSF obtained from the shunt is interpreted in the same way as CSF from a lumbar puncture. A high white cell count with a large number of polymorphonuclear leukocytes, low glucose, and a high protein level indicates a high likelihood of bacterial infection. However, the positive Gram stain and culture make the definitive diagnosis. Unfortunately, there is no standard for the number of white cells that definitively indicates an infection. Some patients with indwelling shunts may have a chronically elevated CSF white blood cell count, albeit with more lymphocytes or eosinophils than polymorphonuclear leukocytes.[3] Refer to Chapter 115 for a more detailed discussion regarding the evaluation of CSF. Antibiotic coverage should be initiated if a shunt is being tapped. *Staphylococcus epidermidis* causes the vast majority of infections with *Staphylococcus aureus* and gram-negative bacilli following in frequency.[17,18] The current management of shunt-related infections has been reviewed by Stenehjem and Armstring.[19] Empiric therapy includes vancomycin with either cefotaxime or ceftriaxone for children and vancomycin with rifampin for adults.[20] Consider additional coverage for methicillin-resistant *Staphylococcus aureus* if indicated.

FUTURE CONSIDERATIONS

The ShuntCheckT (NeuroDx Development, Bensalem, PA) is a new device that allows the noninvasive detection of CSF flow through a shunt.[21] The procedure requires placing an ice cube over the shunt. A single patient use and disposable sensor is placed on the skin of the neck overlying the shunt tubing. The sensor is attached to the ShuntCheckT device with a cable. The ShuntCheckT analyzes the temperature readings from the sensor and determines if CSF flow is present or not.

COMPLICATIONS

There are a few complications associated with the aspiration of a ventricular shunt. The introduction of bacteria into the reservoir can result in meningitis, peritonitis, brain abscesses, shunt occlusion, or infection anywhere along the course of the shunt tubing. It is of the utmost importance to maintain strict aseptic technique. The needle can damage the reservoir and result in a permanent hole necessitating its removal and replacement. A misplaced needle can damage the connections or valves of the shunt system.

SUMMARY

Patients with indwelling ventricular shunt devices are subject to many complications throughout their lives. This most commonly includes obstruction, infection, and malfunction secondary to loss of placement or connection. Emergency Physicians will see patients of all ages with shunts and who present with headache, fever, nausea, vomiting, seizures, irritability, or a change in mental status. The challenge, frequently a formidable one, will be to determine whether or not the patient's complaint is related to the shunt. This chapter discussed some of the common shunt complications and an approach to their diagnosis. The head CT, the plain film shunt series, and the shunt tap will prove most useful. Of course, a careful history and a skilled physical examination will set the Emergency Physician on a path toward a good outcome for the patient. A Neurosurgeon should be consulted if available. A conservative approach to diagnosis, management, and patient disposition is strongly recommended due to the life-threatening nature of shunt complications.

120 Subdural Hematoma Aspiration in the Infant

Eric F. Reichman

INTRODUCTION

Extra-axial fluid collections in children are classified as symptomatic and asymptomatic. Symptomatic, chronic extra-axial fluid collections have been variously classified as hematomas, effusions, or hygromas with differing definitions associated with each. It has been proposed that they all be classified together as extra-axial fluid collections because their appearance on CT scan and the treatment is identical.[1] Symptomatic, chronic extra-axial fluid collections usually show ventricular compression and flattening or obliteration of the

TABLE 120-1 The Etiologies for Intracranial and Extra-Axial Fluid Collections

Brain atrophy
Child abuse
Coagulopathy
Hydrocephalus
Infection
Masqueraders
Craniocerebral disproportion
Extracerebral space is enlarged and filled with CSF-like fluid as a result of the head being too large for the enclosed brain
External hydrocephalus in a child with ventriculomegaly and extracerebral fluid
Neoplastic
Metastatic
Primary
Prior surgery
Spontaneous
Trauma
Vascular
Aneurysm
Vascular malformation
Ventriculoperitoneal shunt malfunction

cerebral sulci on CT scans. Benign subdural fluid collections usually appear as a hypodensity over the frontal lobes with dilatation of the interhemispheric fissure, cortical sulci, and Sylvian fissure. The ventricles are usually normal or slightly enlarged with no evidence of transependymal flow.

Seizures, a large head, vomiting, irritability, depressed level of consciousness, and lethargy are common presenting symptoms of a symptomatic extra-axial fluid collection. The physical examination reveals a full fontanel, macrocephaly, fever, lethargy, hemiparesis, retinal hemorrhages, generalized increased tone, or gaze paresis. Markwalder has done an excellent review of the pathophysiology and experimental studies of chronic subdural hematomas.[2]

The majority of extra-axial fluid collections result from head trauma. Other causes include bacterial meningitis (postinfectious) and the placement of a ventriculoperitoneal shunt. The etiology of intracranial hemorrhage and extra-axial fluid collections are quite varied (**Table 120-1**). Acute and chronic subdural fluid collections are common problems during infancy. Males are affected more commonly than females. **A clear history of injury or trauma should be sought in the presence of an acute or chronic subdural hematoma. Consider the possible etiology of child abuse if a history of injury is not forthcoming or if the history does not make sense. It is incumbent upon the medical team to rule out abuse.** This may require a period of inpatient observation, social services consultation, a radiographic skeletal survey, a bone scan, and possibly an ophthalmological assessment. **The presence of retinal hemorrhages in association with a subdural fluid collection is highly suspicious for child abuse.** Admission to the hospital for further observation is warranted if child abuse cannot be ruled out. The presence of congenital anomalies may predispose the child to subdural hematoma formation.

Percutaneous removal of the subdural fluid is useful in diagnosing an active infection and rapidly lowering the intracranial pressure in the symptomatic patient. Repeated removal of the fluid by percutaneous aspirations has been advocated by some Neurosurgeons for definitive treatment of chronic extra-axial fluid collections.[3,4] Subdural fluid collections in infants have a tendency to increase in size, are often bilateral, can be difficult to diagnose, and are most often seen in children under the age of 2 years. The combination of CT and MRI is usually diagnostic.

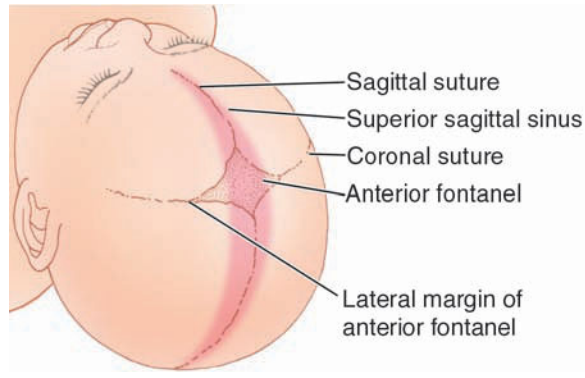


FIGURE 120-1. Surface anatomy of the infant skull. The shaded area represents the underlying superior sagittal sinus.

ANATOMY AND PATHOPHYSIOLOGY

A subdural aspiration (or tap) is usually performed by puncturing the anterior fontanel. However, it can also be approached through the coronal suture as well as through the soft cranium. The diamond-shaped anterior fontanel is formed by the junction of the sagittal, coronal, and frontal sutures (**Figure 120-1**). It measures approximately 4 cm in the anteroposterior plane and 2.5 cm in the transverse plane. The bones of the infant calvarium are separated by connective tissue bands referred to as sutures. The fontanels are readily palpable at the junctions of the sutures. Six of the fontanels are located at the corners of the two parietal bones. Two of these, the anterior and posterior fontanels, are in the midline.

The anterior fontanel, the largest of the neonatal fontanels, is utilized for percutaneous subdural aspiration. The diamond-shaped anterior fontanel is formed by the junction of the sagittal, coronal, and frontal sutures (**Figure 120-1**). It measures approximately 4 cm in the anteroposterior plane and 2.5 cm in the transverse plane. The posterior fontanel is at the junction of the lamboidal and sagittal sutures. In general, the anterior fontanel has usually closed by 18 months of age but can be patent up to the age of 2 years. The posterior fontanel usually closes earlier in life and is usually complete by 6 weeks of age.

The anterior fontanel is composed of connective tissue and easily perforated with a spinal needle. Continued advancement of the needle would then perforate the underlying dura, allowing the tip of the needle to rest within the subdural space. Traversing the dura is usually associated with a definite change in resistance as the subdural space is entered. Successful entry of the tip of the needle into the subdural fluid collection can be confirmed by removal of the stylet and observing spontaneous drainage from the needle hub. The anterior fontanel is readily palpable and bulging in cases of symptomatic chronic extra-axial fluid collections. The lateral extent of the anterior fontanel is continuous with the coronal suture (**Figure 120-1**).

INDICATIONS

A subdural aspiration is performed for diagnostic purposes as well as for rapid decompression of subdural fluid collections, whether acute or chronic. Perform a subdural aspiration in the young child with a subdural fluid collection and radiographic signs of elevated intracranial pressure, a depressed level of consciousness, and/or a changing level of consciousness.[5] Other indications to perform a subdural aspiration include the clinical signs and symptoms associated with elevated intracranial pressure: bulging fontanelles, coma, cranial nerve palsies, hemiparesis, hypotonia, irritability, lethargy,

posturing, seizures, somnolence, and vomiting (repeated or intractable). Aspiration of extra-axial fluid collections can reduce intracranial pressure dramatically. Subdural aspiration of fluid allows for culture and sensitivity, identification of microorganisms, and aids in the selection of bacterial specific antimicrobial agents if an infectious etiology is considered to be the cause of the extra-axial fluid collection.

CONTRAINDICATIONS

The main contraindications to performing a subdural aspiration include localized infections of the scalp, patients who are coagulopathic or thrombocytopenic, children over the age of two, children who have an absence of the anterior fontanel as a result of premature closure, a solid clot that is not liquefied, and children with congenital anomalies of the skull or brain. This procedure should not be performed by those unfamiliar with the technique and its complications. Consult a Neurosurgeon, if available, prior to performing this procedure. Repeated aspirations are rarely indicated as blood or fluid reaccumulation often requires the placement of a drain or a surgical procedure by a Neurosurgeon.

EQUIPMENT

- Sterile skin prep kit
- Povidone iodine or chlorhexidine solution
- Sterile gloves and gown
- Face mask with an eye shield or goggles
- Sterile drapes
- 1% or 2% lidocaine, with or without epinephrine
- 18 to 22 gauge, 1.5 in. spinal needle or angiocatheter
- Tincture of benzoin
- Cotton swab
- Bandage
- Bundling blanket
- Commercially available immobilization device
- Syringe for aspirating fluid
- Sterile specimen containers
- Culture bottles or swabs
- IV extension tubing, optional

All of the basic equipment can be found in commercially available pediatric lumbar puncture kits. The kit needs to be supplemented with personal protective equipment and skin antiseptic.

PATIENT PREPARATION

The patient should be fully monitored with a noninvasive blood pressure cuff, pulse oximetry, cardiac monitor, and end-tidal carbon dioxide monitor (if available). Obtain a CT scan of the head to determine the presence of an extra-axial fluid collection, the location and extent of the fluid collection, the type of fluid (e.g., blood, pus, etc.), and to rule out the presence of a mass. Obtain a complete blood count (hemoglobin, hematocrit, and platelet count) and a coagulation profile (PT, PTT, and INR) to ensure that the patient is not thrombocytopenic or coagulopathic.

Explain the procedure to the parents and/or guardian of the child if time permits. Obtain an informed consent to perform the procedure. Place the patient supine on a stretcher. The child may need to be restrained to prevent movement during the procedure. Bundling an infant in a blanket and placing their head close to the edge of the bed facilitate aspiration. An alternative is to use a commercially available immobilization device (e.g., Papoose board). The aid of an assistant to hold the child's body with the head straight and upright is recommended if the child is restless. Some children may require the administration of parenteral sedatives or procedural sedation.

This procedure requires strict aseptic technique. Shave the frontal and parietal regions of the child's head. Clean any dirt and debris from the scalp. Identify by palpation the anterior fontanel, the coronal suture, and the lateral margin of the coronal suture. The Emergency Physician should don full sterile and personal protective equipment at this point. This should include sterile gloves, a sterile gown, a face mask with an eye shield or goggles, and a cap. Apply povidone iodine or chlorhexidine solution to the skin over the entire scalp and allow it to dry. Ensure that the solution is not allowed to drain onto the baby's face or eyes. Apply sterile drapes leaving the frontal and parietal regions of the skull exposed. A local anesthetic agent is usually not required but may be used at the Emergency Physician's discretion. If used, place a skin wheal using 0.25 to 0.50 mL of 1% or 2% lidocaine at the site the needle will enter the scalp.

TECHNIQUE

Form a Z-tract by gently sliding the scalp skin laterally (**Figure 120-2**). Insert a 22 gauge spinal needle into the lateral margin of the anterior fontanel, about 2.5 to 3 cm off the midline (**Figure 120-2**). Advance the spinal needle beneath the frontal bone until the subdural space is penetrated. This is usually within 5 to 8 mm from the skin surface. A loss of resistance is usually appreciated as the dura is penetrated and the subdural space is entered. **Do not advance the needle any further. Securely hold the spinal needle so that it does not move (Figure 120-3).** An alternative is to insert the needle at a 45° angle to the skin surface, tunnelling it under the scalp and into the subdural space (**Figure 120-4**). Remove the stylet. Spontaneous drainage is often appreciated. This fluid may appear hemorrhagic. However, it is not uncommon, especially in patients who require multiple aspirations, to drain xanthochromic fluid.

The initial subdural aspiration usually results in spontaneous drainage through the spinal needle. The spontaneous cessation of flow through the needle suggests that the extracranial and intracranial pressures are equalized, not that the fluid has been completely evacuated. If the fluid does not spontaneously drain, carefully and gently apply a syringe to the spinal needle and gently aspirate the fluid. **Use minimal negative pressure to just aspirate**

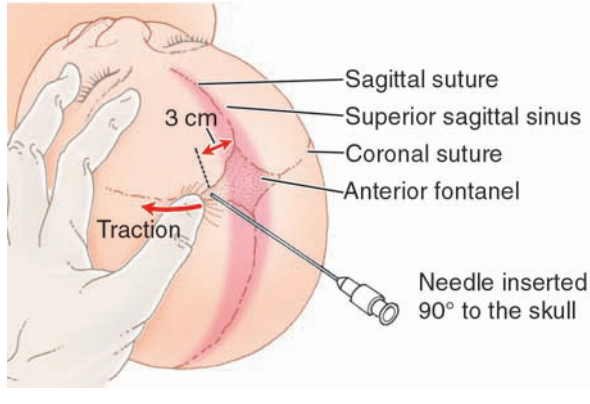


FIGURE 120-2. Subdural fluid aspiration. The needle is inserted at the lateral border of the coronal suture and at 90° to the skull.

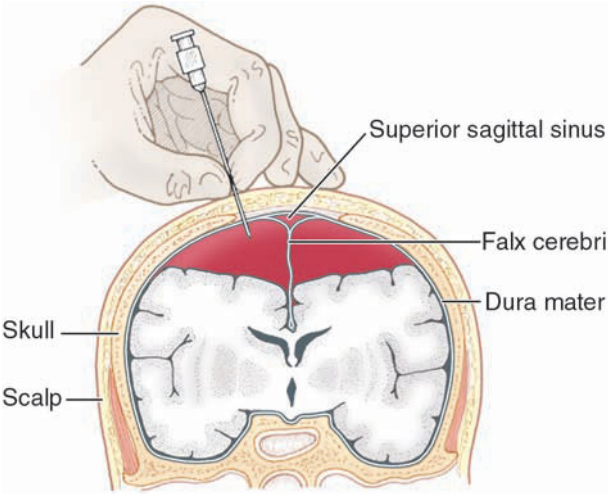


FIGURE 120-3. Coronal section through the skull at the level of the coronal suture. The needle is visible along its trajectory.

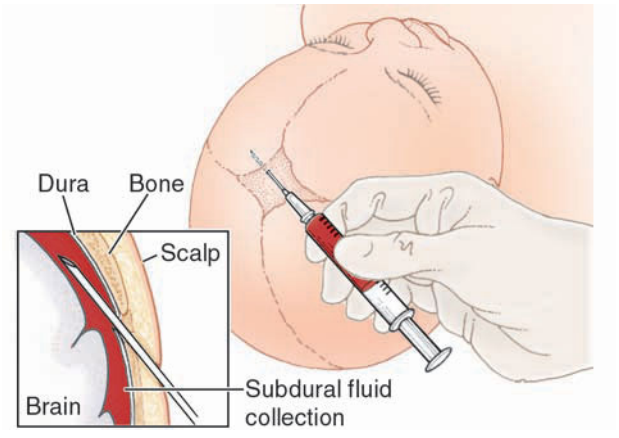


FIGURE 120-4. An alternative method for subdural fluid aspiration. The inset shows the oblique trajectory of the needle into the subdural space.

the fluid collection and prevent pulling the brain or any bridging veins into the needle. Alternatively, apply digital pressure to the anterior fontanelle to increase the flow through the spinal needle. Some Physicians may choose to apply intravenous extension tubing to the spinal needle to allow the subdural fluid to drain away from the patient and directly into the specimen tubes. This is left to the Emergency Physician's preference. Observe the gradual flattening of the anterior fontanel to determine the endpoint for the procedure.[6] Generally, on any one occasion, no more than 25 to 30 mL of subdural fluid should be aspirated. Larger volumes, up to 80 mL, have been safely aspirated.[7] Remove the spinal needle and apply a bandage.

ALTERNATIVE TECHNIQUES

Consult a Neurosurgeon to evaluate and manage the patient. There are numerous alternatives to the aspiration of the fluid collection. These include observation, burr hole drainage, drainage through an external collecting system, placement of a subdural-to-peritoneal shunt, and a craniotomy. A craniotomy should be performed in patients with a symptomatic nonliquefied clot or extensive membrane development precluding aspiration.

Some Physicians prefer to use an intravenous catheter rather than the spinal needle. Removal of the metal needle leaves a soft Teflon catheter in place that minimizes the risk of injury to the brain or intracranial vascular structures. The use of an intravenous catheter set rather than a spinal needle is left to the discretion of the Emergency Physician.

ASSESSMENT

Monitor the child for a change in their level of functioning after subdural aspiration. Comparison to the child's baseline neurological examination is essential. It is mandatory to document timed serial neurological examinations in the patient's chart. The clinical examination is age-related. It is often prudent to observe the infant in the arms of a parent or healthcare worker while monitoring their level of alertness, facial expression, extraocular movement, pupillary response, and limb movement. Obtain daily head circumference measurements and plot them on a head circumference chart. Note the size and feel of the anterior fontanel. Infection can be prevented with careful attention to aseptic technique. A simple bandage placed over the puncture site is usually sufficient and can be removed 48 to 72 hours after the procedure. Continued spontaneous drainage through the puncture site should be monitored carefully as it poses an infectious risk.

AFTERCARE

Perform an ultrasound or CT scan of the head to determine if the fluid collection has been adequately drained. Bedside ultrasonography is an effective tool in neonates and young children. Any change in the child's neurological examination requires an emergent head CT scan or ultrasonography to determine if the subdural fluid collection has reaccumulated. Send the aspirated fluid for the appropriate laboratory analysis if an etiology other than an acute traumatic hemorrhage is suspected. This can include a biochemistry analysis (glucose and protein level), cell count and differential, culture (bacterial, fungal, viral, etc.), cytology, and gram stain. Admit the child to the Intensive Care Unit where they can be appropriately monitored and observed.

COMPLICATIONS

Injury to the superior sagittal sinus or draining veins is best avoided by inserting the spinal needle 2.5 to 3 cm lateral to the midline. **At no time should the trajectory of the needle be in the midline or parasagittal in location.** Overpenetration of the spinal needle can result in intracerebral hemorrhage. Have an assistant immobilize the child to prevent them from moving and the needle lacerating the brain or a blood vessel. Persistent leakage of subdural fluid from the puncture site can be the result of insufficient fluid aspiration or failure to use a Z-tract. This complication can also be prevented by tunneling the needle under the scalp prior to penetrating the lateral margin of the anterior fontanel (**Figure 120-4**). This leakage can usually be controlled with local pressure, head elevation, and rarely by using cotton soaked with tincture of benzoin. Placement of a single suture at the puncture site will usually control continued leakage if less invasive methods fail. Introducing infection into the subdural space has also been reported following a subdural aspiration.[8] This is best avoided by maintaining strict aseptic technique.

SUMMARY

Acute and chronic subdural fluid collections are common problems during infancy. They are regarded as posttraumatic lesions in the great majority of cases. Birth trauma is sometimes implicated

but uncommon. It appears that minor injuries during infancy or even more violent injuries such as infant shaking and/or cranial impact are the inciting events. It is incumbent upon the Emergency Physician to rule out any possibility of child abuse! Report actual or suspected abuse to the appropriate state agency as required by law. Aspiration of extra-axial fluid collections in the symptomatic child can be completed safely with very little risk to the child. Admission and continued observation are mandatory.

121 Skeletal Traction (Gardner-Wells Tongs) for Cervical Spine Dislocations and Fractures

Eric F. Reichman

INTRODUCTION

Traumatic injuries to the cervical spine result from forces acting on the head and neck. The incidence of spinal cord injury in the United States is approximately 5 per 100,000 population.[1] Approximately 60% to 80% of spinal cord injuries involve the cervical spine. Motor vehicle collisions are the most common cause and account for almost half of the cervical spine injuries.[2] The remaining cervical spine injuries result from falls, sports injuries, violence, penetrating wounds, and miscellaneous causes.

The primary aims of therapy in the treatment of the patient with an acute spinal cord injury are to minimize secondary injury to the spinal cord, to realign the spine, to improve neurological recovery, to maintain spinal stability, and to obtain an early functional recovery. This is achieved by decompression of the spinal cord by restoring the normal sagittal diameter of the spinal canal or by removing a compressive lesion surgically. This is particularly important in patients who have sustained an incomplete spinal cord lesion and are found to have a progressing neurological deficit. Restoring the normal anatomic position also provides for pain relief.

Early operative intervention can be performed for the treatment of acute cervical fractures to achieve decompression and restore normal alignment. The use of skeletal traction in the acute spinal cord injury patient remains a very safe and straightforward method of reducing fractures and maintaining the spinal canal in anatomical alignment.

Fabricius Hildanus utilized forceps in treating fractures or dislocations of the cervical spine as early as 1646. Crutchfield developed a pair of self-tightening tongs in 1933 that allowed him to apply traction to the cranium in a patient with a cervical spine fracture.[3] These tongs were subsequently modified and have essentially been replaced by the Gardner-Wells tongs.[4]

ANATOMY AND PATHOPHYSIOLOGY

Cervical spinal cord injuries can be divided into upper (occiput to C3) and lower (C3 to C7) injuries. Numerous classification systems exist. These are based upon the morphology and the mechanism of injury.[5] No classification is ideal. However, critical to all cervical classifications is the determination of stability of a fracture or dislocation. Stability of the vertebral column is dependent upon the integrity of the vertebra, the intervertebral disk, the facet joints, and most importantly the ligamentous structures.

Clinical stability of the cervical spine is determined by the ability of the spine under physiological loads to maintain its normal anatomical relationship so that there is no damage to the spinal cord or nerve roots. It has been proposed that spinal instability be separated into mechanical, neurologic, and combined types. Mechanical instability implies that the injured spine could collapse or distort under normal physiological stresses. Neurological instability implies a risk of neural injury (spinal cord and/or nerve root) subsequent to the initial injury.

It is exigent that a thorough clinical and radiological evaluation be completed to determine if the patient has suffered an unstable cervical spine injury. This begins with a thorough history and physical examination, including a complete neurological examination with particular attention to spinal cord function. Cervical spine radiography (including possibly CT, MRI, and myelography) is indicated to evaluate fracture patterns, disk disruption, vertebral subluxation, vertebral dislocation, vertebral angulation, and ligamentous injury. Ligamentous injury evaluation should look for disruption of each of the major spinal ligaments including the anterior longitudinal ligament, the posterior longitudinal ligament, the apophyseal ligamentous complex, and the posterior ligamentous complex. Radiological findings that indicate instability include vertebral displacement, interspinous process widening, diastasis of the apophyseal joints, widening of the spinal canal, and disruption of the posterior vertebral body line.

White and Panjabi proposed a checklist point value system (**Table 121-1**).[6] A point value is assigned to each of the injuries appreciated on the cervical spine radiographs. A specific point value is allotted to the location of injuries, sagittal plane translation or rotation, spinal cord injury, nerve root injury, and the presence of intervertebral widening, rotation, or angulation. The total point values are then summated. A score of five or more is suggestive of clinical instability. A discussion of the indications for the application of the Gardner-Wells tongs includes evidence of cervical spine instability.

Crutchfield is credited for introducing skeletal tongs in the management of cervical spinal injuries.[3] Gardner-Wells tongs were introduced in the early 1970s and utilize the principle of a spring-loaded point for cervical traction.[4] The spring-loaded pin design and tilting of the pins in the direction of pull ensure a firm and prolonged grasp of the skull. These tongs have the capacity to tolerate at least 65 pounds or more of traction. The amount of weight necessary to accomplish reduction varies considerably. As a rule, 5 pounds of weight should be applied for each vertebral level above the level of the fracture or the dislocation. Most authors have recommended the use of up to 50 to 60 pounds of weight.[7] Others have, on occasion, applied weights in excess of 100 pounds to reduce a cervical subluxation.[8]

TABLE 121-1 Checklist for the Diagnosis of Clinical Instability in the Lower Cervical Spine[6]

Element	Point value*
Anterior element destroyed or unable to function	2
Posterior element destroyed or unable to function	2
Relative sagittal plane translation > 3.5 mm	2
Relative sagittal plane rotation > 11°	2
Positive stretch test	2
Spinal cord damage	2
Root damage	1
Abnormal disk narrowing	1
Dangerous loading anticipated	1
Developmentally narrow spinal canal	1

*Summate the points. A total of five or more points is considered clinically unstable.

The concern for using an excessive amount of traction weight is overdistraction that can result in a traction type of spinal cord injury. Begin by applying 5 to 10 pounds of weights.[2] Add additional weight in 3 to 5 pound increments if the initial application of weights fails to achieve spinal alignment. Obtain lateral cervical spine radiographs 10 to 15 minutes after each addition of weight until the cervical spine is realigned. This time is needed after the application of weight to allow the soft tissues to accommodate. **It is of paramount importance to monitor the patient's neurological status during the entire procedure to prevent iatrogenic injury from overdistraction of an unstable motion segment.**

INDICATIONS

Definitive management of the cervical spine injury would include skeletal traction with Gardner-Wells tongs if clinical instability is demonstrated or suspected. Other indications for the application of Gardner-Wells tongs in a neurosurgical setting are cervical spondylosis, anterior cervical diskectomy with graft fusion, and certain cervical infections or neoplasms. Gardner-Wells tongs should only be applied if the patient requires temporary longitudinal traction.[9] Their use requires the patient to remain bedridden, as compared to halo vest traction.

CONTRAINDICATIONS

Cervical traction is contraindicated in someone who has sustained posttraumatic disc herniation with spinal cord compression. Hence, a good neurological evaluation and an MRI scan should be performed prior to applying cervical traction. Fractures of the skull and infections overlying the potential pin sites are contraindications to the use of skeletal traction. Other contraindications are diseased bone, children less than 3 years of age, atlantooccipital dislocations, and C1-C2 dislocations. Applying Gardner-Wells tongs to someone who survives an atlantooccipital type injury could worsen the patient's condition and/or neurological deficit.

EQUIPMENT

- Prep kit
- Povidone iodine or chlorhexidine solution
- 1% or 2% lidocaine with epinephrine
- 5 mL syringe
- 18 gauge needles
- 22 gauge needles
- Gardner-Wells traction tongs
- Pulley traction system
- Traction weights, 3 to 5 pound increments

Gardner-Wells tongs are a simple device (**Figure 121-1**). It consists of a contoured and rigid stainless steel rod that follows the coronal contour of the calvarium. Gardner-Wells tongs are also available in versions composed of graphite or titanium alloy. These versions are compatible with and facilitate subsequent CT and MRI scans without producing artifacts. It has a threaded hole on each end that accommodates the pins. The spring-loaded pins are threaded screws with sharp cone-shaped points. One of the pins is the calibration pin (**Figure 121-2**). It contains an indicator pin that extends and retracts as the tip penetrates the skull. The pins screw into the rigid rod so that the points are tilted in the direction of the pull. This results in the pins pressing into the skull when traction is applied and ensuring that they do not pull out. A squeezing pressure of 30 pounds is applied to the skull when the pins are properly positioned.[3] An



FIGURE 121-1. The Gardner-Wells tongs.

S-shaped hook is permanently attached to the top of the Gardner-Wells tongs. The string and traction weights are attached to this hook. Permanently attached to the S-hook is a metal plate that is engraved with the instructions (**Figure 121-3**). **The instruction plate faces upward and is readable when the Gardner-Wells tongs are properly applied (Figure 121-4).**

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain an informed consent to apply the Gardner-Wells tongs. Signed consent may be omitted in cases where the patient is immobilized or has an altered mental status. Document the reason for the lack of a signed consent in the medical record. Intravenous sedation may be required in certain cases, at the discretion of the treating Emergency Physician.

Consider the use of some form of deep venous thrombosis prophylaxis since the application of Gardner-Wells tongs requires the patient to remain bedridden. The use of sequential compressive devices (SCDs) is simple, easily applied in the Emergency Department, and will not cause complications. Consult a Spine Surgeon or Neurosurgeon before prescribing intravenous, oral, or subcutaneous anticoagulants.

Identify the anatomic landmarks required to place the Gardner-Wells tongs. The pins are introduced in the temporal region, 2 to 3 finger-breadths (3 to 4 cm) above the pinna of the ear (**Figure 121-5**). Place them directly above the external auditory meatus for neutral distraction, 2 to 3 cm posterior to the external auditory meatus for flexion distraction, and 2 to 3 cm anterior to the external auditory meatus for extension distraction. A helpful landmark is the squamosal line where the temporalis muscle inserts into the skull. Tong placement should be below this line to allow

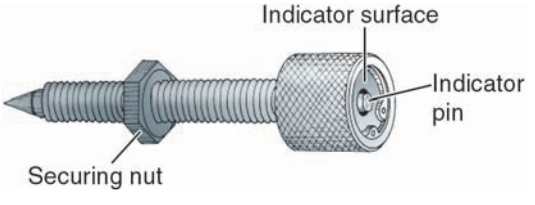


FIGURE 121-2. The calibration pin of the Gardner-Wells tongs.



FIGURE 121-3. Instructions for the use of the Gardner-Wells tongs.



FIGURE 121-4. Application of the Gardner-Wells tongs to a human skull.

adequate traction. Another useful landmark is to observe for the widest biparietal diameter of the patient's skull. This usually corresponds to the landmark just inferior to the squamosal line.

The use of Gardner-Wells tongs does not require shaving the patient's hair at the proposed pin sites. Clean the skin and hair of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the skin and hair at the proposed pin sites and allow it to dry. Infiltrate 1 mL of lidocaine with epinephrine into each of the two proposed pin sites. Infiltrate subcutaneously and down to the level of the periosteum of the skull.

TECHNIQUE

The Gardner-Wells tongs are fast and easy to apply by one person. The patient should already be supine on the gurney. Stand above the patient's head. Assemble the Gardner-Wells tongs by inserting the pins into the threaded holes. Place the pins of the Gardner-Wells tongs over the proposed pin insertion sites. **The instructions on the S-hook must be facing upward and readable. If not, the tongs are upside down.** Apply the Gardner-Wells tongs so the pins are symmetrically located on each side of the head. Screw in the pins equally and symmetrically on both sides of the tongs (**Figure 121-5B**). Note that a small spring-loaded indicator pin is observed on one side of the tongs when adequate tension is applied (**Figures 121-2 & 6**). Recommendations by the manufacturer suggest that the pins should be tightened simultaneously until there is a 1 mm protrusion of the indicator pin beyond the flat surface (**Figure 121-6**). Tighten the securing nuts to prevent the tongs from loosening.

The points of the pins will not pull out when properly applied. The depth of penetration of the pins is self-limited by a gradual lessening of the spring tension and an increase in the surface area of contact between the tips of the pins and the skull. The pressure exerted by each pin is exactly the same, regardless if one pin has been advanced farther than the other. The curve of the rigid rod allows the traction loop to find its proper position.

ASSESSMENT

Gently rock the Gardner-Wells tongs to assure that the pins are properly seated within the outer table of the skull (**Figure 121-7**). Place the patient in the reverse Trendelenburg position (**Figure 121-8**). Tie a rope to the S-shaped hook. Feed the other end of the rope through a pulley at the head of the bed and apply weights. Proper attention to the head position and the axis of distraction are important elements in achieving closed reduction. Initially apply

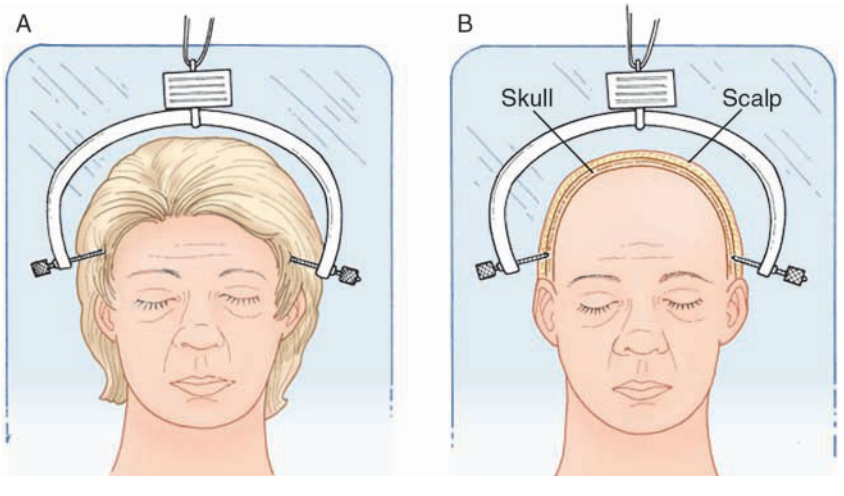


FIGURE 121-5. Application of the Gardner-Wells tongs. **A.** It can be positioned and applied without shaving the patient's entire head. **B.** Schematic demonstrating the pin position into the skull.

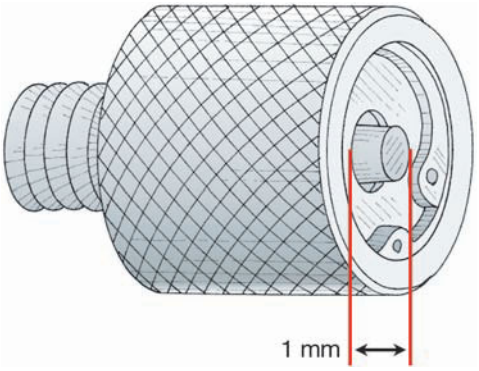


FIGURE 121-6. The calibration pin indicator is at 1 mm when the pins are properly seated in the skull.

a 10-pound weight for the head.[6] Obtain a lateral cervical spine radiograph 10 to 15 minutes after the application of the weight. Add 5 pound weights, one at a time, for each vertebral segment above the level of the injury. Obtain a lateral cervical spine radiograph 10 to 15 minutes after each 5 pound weight is added. Continue to increase the traction weight in 3 to 5 pound increments. Obtain repeat lateral cervical spine radiographs 10 to 15 minutes after each additional weight is added. Stop adding weights when the radiographs demonstrate appropriate alignment of the cervical spine. **Careful assessment and documentation of the patient's neurological function is mandatory throughout the application of weights and skeletal traction.**

AFTERCARE

Clean the pin sites every shift with povidone iodine or hydrogen peroxide solution followed by iodine ointment. Obtain daily cervical spine radiographs to follow the spinal alignment. Reduce the weight by 50% to maintain the alignment if spinal realignment is obtained with traction.

The points of the pins tend to penetrate the outer table of the skull due to the continuous pressure exerted by the springs on a very small area. Readjust the pins in 24 hours, again setting the indicator pin so that it protrudes approximately 1 mm from the flat surface. Further adjustment of the Gardner-Wells tongs is not necessary and is not recommended as it can result in erosion of the pin point through the skull.

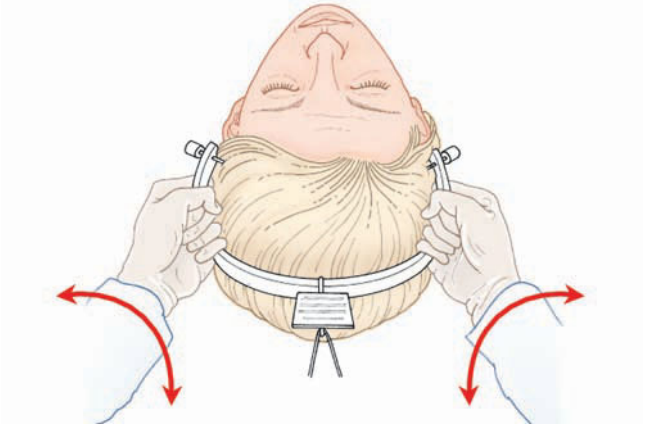


FIGURE 121-7. The Gardner-Wells tongs have been applied. The arms are grasped and gently twisted to confirm proper seating of the pins.

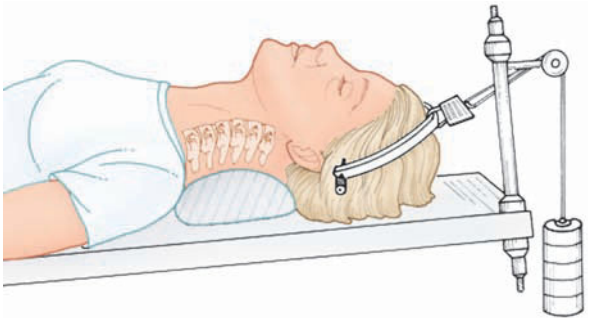


FIGURE 121-8. The patient is placed in reverse Trendelenburg and traction is applied.

COMPLICATIONS

Skull penetration from placing the pins too low in the temporal region where the skull is thinnest can lead to dural tears, epidural hematomas, and possibly intracranial injury. Pins located in the temporal fossa pierce the temporalis muscle and can cause painful mastication. Overdistraction can lead to iatrogenic injury. This is best prevented by the initial use of a minimal amount of weight necessary to distract or reduce the cervical spine injury. Pin site infections are prevented by close attention to surgical technique and daily hygiene. Other complications reported include intracranial aneurysms, CSF leaks, and osteomyelitis of the skull.

SUMMARY

The application of skeletal traction in the form of Gardner-Wells tongs is a safe, simple, and quick procedure when there is evidence of clinical or radiological cervical spine instability. It requires only local anesthesia and antiseptic preparation of the skin. Careful attention to the application technique utilizing the suggested anatomical landmarks will reduce the chances of complications. Monitoring realignment and/or reduction procedures with frequent cervical spine radiographs is prudent. Gardner-Wells tongs are not recommended as a long-term immobilization technique. Definitive management of cervical spine instability requires surgical stabilization and/or halo bracing.

122 Edrophonium (Tensilon) Testing

Eric F. Reichman

INTRODUCTION

Myasthenia gravis is an autoimmune disorder that occurs when polyclonal antibodies bind to a significant number of postsynaptic acetylcholine receptors at the neuromuscular junction leading to inadequate neuromuscular transmission.[1–3] It most commonly affects 10- to 30-year-old females and 70- to 90-year-old males. Multiple tests are available to diagnose myasthenia gravis.[3–7] These include the use of muscle biopsies, curare, edrophonium chloride (Tensilon), electromyography, ice packs, neostigmine, nerve stimulation, and serologic testing. The edrophonium test is the most commonly used diagnostic test for myasthenia gravis.[8–10] Many of these techniques are seldom used and not feasible

to perform in the Emergency Department. For these reasons, only the edrophonium test and the ice pack test will be described in this chapter.

ANATOMY AND PATHOPHYSIOLOGY

Acetylcholine is a neurotransmitter of the neuromuscular junction that is released by the presynaptic nerve terminals when stimulated.[4,11] An electrical potential is produced at the myoneural end plate when sufficient numbers of the postsynaptic receptors at the neuromuscular junction are bound by the released acetylcholine. This electric potential then propagates and ultimately leads to muscle contraction. Simultaneously, acetylcholinesterase rapidly terminates the neurotransmission by metabolizing the acetylcholine in the synaptic cleft of the neuromuscular junction.

Myasthenia gravis is an autoimmune disorder that occurs when polyclonal antibodies bind to postsynaptic acetylcholine receptors at the neuromuscular junction.[2–4,11] This leads to inactivation of the receptors and inadequate neuromuscular transmission. Myasthenia gravis is characterized clinically by muscle weakness that develops after repetitive muscle contraction.

Patients are divided into two clinical groups. The first includes patients who present with ocular complaints. Patients most commonly present with some degree of ocular muscle involvement. Diplopia is the most common patient complaint. Ptosis is the most visible sign noted on the physical examination. Diplopia with disconjugate gaze can be elicited by having the patient maintain a vertical gaze for approximately 3 minutes. Ptosis can also be made to worsen by having the patient maintain an upward gaze for the same duration of time. These patients may or may not have associated weakness of the pharyngeal and facial muscles that present with the complaints of dysarthria and dysphagia. These symptoms can often be elicited by having the patient count backward from 100.

The second group includes patients with proximal muscle weakness. Weakness of the limbs usually involves the proximal muscles and may be asymmetric. Weakness of the muscles can be elicited by having the patient perform repetitive exercises involving the muscle groups in question. **Involvement of respiratory and pharyngeal muscles should be taken very seriously as it may lead to respiratory failure or aspiration.**[2,3,12–15]

Edrophonium chloride is a short-acting acetylcholinesterase inhibitor (anticholinesterase) used in the diagnosis of myasthenia gravis.[3,11] Its onset of action is rapid (within 1 to 2 minutes) and the duration of action is brief (2 to 5 minutes). These characteristics make it ideal to use in the Emergency Department. Edrophonium given intravenously to patients with myasthenia gravis briefly inhibits the actions of the acetylcholinesterase, thus prolonging the interaction between the acetylcholine and the postsynaptic receptors. This results in a temporary but noticeable improvement in muscle contraction.[1,14] Edrophonium can rapidly, and temporarily, reverse the signs and symptoms of myasthenia gravis.

INDICATIONS

Testing is indicated when the patient's condition is suggestive of myasthenia gravis.[4,5] Edrophonium chloride can be used for patients presenting with diplopia, facial muscle weakness, appendicular muscle weakness, or ptosis suggestive of myasthenia gravis. The ice pack test is reserved to evaluate patients presenting with ptosis.[16–18]

CONTRAINDICATIONS

There is the possibility of worsening the patient's symptoms, causing respiratory distress or arrest, and cardiac dysrhythmias. Do not administer edrophonium if resuscitative equipment, Advanced Cardiac Life Support medications, and additional support personnel are not immediately available. Edrophonium should not be administered if the Physician is not properly trained in airway management and rescue techniques. Use caution when administering edrophonium if the patient's medications can cause atrioventricular node blocking or slowing of transmission (e.g., beta-blockers, calcium channel blockers, and digoxin). These can make the edrophonium associated dysrhythmias more pronounced.

Edrophonium testing is relatively contraindicated in patients with known myasthenia gravis that are taking oral pyridostigmine (Mestinon) and present with increasing weakness. The weakness may be due to insufficient drug treatment (myasthenic crisis) or too much drug treatment (cholinergic crisis).[3] The terminology regarding these types of crises is controversial and beyond the scope of this chapter.[19,20] The patient will improve with edrophonium testing if the etiology of the weakness is a myasthenic crisis. The symptoms will worsen with edrophonium testing if the etiology of the weakness is a cholinergic crisis. Consult a Neurologist, for these reasons, prior to performing an edrophonium test on a patient with myasthenia gravis who is already taking oral anticholinergic medications.

A patient with known myasthenia gravis complaining of respiratory distress should be assessed and managed similar to any other patient with respiratory compromise. An edrophonium test is contraindicated if it is being used to improve a patient's respiratory distress. A cholinergic crisis treated with edrophonium can further compromise the patient's respiratory status, possible leading to a respiratory arrest.

The use of edrophonium is contraindicated in pregnancy. It may induce the patient into preterm labor. A neostigmine test is safer if testing is required. Testing should be performed only after consultation with an Obstetrician and a Neurologist.

Edrophonium testing is relatively contraindicated in patients with asthma, bronchospastic disease, cardiac dysrhythmias, or if a group of muscles that are weak are not easily observable. Edrophonium testing should be deferred in favor of neurological consultation and consideration of other testing methods.

EQUIPMENT

- 10 mg edrophonium chloride (Tensilon)
- Tuberculin syringe
- 10 mL syringe containing 9 mL of sterile normal saline
- Intravenous access with normal saline solution attached to the IV catheter
- Cardiac monitor
- Pulse oximeter
- Noninvasive blood pressure monitor
- Supplemental nasal oxygen
- Resuscitative equipment and medications
- Digital camera
- Ice pack, ice cubes, or instant cold packs

PATIENT PREPARATION

Explain the risks, benefits, and potential complications to the patient and/or their representative. Obtain a signed consent for the procedure. Place the patient sitting upright or supine in a bed. Obtain intravenous access. Apply supplemental oxygen, pulse oximetry, cardiac monitoring, and noninvasive blood pressure monitoring. **Resuscitative equipment and medication must be immediately available if required.**

Identify a group of muscles that can easily be observed and monitored for improvement of function. If possible, the muscle group to be tested should be fatigued. For example, have the patient look upward for 3 minutes to accentuate ptosis. Muscle groups of the extremities can be exercised for several minutes until the patient experiences fatigue. Take a picture, if a camera is available, of the muscle group to be observed after it has been fatigued. This is the "before" photograph.

Prepare the edrophonium chloride. **It is essential that the edrophonium concentration be accurate regardless of who (i.e., Emergency Physician, Nurse, or Pharmacist) prepares the solution.** It is supplied in a concentration of 10 mg/mL. Using sterile technique, transfer 10 mg (1 mL of 10 mg/mL) of edrophonium into a syringe containing 9 mL of sterile normal saline. The resulting solution will contain 1 mg of edrophonium chloride per mL of fluid. **Verify the concentration of the edrophonium solution prior to use, especially if it was made by someone else.**

TECHNIQUE

Administer the edrophonium soon after the weakened muscle is identified, carefully noted, and fatigued. Ideally, one person should administer the medication while another person observes the patient for the effects of the edrophonium chloride. **It may be administered in increasing doses up to a total of 10 mg.** Inject 1 mg (1 mL) of edrophonium chloride intravenously followed by a saline flush. Physical improvement in the observed muscle group should be seen within 30 seconds to 2 minutes if the edrophonium is effective. Muscle improvements will revert to their original state after 2 to 3 minutes. **The test is concluded if there is a positive response to the edrophonium in the observed muscle group.** Inject 3 mg (3 mL) of edrophonium chloride intravenously followed by a saline flush if there is no improvement after the first dose. **The test is concluded if improvement is seen in the muscle group**. Inject the remaining 6 mg (6 mL) of the edrophonium chloride intravenously followed by a saline flush if there is no response within 2 to 3 minutes after the second dose. **The test is considered negative and concluded if there is no response to the third dose of edrophonium (total of 10 mg). A negative test argues against myasthenia gravis, but does not completely exclude the diagnosis.**[13,15]

Some Neurologists prefer to give the entire 10 mg (10 mL) dose of edrophonium chloride as a single intravenous bolus and observe the muscle group for improvement. **This has the potential to cause significant bradycardia and is not recommended.**

The total dose of edrophonium to administer to children is 0.15 mg/kg, not to exceed 10 mg of edrophonium.[5] An initial dose of 1 mg is appropriate for children. Administer subsequent doses of 1 to 2 mg to a maximum of 0.15 mg/kg or 10 mg of edrophonium.

ALTERNATIVE TECHNIQUE

ICE PACK TEST FOR OCULAR MYASTHENIA GRAVIS

The ice pack test can be used to diagnose patients with ocular signs of myasthenia gravis.[16–18] This test is reserved for the patient presenting with ptosis and/or diplopia suggestive of myasthenia gravis. The basis of this test is the finding that patients with myasthenia gravis have symptoms that worsen in warm weather and that improve in cold weather. Based on this clinical observation, studies have shown that placement of a bag of ice directly over the eyes of myasthenia patients with ptosis actually relieved the symptoms and signs of ocular myasthenia gravis.[16,17] This test is quick, simple, inexpensive, and easy to perform in the Emergency Department. It has none of the potential complications associated with the intravenous administration of edrophonium chloride. There are no contraindications to performing in this test.

Place a bag of ice directly over the eye with ptosis and/or diplopia for 2 minutes or until the patient is no longer able to tolerate the cold. An alternative to an ice pack is ice cubes placed in a glove or instant cold packs that are activated by compression. Remove the ice pack from the eye and observe the patient for any improvement in the ptosis or diplopia. **A clear improvement of the ptosis indicates a positive test.** This test may be limited by the patient's intolerance to the ice pack.

ASSESSMENT

These tests can be positive and confirm the diagnosis of myasthenia gravis. **Objective findings of improved muscle function must be observed to identify the test as positive.** It is very common to observe fasciculations of the facial muscles or tongue after the intravenous administration of edrophonium chloride. **Muscle fasciculations are not considered a positive test.** The patient having the subjective feeling of "feeling better" without objective evidence of improved muscle function is also not considered a positive test. Document improvement by taking a photograph. This is the "after" photograph. Place both the "before" and "after" photographs in the patient's medical record.

AFTERCARE

The patient may be safely discharged if they are ambulatory and without respiratory distress. All patients with suspected or proven myasthenia gravis should be referred to their Primary Care Physician and a Neurologist for further evaluation and management.

COMPLICATIONS

Muscarinic side effects can be seen due to the prolonged cholinergic stimulation in patients hypersensitive to edrophonium chloride. These effects include increased salivation, increased lacrimation, and miosis. Some patients may experience bradycardia, junctional rhythms, and ventricular dysrhythmias due to the increased vagal effects of the prolonged acetylcholine stimulation of the heart.[11] Older patients may experience a resultant postural syncope. **These effects are usually transient and self-limited. Intravenous atropine in low doses (0.5 mg) is effective to counteract any of the above symptomatology**.

There are no complications associated with the proper use of the ice pack test. Leaving the ice pack on the eyelids too long can result in a frostbite injury.

SUMMARY

Myasthenia gravis is an autoimmune disease that results in muscle weakness. The edrophonium test allows for a rapid, simple, and safe way to diagnose myasthenia gravis in the Emergency Department. The ice pack test for ocular myasthenia gravis offers a simple alternative to diagnose myasthenia gravis. Obtain prompt Neurological consultation for all patients presenting with signs and symptoms suggestive of myasthenia gravis.

SECTION 9

Anesthesia and Analgesia

123 Local Anesthesia

Michael A. Schindlbeck

INTRODUCTION

Modern medicine can trace the use of local anesthetics back to the year 1884, when the Austrian Physician Karl Koller first used topical cocaine to assist with an ophthalmological operation.[1] The following year, the premier Surgeon William Halstead first used injected cocaine to generate the intentional blockade of nerve transmission.[2] Unfortunately for Halsted, his experiments with cocaine soon led to a concurrent dependency.[3] The emerging illicit market for this compound soon prompted the search for a less toxic agent.[3] Procaine, more commonly known by its trade name Novocain, was the first synthetic local anesthetic. It is a benzoic acid ester derivative developed by the German chemist Alfred Einhorn in 1904. Although it had less drawbacks than its cocaine predecessor, it was far from the ideal agent. Lidocaine was the first amide local anesthetic agent and was first produced in 1945. The market for more effective agents continued to blossom. Over the following decades, no less than 20 additional agents were developed for use as a local anesthetic agent, each possessing unique pharmacokinetic properties to tailor its utility to specific clinical applications. They are all synthetic derivatives of cocaine.

Parallel to this proliferation in pharmacologic development, the clinical utilization of these agents has become widespread throughout all medical specialties. The daily practice of Emergency Medicine presents multiple scenarios that necessitate their use. The Emergency Physician must maintain a familiarity with the local anesthetic agents available and their unique characteristics, have an expertise in their delivery, be knowledgeable of the potential side effects, and know how to avoid and treat adverse reactions to ensure the safest and most optimal pain relief.

PHARMACOLOGY AND PATHOPHYSIOLOGY

At a cellular level, nerve cell function and signal conduction are dependent upon a resting negative intracellular electrical potential (approximately −70 mV) as compared to the surrounding extracellular environment. This polarity results from the abundance of sodium (Na^+) cations found within the extracellular space. Membrane-based sodium–potassium (Na^+/K^+) pumps establish this sodium gradient. Adjacent voltage-gated sodium channels maintain the gradient by inhibiting the concentration mediated and electrically driven sodium influx that would invariably result. Upon the stimulation of an idle neuron, a small intracellular sodium influx ensues. This sodium influx results in a slight depolarization of the resting membrane potential. When a critical threshold of sodium influx is met, the voltage-gated sodium channels reflexively open. This results in a massive sodium ion influx and widespread membrane depolarization.[4–6] Impulse transmission proceeds as this membrane depolarization is propagated down the entire length of the nerve fiber.[7]

Local anesthetic agents function by reversibly binding to membrane-based sodium channels, thereby inhibiting the initial sodium influx that results upon the stimulation of an idle neuron.[4–9] If a significant number of these channels are blocked, the critical threshold of sodium influx required for the voltage-gated sodium channel opening cannot be met, widespread membrane depolarization cannot occur and nerve impulses will not be transmitted. Careful examination of neuronal cells reveals that the actual binding sites for local anesthetic agents are located on the internal surfaces of their cellular membranes. Therefore, in order to function, the local anesthetic agent must first diffuse across the bi-lipid cellular membrane as an uncharged lipophilic compound. Once intracellular, the local anesthetic agent is converted to its active cationic state, terminating signal transduction and subsequently producing tissue anesthesia.[13]

All local anesthetic agents generally share the same molecular framework. They contain a lipophilic aromatic group linked to an ionizable group, usually a tertiary amine, via an intermediate linkage.[4,7] This intermediate linkage comes in two types, namely an amino-amide or an amino-ester bond. This property is used to classify the local anesthetics as either "amides" or "esters." Beyond this basic dichotomy, further variations on this generalized structure generate the altered pharmacokinetics that impart the unique qualities to the individual local anesthetic agents.[7]

The potency of a given local anesthetic agent is directly proportional to its lipid solubility.[9,10] More lipophilic agents tend to be more potent, as the more soluble agent will readily diffuse across the cellular membrane despite a lower concentration of the extraneuronal anesthetic. Therefore, a lower quantity of local anesthetic is needed to elicit the same endpoint response.[11] However, variable potencies are rarely of significance to the Emergency Physician. The available preparations utilize concentrations of the local anesthetic specifically formulated to correct for this variable potency.

The primary determinant of a local anesthetic's onset of action is its pKa.[12] The pKa is the pH at which a given drug exists in equal proportions as ionized and unionized molecules. The unionized molecules more readily cross the nerve cell membrane. A portion of the molecule becomes charged once inside the neuron. It is this ionized portion that binds most completely to receptor proteins within the sodium channels.[4,10] Commercially available local anesthetic agents are weak bases with pKa's of 7.6 to 8.9.[4] Agents with a lower pKa at physiologic pH (7.4) will have relatively more uncharged molecules free to cross the nerve cell membrane (i.e., faster onset) than agents with a higher pKa.[6,10] Low tissue pH, such as seen in abscess cavities, results in so little local anesthetic in the uncharged form that the agent is ineffective.[6] This phenomenon explains why local anesthetics function poorly in acidic environments (e.g., abscess cavities) as a greater percentage of the agent is secondarily converted to its ionized state within the extracellular environment. It also explains why the addition of a buffering agent such as sodium bicarbonate increases the pH of the injected local anesthetic solution, increasing the ratio of nonionized local anesthetic agent present, and enhancing the rapidity of anesthesia onset. Increasing the total quantity of local anesthetic injected, whether by manipulating its concentration or increasing the overall

volume, will hasten the onset of activity by augmenting the diffusion gradient and more aggressively driving the local anesthetic agent intracellularly.[7,8] Conversely, once successfully intracellular, local anesthetic agents with higher intrinsic pKa's generate more effective sodium channel blockade via their tendency to persist in an ionized and functionally active state.[8,13] The rate at which a local anesthetic agent diffuses through surrounding non-neuronal tissues also appears to be an important variable.[5,8]

A local anesthetic agent's duration of activity is typically proportional to the overall degree of protein binding.[6–8,10] Those that possess a higher affinity for the target receptor are less likely to be dislodged and thus exhibit a longer duration of action.[7,10] All of the available local anesthetic agents produce a degree of localized vasodilation. This serves to increase regional blood flow, promote systemic absorption of extracellular fluid, and thusly decrease the total duration of activity.[5,7,10] Therefore, counteracting this phenomenon by compounding a vasoconstrictor with the local anesthetic agent represents another practical way to increase the duration of action of a particular agent.[4,14] This is accomplished clinically via the addition of small doses of epinephrine.

The two classes of local anesthetic agents undergo metabolism via different mechanisms.[5,7,15–17] Esters are metabolized rapidly by plasma pseudocholinesterase to the major metabolite *para*-aminobenzoic acid or PABA.[5,7,15] PABA is allergenic and likely responsible for the infrequent allergic reactions to ester agents.[5,7,16] Patients with atypical pseudocholinesterase are at increased risk for systemic toxicity from ester anesthetic agents.[16,17] Amide anesthetic agents are metabolized more slowly by the liver to a variety of metabolites that are unrelated to PABA. Patients with impaired liver function are at increased risk for systemic toxicity from amide anesthetic agents.[16,17]

INDICATIONS

Local anesthetic agents are used in the Emergency Department for local infiltration, regional nerve blockade (Chapter 126), peripheral nerve blockade, and topical application (Chapter 124). General principles concerning their use and local infiltration will be discussed in this chapter. A complete review of specific techniques and procedures are available elsewhere in this text.

Localized injected anesthesia, or infiltrative anesthesia, represents the most common use of local anesthetic agents within the Emergency Department. It is generally a safe procedure that is technically easy to perform and well tolerated by the patient. It can be readily used for the majority of surgical procedures that are routinely performed by the Emergency Physician. This includes wound repair, foreign body removal, cutaneous abscess drainage, intravascular catheter placement, and hematoma blocks to name a few.

CONTRAINDICATIONS

The primary and most important contraindication to the use of a local anesthetic agent is a history of an allergic reaction. Less than 1% of all adverse reactions from local anesthetic agents are due to true IgE-mediated allergic phenomena.[18] Ester agents are responsible for the majority of such cases, whereas allergic reactions to amide anesthetics are exceptionally rare.[7,15,19–21] The physiology behind this finding is rooted in the divergent metabolism of the two classes of local anesthetic agents.

The ester-type local anesthetic agents are rapidly metabolized within the bloodstream by serum pseudocholinesterase, explaining their very short plasma half-lives. The secondary metabolites are derivatives of the organic compound PABA. They exhibit allergenic properties and are the agents responsible for the allergic response. This property makes ester-type local anesthetic agents (e.g., cocaine, procaine, and tetracaine) a less commonly used option in daily practice. Amide-type local anesthetic agents, however, are metabolized in the liver into nonallergenic byproducts via cytochrome P-450 mediated pathways. Allergic reactions to the amide-type local anesthetic agents are very rare but do occur. Methylparaben is a close analog of PABA and a preservative commonly used in multidose preparations of amide agents. It may account for the rare occurrence of an apparent allergic reaction to the amide class of local anesthetic agents.[7,15,16,21–24]

An agent from the opposite class may be chosen if a history of a prior allergic reaction to a particular agent is obtained from a patient requiring local anesthesia. There is no true cross reactivity between the esters and the amides.[7] A preservative-free preparation should be chosen, however, to avoid possible reaction from this source.[22] Solutions intended for single use or intravenous use tend to be free of preservatives. Intravenous formulations of lidocaine can be found in any standard Emergency Department "crash cart."

The size of the anesthetic field required for a given procedure can further dictate the utility of infiltrative anesthesia. Larger fields, by default, will require the injection of larger quantities of local anesthetic solution. Do not exceed the maximum safe dose of a local anesthetic agent (**Table 123-1**). Consider an alternative anesthetic technique (e.g., regional nerve blockade, procedural sedation) if infiltrative anesthesia requires potentially toxic local anesthetic doses. An alternative is to dilute the local anesthetic solution in half using sterile normal saline. This diluted local anesthetic solution may not provide adequate anesthesia.

Certain procedures necessitate meticulous tissue reapproximation (e.g., facial lacerations). The injection of local anesthetic solution, especially in higher volumes, can distort the surrounding tissue and diminish the probability for an optimal outcome. Consider an alternative anesthetic technique in these situations.

TABLE 123-1 Properties and Dosages for Injectable Local Anesthetic Agents

Local anesthetic class	Anesthetic agent	Relative potency	Relative onset of action	Duration of action (min)*	Maximum dose with epinephrine		Maximum dose without epinephrine	
					(mg/kg)	(mg)	(mg/kg)	(mg)
Ester	Procaine (Novocaine)	1	Slow	60–90	9.0	500	7.0	600
Ester	Chloroprocaine (Nesacaine)	3	Rapid	15–90	11.0	800	14.0	1000
Ester	Tetracaine (Pontocaine)	8	Slow	120–480	1.5	100	2.5	200
Amide	Lidocaine (Xylocaine)	2	Rapid	90–200	7.0	300	4.5	500
Amide	Mepivacaine (Carbocaine)	2	Rapid	120–240	8.0	300	7.0	500
Amide	Bupivacaine (Marcaine)	8	Moderate	180–600	3.0	175	2.0	225
Amide	Etidocaine (Duranest)	8	Fast	120–240	0.4	300	8.0	400

*Longer times represent the addition of epinephrine to the local anesthetic solution.

Topical anesthetic agents are contraindicated on mucous membranes, the eye, denuded skin, or burned skin as they are rapidly absorbed through these tissues. Such absorption can produce severe systemic toxicity and death. Eye contact can produce corneal injury. Topical agents containing cocaine and epinephrine are contraindicated in regions of end artery flow because they can result in intense vasoconstriction.[25]

Infiltration of a wound with 1% diphenhydramine is clinically effective as an alternative agent in the rare circumstance that a patient has a true IgE-mediated allergy to the local anesthetic agents.[26] Diphenhydramine is more painful to inject than the local anesthetic agents. It was less effective at attaining adequate anesthesia when compared to local anesthetic agents. **Reserve the use of diphenhydramine for the rare instance of a patient with an actual local anesthetic allergy.[26]** Dilute the 5% parenteral formulation of diphenhydramine to 1% (add 1 mL of diphenhydramine to 4 mL of normal saline) to make a solution for local infiltration.

EQUIPMENT

- Syringes, 1 mL to 20 mL sizes
- Needles, various sizes and lengths
- Local anesthetic solution, with and without epinephrine
- Alcohol swabs, povidone iodine, or chlorhexidine
- Gauze squares
- 8.4% sodium bicarbonate solution (1 meq/mL)
- Gloves
- Face mask with an eye shield or goggles
- 5% parenteral diphenhydramine solution

Universal precautions are of utmost importance in performing any procedure using a local anesthetic agent. It is vital to wear gloves when administering topical anesthetic agents to protect the fingers, to prevent absorption of the local anesthetic agent through the fingers of the healthcare worker, and to prevent introduction of bacteria into the wound. Wear a mask with a face shield or goggles to prevent accidental mucous membrane exposure if the injectable local anesthetic solution shoots out of the wound margins.

One of the most important determinants of pain response during administration of a local anesthetic agent is needle size. Use a 25 or 27 gauge needle for infiltration to minimize pain. A long needle allows for the infiltration of a larger region with a single needle pass and decreases the number of times tissues must be punctured. A 2.0 inch, 27 gauge needle is typically an optimal choice. The needle should not be inserted more than two-thirds of its length to prevent inadvertent breakage within the tissues.[12] Another important factor is the rate of infiltration. A slow steady method minimizes the pain response.

Many Emergency Departments have a small local anesthesia tray or basket containing the necessary equipment for providing local anesthesia. Such a kit may include the following items. Needles in sizes from 18 to 30 gauge, 1 to 2 cm long and 4 cm long. Syringes ranging from 1 mL (tuberculin) through 10 mL. Cotton-tipped applicators for the application of topical agents. Local anesthetic agents such as 1% and 2% lidocaine, 0.25% and 0.5% mepivacaine and bupivacaine, and the same agents combined with 1:200,000 epinephrine. Sodium bicarbonate may be used for buffering the local anesthetic agent. Alcohol swabs, povidone iodine swabs or solution, or chlorhexidine are required for cleansing the skin. Nonsterile and sterile examination gloves are required for the infiltration of the local anesthetic agent and performing the procedure.

PATIENT PREPARATION

Discuss the procedure with the patient and/or their representative. The most common adverse reaction to a local anesthetic agent is a vasovagal reaction.[12] This complication is more likely when patients are anesthetized while sitting in an upright position (e.g., dental procedures). The Emergency Physician must take precautions to alleviate secondary injury to the patient. Whenever possible, place the patient lying in a bed with side rails up to prevent injury no matter how minor the procedure. Friends and family members have been reported to syncopize upon witnessing injections. Therefore, they should either be asked to leave the room prior to starting or kept in a sitting position throughout the duration of the procedure. Sedation can minimize the response to treatment while maintaining stable vital signs and spontaneous respirations when the patient exhibits considerable anxiety. Refer to Chapter 129 regarding the details of procedural sedation.

Prepare the area prior to injecting local anesthetic solution. Clean the skin of any dirt and debris. Apply an alcohol swab, povidone iodine, or chlorhexidine to the skin over the injection site and the surrounding area and allow it to dry. Apply sterile drapes, if applicable, to delineate a sterile field.

LOCAL INFILTRATION AND PERIPHERAL NERVE BLOCKADE

LOCAL ANESTHETIC DOSING

Infiltration anesthesia refers to the injection of a local anesthetic solution directly into the subcutaneous tissues about to be manipulated. The first step to be considered is the selection of the proper anesthetic. Barring a history of an allergic reaction to a given class of local anesthetic agents, the amide anesthetics lidocaine (Xylocaine) and bupivacaine (Marcaine) are the most common agents employed within the Emergency Department. The choice between these agents should be tailored to the individual patient and situation. Lidocaine exhibits a quicker onset of activity, whereas bupivacaine exhibits a longer duration of action (**Table 123-1**). Lidocaine possesses a wider margin of safety, with larger doses required to illicit a toxic response. In amide allergic patients, the ester agent procaine (Novocain) is a reasonable alternative.

It is important to keep in mind the maximal recommended doses for the chosen local anesthetic agent to avoid systemic toxicity (Table 123-1). The disadvantage of local infiltration is that a large amount of local anesthetic must be used for a small area. Extensive wounds may require toxic doses of local anesthetic agents. A lower concentration or the addition of epinephrine will allow a larger volume of local anesthetic to be used. Local infiltration may distort the wound edges and complicate the repair.

The maximal recommended dose of a local anesthetic agent is the same for local infiltration or regional nerve blockade. **It is important to properly calculate the amount of local anesthetic agent administered to a patient.** Local anesthetic solutions are supplied with the concentration denoted as a percentage (e.g., 1% lidocaine, 0.25% bupivacaine, 4% cocaine). This percentage must be converted to mg/mL. A 1% local anesthetic solution is prepared by dissolving 1 g of the local anesthetic agent in 100 mL of diluent. This results in a concentration of 10 mg/mL (1 g/100 mL = 1000 mg/100 mL = 10 mg/mL). **A simple method to calculate the strength of a local anesthetic solution is to move the decimal point one place to the right to convert from a percentage to a concentration in mg/mL (e.g., 0.25% = 2.5 mg/mL, 2% = 20 mg/mL, 4% = 40 mg/mL). This value must be multiplied by the volume to be administered**

to determine the total amount (in mg) of local anesthetic agent administered. This value must be compared to the maximal allowable dose (Table 123-1) to ensure it is not a toxic dose.

EPINEPHRINE CONTAINING AGENTS

Epinephrine can be added to a local anesthetic solution to prolong its duration of action, to assist with hemostasis by local vasoconstriction, and to slow the absorption of the local anesthetic agent. This allows for larger quantities of local anesthetic solution to be injected without the concern for systemic toxicity. Local anesthetic agents are generally compounded with epinephrine in a 1:100,000 or 1:200,000 solution and usually come packaged as such by the manufacturer.

If a compounded solution is not available, one can be readily formulated. Begin by obtaining 1:1000 epinephrine that is usually administered to patients for severe allergic reactions or bronchospasm. This solution of 1:1000 contains 1 g of epinephrine per 1000 mL or 1 mg/mL of epinephrine. Diluting this solution by a factor of 100 will result in the desired 1:100,000 concentration. Place 0.1 mL of 1:1000 epinephrine into 10 mL of local anesthetic solution to make a dilution of 1:100,000 (or 0.010 mg/mL). Place 0.1 mL of 1:1000 epinephrine into 20 mL (or 0.05 mL in 10 mL) of local anesthetic solution to make a dilution of 1:200,000 (or 0.005 mg/mL).

REDUCING THE PAIN OF INFILTRATION

Local anesthetic agents are weak bases. They are packaged, however, as hydrochloride salts with a pH of 4 to 6 to increase their solubility and shelf life. This acid pH causes much of the pain associated with the injection of local anesthetic agents.[4,6] Because epinephrine is unstable at a physiologic pH, commercial solutions containing epinephrine are generally formulated with similarly acidic pH values. **Buffering lidocaine, mepivacaine, or bupivacaine with sodium bicarbonate has been shown to reduce the pain of injection significantly.**[25,27,28] Raising the pH of the local anesthetic agent increases the percentage of local anesthetic molecules in the nonionized diffusible state.[27] This may allow nearly instantaneous penetration of the nerve cell membrane by the anesthetic molecules and block or reduce the pain of infiltration.[27,29,30] Raising the pH also contributes to decreasing the pain of the injection. Buffering local anesthetic agents does not appear to affect the duration or degree of anesthesia. There does not appear to be an increase in the degree of anesthesia, the serum levels of the local anesthetic agent, or in toxicity of buffered anesthetic agents.

Caution must be exercised when buffering highly lipophilic and less soluble anesthetic agents, like bupivacaine, because precipitation can occur.[4] To buffer a local anesthetic agent, use the prepackaged 50 mL ampules of 8.4% (1 meq/mL) sodium bicarbonate found in any "crash cart." Add 1 mL of 8.4% (1 meq/mL) sodium bicarbonate to 10 mL of 1% lidocaine or 1% mepivacaine, with or without epinephrine, to achieve buffering.[27] Add 0.05 to 0.10 mL of 8.4% (1 meq/mL) sodium bicarbonate to each 10 mL of 0.5% bupivacaine.[28]

The use of warm lidocaine [37°C (98.6°F) to 42°C (107.6°F)] decreases the pain of infiltration.[31,32] The exact etiology of this is unknown. It is hypothesized that warm lidocaine does not stimulate cold receptors and it diffuses into tissues faster. Warm the local anesthetic agent by placing it in a blanket warmer or a water bath. The combination of both warming and buffering a compound results in an even less painful procedure.[32,33]

Other simple measures can help to limit the pain of the local anesthetic injection. Limit the infiltration of a local anesthetic solution to the subdermal space. This practice helps to limit the overall pain of injection, minimize the degree of tissue distortion, and protect the patient from the inadvertent injection into an intravascular space. When anesthetizing an open wound, make every attempt to infiltrate through the exposed wound edges rather than puncturing through the adjacent intact skin (**Figure 123-1**).[34] This will provide a much less painful experience for the patient. Infiltrate grossly contaminated wounds percutaneously through clean and intact skin to decrease the risk of spreading the contamination and to decrease the risk of an infection related to the infiltration. Also limit the number of needle punctures through uninjured skin in contaminated wounds. The application of gentle pressure to the injection site prior to the injection, such as pressing a sterile cotton-tipped applicator against the skin, limits the pain associated with childhood vaccinations.[35] Dentists have been using similar techniques for many years to perform dental blocks. The use of this technique in the Emergency Department is limited by the fact that infiltrations into previously inflamed tissue, and thus any kind of additional stimulation, may simply expose the patient to unwarranted additional pain. A slower rate of local anesthetic solution injection is associated with less pain.

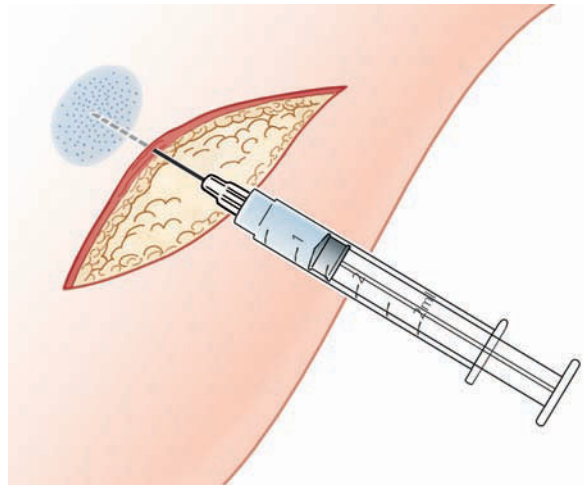


FIGURE 123-1. The needle is inserted through the wound edge to inject local anesthetic solution.

Insert the needle into an open wound at its apex (**Figure 123-2**). Tunnel the needle its entire length down the wound margin. Inject the local anesthetic solution while slowly withdrawing the needle.

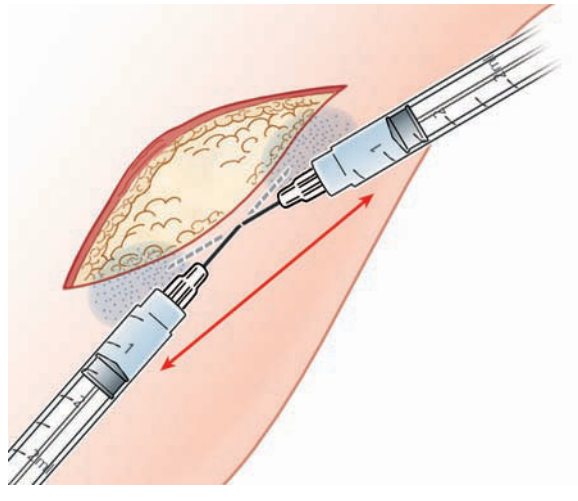


FIGURE 123-2. The needle is inserted through the intact skin below the wound to inject local anesthetic solution.

Do not completely withdraw the needle from the skin. Redirect it along the opposing wound margin and repeat the technique. This can be performed down the entire length of the wound as necessary. Minimizing the number of skin punctures will help to minimize pain.

The pain upon injection of local anesthetic agents can be reduced by following a few simple suggestions. Warm and/or buffer the local anesthetic agent as discussed previously. Inject the local anesthetic agent slowly. Inject open wounds through the wound edges and not through intact skin. An exception to this is grossly contaminated wounds. Infiltrate subdermally to minimize pain and tissue distention. Insert and advance the needle to create a tract and inject as the needle is withdrawn to minimize tissue distention. Do not totally withdraw the needle after infiltration. Leave the tip of the needle within the skin and redirect the needle to prevent excessive skin punctures.

COMBINING LOCAL ANESTHETIC AGENTS

Physicians have for some time combined various local anesthetic agents in an attempt to exploit the unique properties of each individual local anesthetic agent and achieve both a rapid onset of action and a prolonged duration of action.[36,37] Lidocaine, with its rapid onset, can be safely mixed in a 1:1 ratio with longer acting bupivacaine or mepivacaine. Employing this mixture may be no more dangerous than sequentially administering equal doses of either parent compound. **The value of such an approach is questionable.** Enough concern still persists regarding the potential toxicity of this mixture to often preclude its use within the Emergency Department. The combined benefits might not be as relevant within the Emergency Department, as the majority of the studies referenced come from the anesthesia and surgical literature.

It is important to realize that the toxic effects in an overdose situation are additive, even if an amide and ester are combined.[38,39] Mixing two local anesthetic agents can complicate the overall dosage calculations and enhance the potential for a toxic injection. **It is also difficult to determine the maximum dose if two local anesthetic agents are mixed together.** If the patient develops an allergic reaction, it will be impossible to determine which local anesthetic agent is the causative agent. The combination of local anesthetic agents can therefore not be currently recommended. **Use lidocaine containing epinephrine to prolong the anesthetic effect rather than combining it with a second local anesthetic agent.**

ALTERNATIVE TECHNIQUES

It has been known since the 1940s that injected antihistamines exhibit anesthetic properties. A 1956 study comparing the infiltration of diphenhydramine to procaine demonstrated equal anesthetic properties. Subsequent Emergency Medicine based studies have shown equal anesthetic results when comparing the injection of 1% solutions of either lidocaine or diphenhydramine, although the latter was associated with a more painful infiltration. A further study comparing 0.5% diphenhydramine to 1% lidocaine demonstrated a resolution in the disparity regarding the pain of injection, although at the expense of a decreased anesthetic effect.[40] The overall duration of anesthesia produced by infiltrated diphenhydramine is shorter than that of lidocaine. A concern has arisen regarding the possible destruction of local tissue and subsequent skin necrosis associated with diphenhydramine infiltration. Multiple early experiences had reported this complication. However, an appropriate dilution prior to injection should eliminate this potential complication. Dilute 1 mL of standard parenteral 5% diphenhydramine solution with 4 mL of sterile normal saline to achieve a 1% solution that is suitable for injection.[41,42] Diphenhydramine should be considered a viable alternative to the more commonly used local anesthetic agents when they are contraindicated.

ASSESSMENT

It is important to wait long enough after the local anesthetic agent is administered to allow the onset of adequate anesthesia before the planned procedure is started. A period of 5 to 10 minutes is adequate for subcutaneous local infiltration. A period of 15 to 30 minutes may be required for peripheral nerve blocks. A simple examination of the area being anesthetized with fine touch and pinprick is important to insure adequate anesthesia prior to the procedure. It may be necessary to inject additional local anesthetic solution in areas of continued sensitivity, keeping in mind the total dose injected to avoid toxicity.

AFTERCARE

The Emergency Physician should observe the patient for a minimum of 15 minutes following the use of local anesthesia to insure no evidence of an adverse reaction. The length of time analgesia is maintained depends upon the agent used for the procedure (**Table 123-1**). The patient need not wait in the Emergency Department for normal sensation to return prior to discharge. They should be instructed to return to the Emergency Department if normal sensation has not returned within 12 to 24 hours.

COMPLICATIONS

Toxic reactions to local anesthetics agents are far more common than allergic sequelae.[12,17,43] The propensity for toxicity is directly proportional to the potency of the drug.[7,9,10] **Table 123-1** lists the recommended maximal doses for commonly used local anesthetic agents. **These are only estimates and in certain circumstances the toxic dose might be considerably less.[7,20] Infiltration into highly vascular areas, inadvertent intravascular injection, or application to mucous membranes may cause toxicity at accepted standard doses.**[7]

It is unlikely that toxic serum concentrations of local anesthetic agents will be reached in most clinical situations in the Emergency Department. For example, the maximum dose of 1% lidocaine without epinephrine in a 70 kg patient would be approximately 31.5 mL, a volume more than adequate for most wounds. **It is important to be vigilant of the total dose administered, especially in patients with large or multiple lacerations in whom higher doses of local anesthetics may be required.** A less concentrated form of the local anesthetic agent (e.g., 0.5% lidocaine as opposed to 1%) may be used when the maximum dose could be exceeded. General anesthesia in the Operating Room may be required to repair larger wounds.

The major manifestations of local anesthetic toxicity occur in the central nervous system (CNS) and the cardiovascular system.[6,9,12,15] Initial signs and symptoms are of CNS excitation. This occurs as a result of the suppression of inhibitory cortical neurons that permits unopposed functioning of facilitatory pathways. Signs and symptoms include lightheadedness, dizziness, nystagmus, sensory disturbances (e.g., visual difficulties, tinnitus, perioral tingling, metallic taste in the mouth), restlessness, disorientation, and psychosis. Slurred speech, muscle twitching, and/or tremors may immediately precede seizures. There may also be augmentation of medullary and sympathetic activity with resultant tachypnea, hyperpnea, hypertension, and tachycardia. Generalized depression of the entire CNS can occur and is manifested as drowsiness, coma, and respiratory arrest.[9,15]

Management of CNS toxicity should begin with an assessment of the patient's airway, breathing, and circulation. Treatment is primarily supportive. Hypoxia and acidosis enhance CNS and myocardial absorption of local anesthetic agents and must be addressed aggressively. Hypocapnia raises the seizure threshold (to prevent convulsions) by inducing cerebral vasoconstriction and by decreasing the delivery of the local anesthetic agent to the CNS.[7,44] An alert and cooperative patient may be instructed to hyperventilate if early signs of toxicity are present.[6,20,45] Manage seizures with intravenous benzodiazepines as they raise the CNS threshold to local anesthesia-induced convulsions. The metabolism of local anesthetics is short enough that loading patients with long-acting antiseizure agents, such as phenytoin, is generally not required. The effect of phenytoin upon sodium channel conduction can potentiate the arrhythmogenic property of local anesthetics. Administer short-acting neuromuscular blocking agents, such as succinylcholine or vecuronium, until serum levels of the local anesthetic agent decline if the seizures fail to respond to benzodiazepines.[7] Succinylcholine, however, is metabolized by pseudocholinesterase. This is the same plasma enzyme that metabolizes ester anesthetic agents. Therefore, avoid succinylcholine in ester-induced seizures.[7,6,20]

The cardiovascular system is relatively resistant to local anesthetic toxicity in comparison with the CNS.[17,24] The cardiovascular system does not exhibit toxicity until much higher blood levels are reached.[17,24] Cardiovascular toxicity results from the direct effects upon cardiac and vascular smooth muscle and the indirect effects upon autonomic tone. Complications are the result of negative inotropism, peripheral vasodilatation, and slowing of the myocardial conduction system.[9,15] Arterial dilation combined with decreased cardiac contractility leads to progressive hypotension and eventual cardiovascular collapse. Additionally, the sodium and calcium channel blockade exhibited at more toxic doses of local anesthetic agents predisposes the patient to fatal arrhythmias. The end results are hypotension, bradycardia, prolonged electrocardiographic intervals, and cardiac arrest.[9,10,15] Treatment is supportive with intravenous fluids, vasopressors, and inotropes as the mainstays of therapy. Avoid class IB antidysrhythmics due to their potential to accentuate cardiac sodium channel blockade. Vasopressors with positive inotropic effects, such as dopamine, will treat profound cardiovascular depression.[7]

Bupivacaine is more cardiotoxic than other local anesthetic agents. Treatment of bupivacaine cardiotoxicity has shown a potential benefit with the use of high dose intravenous insulin (2 IU/kg) in concert with supplemental intravenous glucose and intravenous potassium boluses.[46] The infusion of a lipid emulsion (i.e., Intralipid) has been proposed for use in bupivacaine-associated cardiac arrests. Several recent case reports have substantiated the use of Intralipid. The actual mechanism of action is unclear, but proposals include the extraction of lipophilic anesthetics from their target tissues via the fatty emulsion and/or the direct antagonization of anesthetic mediated suppression of cardiac fatty acid metabolism.[47]

There is no accepted standard protocol for the administration of Intralipid. A proposed dosing regimen is described here. Of note, these rescue interventions should be attempted only in patients failing to respond to standard ongoing ACLS protocols. Administer an initial bolus of 1.5 mL/kg of a 20% Intralipid solution. This is the standard used for adult total parenteral nutrition (TPN). Repeat this dose up to two additional times over a 5 minute period for patients in refractive asystole. If the return of spontaneous circulation ensues, initiate a maintenance intravenous infusion of 0.25 mL/kg/min for 30 to 60 minutes. This allows the toxic effects of the local anesthetic agent to dissipate. The Intralipid infusion can be easily titrated to maintain a stable perfusing blood pressure. Of note, although often readily available, the drug propofol is compounded in a 10% lipid solution and therefore not applicable for similar use. The volume of propofol solution needed to reverse bupivacaine toxicity would require the administration of a toxic dose of propofol.[48–50]

Adding epinephrine to a local anesthetic agent increases both the amount of drug that can be administered and the duration of action.[4,14] It also decreases bleeding into the surgical field. There are, however, significant drawbacks to the use of epinephrine. This includes increased pain of infiltration, increased wound inflammation, increased wound infection rates, uncomfortable side effects in susceptible patients (e.g., palpitations, tremors, syncope), and the potential for severe tissue ischemia if used in regions of end arterial circulation such as the digits, the tip of the nose, the pinna, or the penis.[12] Emergency Medicine dogma cautions against the use of an epinephrine containing local anesthetic agent in these regions in order to avoid potential distal tissue infarction and necrosis. However, the clinical evidence supporting this concern is questionable, and the little that does exist is over 50 years old. A study of elective hand procedures demonstrated no adverse consequences following over 3000 digital injections of epinephrine containing local anesthetic solutions.[51,52] Literature focused on the inadvertent infiltration of epinephrine into fingers via improperly used autoinjectors has failed to demonstrate a single significant case of tissue necrosis. The majority of these cases demonstrate a spontaneous return of perfusion with only conservative treatments (i.e., warm soaks and digital massage). Prolonged vasospasm and ischemia in these areas can be reversed with the subcutaneous infiltration of 1.0 mL of 1:1000 phentolamine (i.e., 1 mg) diluted with saline in a 1:1 mixture at the local anesthetic injection site.[53–57] A less invasive alternative is to apply topical nitroglycerine paste to the affected area. Caution must be used when administering epinephrine to patients who are elderly, taking beta-blockers, or with a history of coronary artery disease, hypertension, hyperthyroidism, or pheochromocytoma.[6,12] Inadvertent intravascular injection of epinephrine can have fatal consequences.[58,59]

The potential systemic complications unique to epinephrine are not often an issue. Using 1:100,000 preparations, one must infiltrate 30 mL of local anesthetic solution to attain a cumulative dose of 0.3 mg, a quantity commonly used subcutaneously in the practice of Emergency Medicine. Such a large volume is rarely encountered with infiltrative anesthesia. Consider an alternative anesthetic technique if such a large volume of local anesthetic solution containing epinephrine is required. Rare reports of patient mortality secondary to an inadvertent intravenous injection have been reported. Extreme care should be taken when using such preparations in any patient with suspected cardiovascular disease.

True allergic reactions are rare adverse events to the local anesthetic class of medications. Effective management of an allergic reaction depends upon its severity and may include the use of epinephrine, antihistamines, steroids, and vasopressors. A complete review of the management of allergic reactions and anaphylaxis can be found in standard Emergency Medicine textbooks.

Methemoglobinemia has been reported to occur following the use of both classes of local anesthetic agents. It is most commonly seen after the use of the topical agent benzocaine.[60] The use of this medication is discussed elsewhere in this book. The Emergency Physician must be aware of this potential complication and intervene appropriately.

Injection of local anesthetic agents can cause complications in the area of the infiltration. These agents have not been shown to increase the incidence of wound infections. Do not inject local anesthetic agents into a joint prior to obtaining synovial fluid. They

can result in false-negative culture results, false-negative crystal analysis, and false-positive (anesthetic crystals) crystal analysis. Needle punctures of arteries, nerves, and veins are usually a temporary inconvenience with no long-lasting consequences. Intraneural injection can result in temporary or permanent nerve injury. Never inject local anesthetic agents if the patient experiences paresthesias (indicating intraneural needle placement). Withdraw the needle 1 to 2 mm and allow the paresthesias to resolve before infiltrating with the local anesthetic solution. Never redirect the needle when more than the tip is subcutaneous to prevent needle breakage.

SUMMARY

Local anesthetic agents have become an indispensible tool in the practice of Emergency Medicine. Emergency Physicians often rely on local anesthetic agents to relieve patient discomfort and provide wound care. Infiltrative anesthesia represents one of the most prevalent uses for these agents. It is relatively quick, easy to perform, well tolerated, and when performed correctly, has a large margin of safety. Complications can and do arise. The Emergency Physician must be ready to recognize the warning signs of local anesthetic toxicity and intervene appropriately. An expertise in the use of these agents plays an important role in the practice of the art of medicine. For hundreds of years physicians have sought to relive the pain and suffering of our patients. These agents allow us to come closer to attaining that goal.

124 Topical Anesthesia

Erika D. Schroeder and Peter Taillac

INTRODUCTION

Invasive procedures can cause significant anxiety in patients both young and old, much of which is related to fear of the associated pain. Topical anesthesia has been shown to decrease pain and anxiety surrounding procedures such as lumbar puncture, intravenous access, and laceration repair.[1] This chapter will discuss topical anesthetic agents and the range of techniques that are available for delivery of these agents.

ANATOMY AND PATHOPHYSIOLOGY

Mechanical, thermal, and chemical stimuli are detected by nerve endings called nociceptors. These pain receptors are located in the skin, specifically in the dermis and the epidermis, below the stratum corneum (**Figure 124-1**). Nociceptors are free nerve endings that have their cell bodies outside the spinal column in the dorsal root ganglia. The intact stratum corneum, the outer layer of cornified epithelial cells of the skin, is an effective barrier to the outside environment. Local anesthetics must transverse the stratum corneum to be delivered to the terminals of cutaneous sensory nerve fibers.

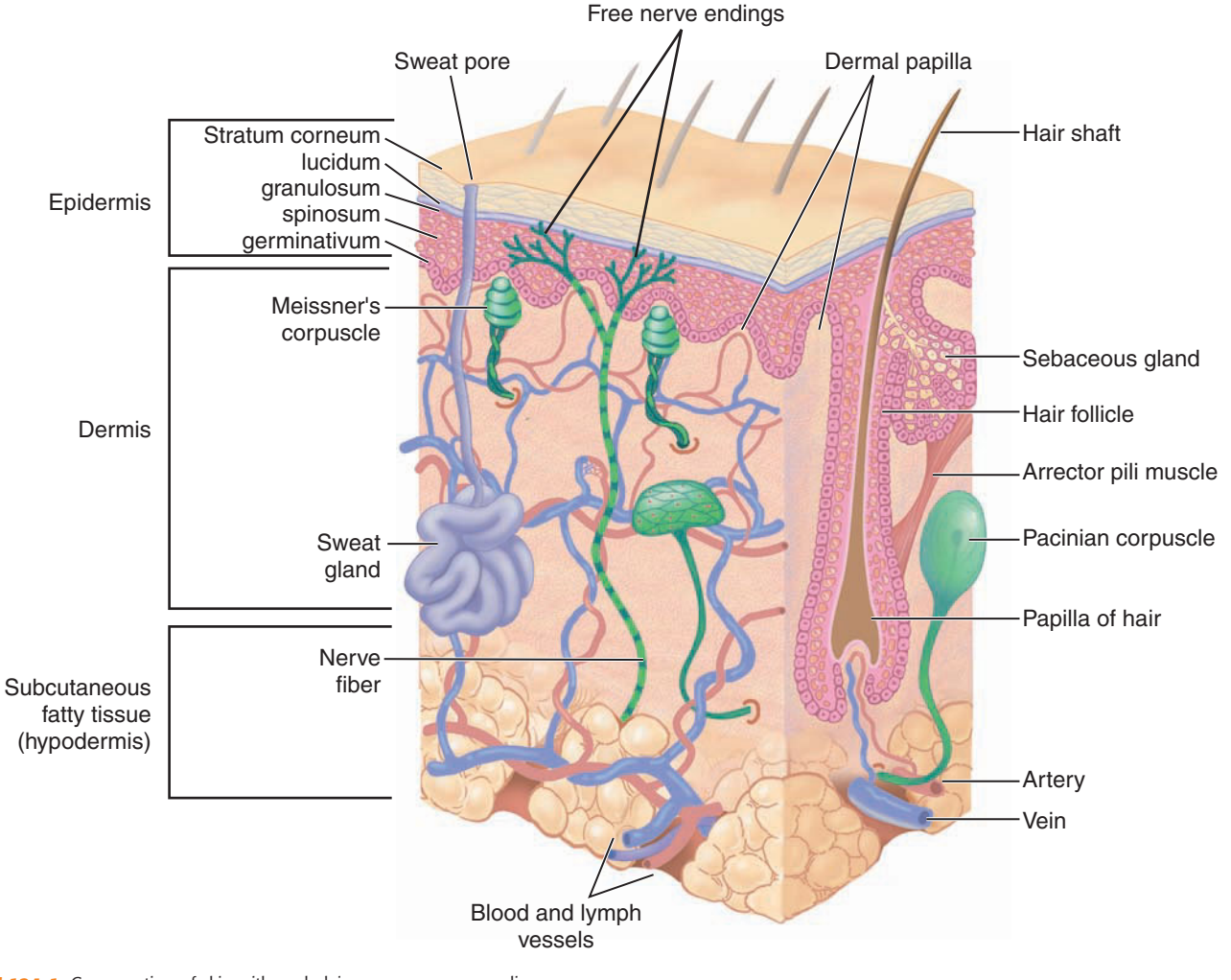


FIGURE 124-1. Cross section of skin with underlying sensory nerve endings.

The three methods by which the stratum corneum can be bypassed to deliver a local anesthetic are direct injection, passive diffusion, and needle-free drug delivery strategies. Refer to Chapter 123 for the complete details regarding the direct injection of local anesthetic solution. This chapter will discuss techniques for enhancing passive diffusion and needle-free administration of local anesthetic agents, collectively known as topical anesthesia.

INDICATIONS

Topical anesthesia is commonly utilized in the Emergency Department in two situations. The first is the patient experiencing pain from an injury such as a laceration, abrasion, or contusion. The second is in the patient who will undergo a painful procedure such as venipuncture, lumbar puncture, abscess incision and drainage, or laceration repair.

Topical anesthetic agents offer several potential advantages over local infiltration anesthesia. They are less painful to apply, do not distort the wound margins, and decrease the need for sedation.[2] The major limitations of topical anesthesia have been the extended time required to achieve anesthesia and the lack of sufficient analgesia in many clinical situations that often requires supplemental infiltration anesthesia. These constraints have limited the use of topical anesthesia in the Emergency Department. Several new agents and delivery techniques have addressed these limitations with some success, offering the Emergency Physician more options for providing anesthesia.

CONTRAINDICATIONS

There are very few contraindications to the use of topical anesthetics. The topical anesthetic agent is typically not systemically absorbed to any significant degree. However, they can cause local adverse reactions and should not be used in patients who are allergic to the medication or its components (such as preservatives). **Use care when applying topical anesthetics to mucous membranes, as absorption is typically more rapid and efficient than through skin and more substantial systemic absorption can occur.** A relative contraindication to using topical anesthetic agents are patients taking Class 1 antiarrhythmics such as mexiletine and tocainide, as they can produce additive and possibly toxic effects. Many of the topical anesthetics are contraindicated or require special ophthalmic formulations for use in the eye. When using topical anesthetics in neonatal patients, special care and attention to dosing is imperative to avoid toxicity. Specific contraindications and concerns for each topical agent and application technique are addressed later in this chapter as well as in Chapter 123.

EQUIPMENT

General Supplies

- Alcohol swabs
- Povidone iodine or chlorhexidine solution
- Gauze squares, 2 × 2 and 4 × 4
- Gloves

Topical Cream, Gel, or Liquid

- TAC (0.5% tetracaine, 1:2,000 epinephrine, and 11.8% cocaine)
- LET (0.5% tetracaine, 1:2,000 epinephrine, and 4% lidocaine)
- EMLA (2.5% lidocaine and 2.5% prilocaine)
- LMX-4 or LMX-5 (4% or 5% liposomal lidocaine)
- Topicaine (4% lidocaine gel)

Iontophoresis

- 2% lidocaine hydrochloride containing 1:100,000 epinephrine
- Device to administer iontophoresis (e.g., Phoresor II or Dupel)
- Iontophoresis System

Ultrasound-assisted Local Anesthetic Delivery

- Ultrasound device (e.g., SonoPrep)
- Topical local anesthetic agent

Powdered Anesthetics

- Needle-free powder lidocaine delivery system

Lidocaine Needle-free Injection

- Needle-free injection system, prefilled or fillable
- 1% or 2% lidocaine

Heat-enhanced Diffusion

- Lidocaine–tetracaine thermal patch

Laser-assisted Transdermal Passage

- Cutaneous resurfacing laser
- Topical anesthetic agent

Topical Vapocoolant Sprays

- Topical vapocoolant spray

PATIENT PREPARATION

Discuss the procedure, its risks, benefits, complications, and alternatives with the patient and/or their representative. Take precautions to prevent further injury or pain to the patient. Cleanse the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the skin and allow it to dry. Consider administering a supplemental anxiolytic or procedural sedation if required.

PASSIVE DIFFUSION OF LOCAL ANESTHETIC AGENTS

Topical local anesthetic agents are often applied in the form of a gel or cream. There are numerous combinations of anesthetic agents to use topically on wounds. TAC (tetracaine, adrenaline, and cocaine), LET (lidocaine, epinephrine, and tetracaine), and EMLA (eutectic mixtures of lidocaine and prilocaine) are three commonly applied combinations (**Table 124-1**). Other topical local anesthetic agents include lidocaine gel and liposomal lidocaine.

TAC

Many Emergency Departments use TAC for topical anesthesia. It is a combination of 0.5% tetracaine, 1:2000 or 0.05% adrenalin (epinephrine), and 11.8% cocaine. TAC can be purchased or Hospital Pharmacists can compound these agents into a gel or liquid. It can be partitioned into individual use vials for easy application. The degree of anesthesia achieved with TAC is comparable to that of local infiltration with lidocaine for wounds on the face and scalp.[3] The effects are less profound, however, for wounds on the trunk and extremities.

The cocaine component in TAC is a powerful and effective local anesthetic agent as well as a vasoconstrictive agent. Unfortunately, TAC is a controlled substance. This makes it's storage, utilization, and monitoring subject to stringent regulation and documentation requirements. This may limit the availability and use of TAC in some institutions.

Dose recommendations generally call for 5 mL of TAC for lacerations smaller than 3 cm in length and 10 mL for lacerations greater

TABLE 124-1 Characteristics of Topical Anesthetic Agents

Medication or method	Time to anesthesia (min)	Side effects
Liposomal lidocaine (LMX-4 and LMX-5)	15–30	Skin erythema
Lidocaine, epinephrine, and tetracaine (LET)	15–30	None
Tetracaine, adrenaline, and cocaine (TAC)	20–30	Seizures, cardiac arrest (rare)
Lidocaine gel (Topicaine)	30	Local skin reactions
Eutectic mixture of lidocaine and prilocaine (EMLA)	60	Local skin reactions
Iontophoresis with lidocaine with epinephrine	10–20	Burns, local skin reactions
Ultrasound-assisted delivery	5	Local skin reactions
Powdered lidocaine injector	1–3	Contusions, minor bleeding, cellulitis
Jet lidocaine injection	1–3	Contusions, minor bleeding, cellulitis, administration pain
Heat-enhanced diffusion	10	Local skin reactions
Laser-assisted transdermal	5	Local skin reactions, administration pain
Vapocoolant sprays	0.1–0.2	Frostbite, skin erythema

than 3 cm in length.[3] Apply the chosen volume of TAC liquid or gel onto a 2 × 2 gauze square or a cotton ball. Invert the gauze square or cotton ball to apply TAC within the wound margins. Allow TAC to remain for up to 15 minutes or until visible skin blanching occurs. **Blanching indicates the presence of vasoconstriction and adequate analgesia.** The gauze pad can be held in place by the patient's gloved hand, the patient's representatives gloved hand, or with tape.

TAC is not free of complications. **Always wear gloves when handling TAC to prevent percutaneous absorption.** Do not apply TAC to tissues with an end-arteriole supply. This includes the fingers, toes, nose, ear, and penis. There is the possibility of vasoconstrictive ischemic injury to these tissues. The systemic absorption of cocaine as a result of TAC administration has been implicated in rare episodes of respiratory arrest, seizures, and death.[4,5]

LET

LET is an alternative to TAC. It is a combination of 4% lidocaine, 0.1% (1:1000) adrenaline (epinephrine), and 0.5% tetracaine. It is considered safer, similarly effective, more practical, and more cost effective to use than TAC. LET does not contain a controlled substance and has no potential for abuse. The resultant security and documentation requirements are therefore much less complicated than those required for TAC. Hospital Pharmacists can compound this agent.

Apply liquid LET by dripping it into the wound or taping a LET soaked cotton ball or 2 × 2 gauze square over the wound. The addition of methylcellulose to liquid LET makes a gel that is more adherent and can be painted on wounds. The gel form will not drip or run. Similar to TAC, it should not be placed on the digits, ear, nose, penis, or other areas that are supplied by end arteries due to the strong vasoconstrictive effect and risk of ischemia. This dogma is currently being challenged.[6]

EMLA CREAM

The use of EMLA (eutectic mixture of local anesthetics) cream has gained significant popularity, particularly in pediatric patients. It is an emulsion of 2.5% lidocaine and 2.5% prilocaine in a 1:1 ratio by weight. Each gram of EMLA contains 25 mg of lidocaine and 25 mg of prilocaine. **Apply EMLA only onto intact skin and not into open wounds.** It is nonsterile and preservative free. It is also commercially available in prepackaged transdermal disks.

EMLA is indicated prior to performing venipuncture, arterial punctures, accessing indwelling ports and reservoirs, lumbar puncture, minor skin procedures, or regional nerve blockade. Apply EMLA cream to intact skin and cover it with an occlusive dressing (e.g., Tegaderm) or apply a transdermal disk. Allow at least 1 hour for the EMLA to take effect. Analgesia is usually satisfactory after 1 hour, peaks at 2 hours, and persists for about 1 hour after it is removed from the skin. The prolonged time required for anesthesia to take effect limits its practical use in the Emergency Department. EMLA should not be applied to infants less than 3 months of age due to the risk of methemoglobinemia.[7]

LIPOSOMAL AGENTS

Liposomal Lidocaine (LMX-4 or LMX-5) is a 4% or 5% lidocaine cream that is a liposome-encapsulated formulation. The encapsulation of lidocaine keeps it from being rapidly metabolized. The lipid content of the liposomes allows for better drug penetration of the stratum corneum. The LMX-4 cream has several advantages over other topical anesthetic agents. This includes a more rapid onset of action and not requiring an occlusive dressing.[1] The most frequent adverse reaction is local erythema. Although no serious side effects have been reported with the use of LMX-4, it is recommended that it be applied to an area less than 100 cm^2 in patients who weigh less than 20 kg.[8] When compared to a placebo, intravenous cannulation after the application of LMX-4 showed improved success rates on the first attempt.[9] LMX-4 is as effective as EMLA.[10] However, buffered lidocaine injection decreased the pain associated with intravenous catheter insertion to a greater extent than lidocaine cream.[1]

TOPICAINE

Topicaine is a 4% lidocaine gel that is used for a number of procedures in the Emergency Department including placement of Foley catheters and nasogastric tubes. It is readily available and easy to use. Patients can develop a contact dermatitis, particularly if they have an allergy to amide-type local anesthetic agents. Apply Topicaine for 30 minutes prior to a procedure for maximum efficacy.

ACTIVE NEEDLE-FREE LOCAL ANESTHETIC DELIVERY

An alternative to either the injection of local anesthetic solution or the use of topical creams and gels are needle-free drug delivery systems. These techniques utilize various strategies designed to speed the delivery of the local anesthetic agent across the stratum corneum.

IONTOPHORESIS

Iontophoresis is a process by which direct electrical current facilitates dermal penetration of positively charged lidocaine molecules when placed under a positive electrode. The dose is calculated by multiplying the duration of delivery with the current used to deliver the local anesthetic agent. Studies evaluating this method typically use 20 to 30 mA and 2% lidocaine hydrochloride with 1:100,000 epinephrine.[11,12] It takes approximately 10 to 20 minutes to obtain adequate analgesia for intravenous catheter placement. The side effects of iontophoresis include skin blanching, erythema, tingling, itching, and burning sensations. Burns have been reported to rarely

occur during iontophoresis with an incidence of 1 per 15,000 to 20,000 treatments.[13] Iontophoresis has been successfully used prior to intravenous catheter placement and lumbar puncture.[14]

ULTRASOUND-ASSISTED LOCAL ANESTHETIC DELIVERY

Ultrasound has been utilized to accelerate the delivery of topical anesthetic agents. Ultrasound disrupts the layers of the stratum corneum forming temporary pores that facilitate the distribution of topical anesthetic agents below the epidermis.[15] Focal ultrasound followed by a 5 minute application of 4% liposomal lidocaine provided more effective anesthesia when compared with a placebo or standard care.[16,17] Ultrasound reduces the time to achieve anesthesia with EMLA cream from 60 minutes to 5 minutes.[18] The use of ultrasound prior to a 5 minute application of liposomal lidocaine produced the same amount of pain relief as the typical 30 minute application of liposomal lidocaine.[19] Ultrasound-assisted delivery is effective for intravenous catheter placement and phlebotomy.[20]

POWDERED ANESTHETICS

Another alternative to the injection of lidocaine solution is the transepithelial injection of powdered lidocaine using a specialized delivery system. The delivery system is a prefilled, disposable, single use device that is designed to produce rapid analgesia for venipuncture and intravenous catheter placement. The system is applied 3 minutes prior to venipuncture or intravenous cannulation. The device works by releasing pressurized helium, which in turn ruptures a cassette of lidocaine powder. The particles of lidocaine powder are accelerated to a velocity that is sufficient to penetrate the stratum corneum and become deposited in the subepithelial layer. The onset of anesthesia is approximately 1 to 3 minutes after the injection.[21] When compared with a placebo, this delivery system results in a significant reduction in pain.[22] The potential adverse effects of powdered lidocaine administration include local skin contusion, application site bleeding, and a subsequent cellulitis.

JET LIDOCAINE

Another form of needle-free lidocaine injection is commonly referred to as jet lidocaine. The device uses pressurized CO_2 to inject up to 0.5 mL of aqueous lidocaine into the subcutaneous tissue. To use the device, the lidocaine is drawn up into the reservoir and it is then held firmly against the skin where the proposed procedure is to occur. The CO_2 cartridge is activated, forcing the microaerosolized lidocaine thru the stratum corneum, depositing it the subcutaneous tissues. The onset of anesthesia is approximately 1 to 3 minutes after the injection. Approximately 19.5% of patients in a randomized trial experienced pain from administration of the system.[23] Other complications include device failure 10% of the time and minor local bleeding. In studies comparing jet lidocaine to EMLA or liposomal lidocaine, jet lidocaine was found to provide more effective anesthesia.[24,25] Jet lidocaine has been found to be more effective than placebo.[26,27] Interestingly, a study compared jet lidocaine to jet placebo (saline).[28] It found jet lidocaine to be no more effective at providing local anesthesia, suggesting that the injection itself may play a role in providing anesthesia.

HEAT-ENHANCED DIFFUSION

The application of heat improves the dermal absorption of topical anesthetics. The lidocaine–tetracaine topical patch consists of 70 mg of each local anesthesia agent, combined with an air-activated heating system incorporated into an adhesive patch. It is specifically designed to warm the skin which, in turn, accelerates the absorption of the local anesthetic agents. The heating component of the patch is automatically activated when the patch is removed from its packaging. The lidocaine–tetracaine patch can be used for minor invasive procedures such as lumbar puncture, intravenous catheter placement, and arterial puncture. The lidocaine–tetracaine patch can provide effective anesthesia after 10 minutes. It was more effective than EMLA or a placebo at all application times shorter than 60 minutes.[29,30] Common side effects include skin erythema, blanching, and edema.

LASER-ASSISTED TRANSDERMAL PASSAGE

Another technique to break down the stratum corneum skin barrier involves the use of a laser.[31] A cutaneous resurfacing laser is used to ablate the outer layer of skin, generally an area about 6 mm in diameter. Topical anesthetic is then applied to this area and is able to rapidly penetrate through the ablated skin to the subcutaneous pain receptors. The ablation procedure is typically painless. Anesthesia occurs approximately 5 minutes after the local anesthetic application. The amount of energy used for the ablation varies but typically is in the range of 2.0 to 3.5 J/cm^2. Side effects may include mild pain, erythema, and itching at the ablation site. In addition, patients may experience temporary hyperpigmentation or hypopigmentation at the treatment site. The biggest drawback to this technique is the cost of the handheld laser.

VAPOCOOLANT SPRAYS

Vapocoolant sprays, also known as vapocoolants and refrigerant sprays, are an alternative to topical local anesthetic agents. Vapocoolant sprays are a good choice for patients requiring brief procedures or with allergies to the medications used in topical anesthetics. Vapocoolant sprays work immediately, are easy to use, cost-effective, and may be repeatedly applied without the risk of methemoglobinemia or systemic toxicity. Vapocoolant sprays are sterile liquids that vaporize upon contact with the skin. As the liquid vaporizes, it cools the skin surface and provides brief topical anesthesia. Commonly used vapocoolants include ethyl chloride, fluorohydrocarbons, and alkane mixtures.

They are commercially available in containers with a tip that directs a precise stream of liquid to the desired area. The vaporization of the liquid lowers the skin temperature in the area of contact to approximately −20°C (−4°F) as it vaporizes. The skin becomes temporarily cold then frozen. Vapocoolant sprays are convenient, effective, "needle-less", and provide immediate anesthesia.[32] Their use is limited by a very brief duration of action of approximately 30 seconds. **These sprays only provide superficial anesthesia.** Vapocoolant sprays can be used prior to accessing indwelling ports and reservoirs, arterial puncture, venipuncture, intravenous catheter placement, intramuscular injections, local anesthetic injection, lumbar puncture, and minor skin procedures.[33]

Using the vapocoolant spray is very simple. Assemble and gather all the equipment required for the procedure to be performed. Clean and prep the skin. Apply sterile drapes if applicable. Hold the inverted container of refrigerant spray 10 to 15 cm above the skin surface. Spray the liquid onto the skin until a white frost appears and the skin turns white. This usually takes 7 to 12 seconds. Immediately perform the procedure to ensure an adequate anesthetic effect.

Avoid spraying the liquid onto the skin for prolonged periods as it may result in frostbite. Do not use vapocoolant sprays on mucous membranes. The vapocoolants are significantly absorbed through mucous membranes and can result in adverse reactions and toxicity. These agents are highly volatile and must be used in well-ventilated

areas. Never spray around open flames or an electrocautery unit as some vapocoolant sprays are highly flammable. Do not use vapocoolant spray on open wounds as it may delay wound healing. The application of ice packs work just as well but takes longer to achieve anesthesia.

MUCOUS MEMBRANE ANESTHESIA

Mucous membranes warrant a special note as the systemic absorption from mucous membranes is much more rapid and effective than absorption through the skin and results in higher blood levels of the anesthetic agent. Numerous agents may be used to provide anesthesia to mucous membranes. This commonly includes benzocaine, cocaine, lidocaine, and tetracaine. These local anesthetic agents produce only superficial anesthesia. They do not provide for any pain relief that originates submucosally or deeper. The total dose applied should be one-third to one-half the dose used for infiltration. Use these agents cautiously on the oral mucosa as they can suppress the gag reflex and increase the risk for aspiration.

Benzocaine is a commonly used mucous membrane anesthetic. It is available in spray, liquid, and gel form in a concentration of 14% to 20% (e.g., Cetacaine, Hurricaine, Americaine). It is nontoxic when applied to intact mucous membranes due to its poor water solubility. It provides brief analgesia. Overuse of benzocaine has the potential to produce methemoglobinemia.[34,35]

Cocaine is supplied in solution at concentrations of 4% and 10%. It is an extremely effective mucous membrane anesthetic with significant vasoconstrictive properties. Systemic absorption is enhanced when it is applied to inflamed mucous membranes. The maximum dose is 3 mg/kg. This dose still has the potential to result in toxicity and serious complications. **Do not use cocaine in patients with hypertension, cardiomyopathy, known or suspected coronary artery disease, or patients sensitive to exogenous catecholamines.**

Lidocaine is available in jelly and liquid form with a concentration of 2% to 10%. The 2% and 4% viscous solutions are often used in the Emergency Department. Instruct the patient to swish the solution in their mouth for 30 to 60 seconds then spit it out. It can result in significant systemic absorption if swallowed. The maximal dose is 300 mg in adults (15 mL of 2% or 7.5 mL of 4%) and 3 mg/kg in children. **Use extreme caution when sending patients home with viscous lidocaine for intraoral use.** Frequent use and swallowing can both result in elevated blood levels of the parent drug and its metabolites, both of which can result in potential adverse and toxic effects.[36,37]

Tetracaine is available in liquid and aerosol form with a concentration of 0.25% to 1.0%. It has significant cardiotoxic effects. It is therefore not often used for mucous membrane anesthesia. Tetracaine should not be used for mucous membrane anesthesia in the Emergency Department.

MISCELLANEOUS AGENTS

Several alternative topical anesthetic techniques have been used to provide analgesia. S-Caine Peel (Zars Pharma) has been developed as a local anesthetic peel. It is applied to an area for 20 to 30 minutes. It dries into a flexible membrane that can be peeled off after the application period. This agent is easily applied to non-flat body surfaces. Its primary use has been for laser vein treatments and laser tattoo removal.[38–40] Acupressure has been used for hundreds of years to relieve pain. It has been recently used in acute painful conditions.[41] The ShotBlocker (Bionix, Toledo, Ohio) is a plastic device that is pressed against the skin just before and during an injection.[42] It may be used to decrease the pain of local anesthetic injections. These techniques all have the potential to decrease the pain due to procedures. More information and trials are required before these can be used in the Emergency Department.

ASSESSMENT

It is important to wait long enough after the topical agent is administered to allow the onset of adequate anesthesia before the planned procedure is started. The period of time necessary for the onset of anesthesia is highly variable and dependent on the topical anesthetic used and the delivery technique utilized. A simple examination of the area being anesthetized with fine touch and pinprick is important to insure adequate anesthesia prior to the procedure. It may be necessary to apply additional anesthetic or use an alternative anesthetic technique in areas of continued sensitivity, keeping in mind the total dose applied to avoid toxicity.

AFTERCARE

The Emergency Physician should observe the patient for a minimum of 15 minutes following the use of topical anesthesia to ensure no evidence of an adverse reaction. The patient need not wait in the Emergency Department for normal sensation to return prior to discharge.

COMPLICATIONS

There are case reports of patients developing CNS toxicity after the application of topical anesthetics.[43] There have been cases of methemoglobinemia reported in patients, particularly with the use of benzocaine.[34] Topical anesthetics in patients taking Class 1 antiarrhythmics such as mexiletine and tocainide can produce additive and possibly toxic effects. EMLA has been reported to cause ulceration of the gingival mucosa and thus should not be used for mucosal anesthesia.[44] Many of the topical anesthetics are contraindicated or require special ophthalmic formulations for use in the eye. When using topical anesthetics in neonatal patients, special care and attention to dosing are imperative to avoid toxicity.

SUMMARY

There are a number of effective techniques available to decrease the pain and anxiety associated with invasive procedures. Topical anesthetic agents, particularly those with fast acting properties, are excellent adjuncts for use in the Emergency Department. Topical anesthetic creams, active medication delivery, or alternative techniques should be considered prior to performing a painful invasive procedure.

125 Hematoma Blocks

Thomas P. Graham

INTRODUCTION

Distal extremity fractures are commonly seen in the Emergency Department. These fractures often require closed reduction by manipulation, which can be a painful and frightening experience for the patient. Achieving adequate analgesia is important to facilitate reduction and to minimize patient discomfort. However, studies suggest that Physicians frequently provide inadequate analgesia to patients, and particularly children, with extremity fractures.[1,2]

ANATOMY AND PATHOPHYSIOLOGY

The hematoma block is a technique to inject a local anesthetic solution into the hematoma between the fractured bone fragments. Fracture manipulation can then often be undertaken painlessly or with significantly reduced pain. Hematoma blocks of the distal forearm are considered safe in children and adults.[3–8] Another advantage is the relative ease of the procedure. A hematoma block may be superior to intravenous sedation in alleviating discomfort during fracture reduction.[9] The hematoma block, unlike procedural sedation, avoids the side effects of sedating drugs, does not require intravenous access and cardiac monitoring, and is not associated with a prolonged recovery phase. One Physician can safely perform a hematoma block, whereas the presence of two Physicians is generally recommended for procedural sedation. The disadvantages of the hematoma block include the discomfort and anxiety resulting from injecting into the fracture site, and the potential for a rare complication.

Extremity fractures, when displaced or angulated, generally result in the formation of a hematoma between the fracture fragments. The hematoma is easily accessible with a needle and the injection of local anesthetic solution can significantly alleviate pain. The majority of important neurovascular structures in the upper extremity are contained in the volar soft tissue, making the dorsal or lateral approach preferred. The majority of important neurovascular structures in the lower extremity are contained in the proximal anterior thigh or posteriorly in the leg, making the lateral approach preferred in the proximal thigh and the anterior or lateral approach from the mid-thigh distally.

Other techniques are available to provide analgesia and anesthesia. Some authors have concluded that a Bier block (intravenous regional anesthesia, Chapter 127) may lead to more effective anesthesia and require fewer re-manipulations for the reduction of forearm fractures when compared to the hematoma block.[10–12] However, the Bier block is a technique that most Emergency Physicians are not familiar and have not developed proficiency, requires equipment not commonly available in the Emergency Department, and can be associated with adverse outcomes. Intraarticular injection of local anesthetic solution for the reduction of intraarticular fracture-dislocations, though not as well studied or widely utilized as a hematoma block, have also been advocated as safe and effective.[13,14] The joints of the extremities are easily entered by performing an arthrocentesis (Chapter 77). Local anesthetic solution injected intraarticularly diffuses throughout the joint cavity and exits through the fracture site to alleviate pain.

INDICATIONS

A hematoma block is indicated in adult and pediatric patients with closed fractures of the extremity that require manipulation or closed reduction. Consider performing a hematoma block when medical resources are limited or scarce. It is an alternative when procedural sedation is impossible or impractical. A hematoma block may be performed purely for analgesia when fracture manipulation is unnecessary and/or other methods of analgesia are ineffective or contraindicated.

CONTRAINDICATIONS

Hematoma blocks are contraindicated when there is a history of allergic reactions to local anesthetic agents. The procedure is also contraindicated in the setting of an open fracture, cellulitis overlying the fracture site, or the presence of a neurovascular deficit. A hematoma block should not be performed if a sterile field cannot be maintained or the safety of the medical staff cannot be assured due to an uncooperative patient. Relative contraindications include patients with bleeding disorders and those taking anticoagulants. The potential additional hemorrhage from the injection of local anesthetic solution into a closed space may result in a compartment syndrome.

EQUIPMENT

- Sterile gloves and gown
- Face mask and cap
- Povidone iodine or chlorhexidine solution
- Sterile drapes
- Local anesthetic solution without epinephrine, usually 1% lidocaine
- Syringes, various sizes
- 22 or 23 gauge, 2-inch long needles
- Spinal needles for obese patients

Optional Equipment

- Ultrasound machine
- 7.5 to 10 MHz ultrasound probe
- Sterile ultrasound gel
- Sterile ultrasound probe cover

PATIENT PREPARATION

Explain the risks, benefits, complications, and alternatives to the patient and/or their representative. The technique for adult and pediatric patients is identical. An adult usually tolerates the hematoma block injection without any supplemental analgesia or sedation. Some adults and children may require supplemental nitrous oxide, intravenous sedation, or an intravenous anxiolytic agent to facilitate the hematoma block.

Prepare for the procedure. **The hematoma block must be performed using strict aseptic technique.** Cleanse the skin of any dirt and debris over the fracture site and surrounding skin. Apply povidone iodine or chlorhexidine solution onto the skin and allow it to dry. Apply sterile drapes to form a sterile field. The Emergency Physician should be wearing sterile gloves and a sterile gown during the procedure. The use of a face mask and cap is also recommended. Using aseptic technique, draw up sterile 1% lidocaine without epinephrine into a syringe armed with a 22 or 23 gauge, 2-inch long needle. A longer spinal needle may be required in the obese patient. Fill the syringe with 0.3 mL/kg to a maximum of 10 mL of lidocaine, the volume to be injected. Larger volumes maybe required in adults and larger fractures. Always be aware of the maximum safe dose of 4.5 mg/kg when using lidocaine without epinephrine.

TECHNIQUES

HEMATOMA BLOCK FOR DISTAL RADIUS FRACTURES

Follow strict aseptic technique throughout the procedure. Inform the patient of the early signs of local anesthetic toxicity. These include circumoral and tongue numbness, dizziness, lightheadedness, mental status decline, tinnitus, and visual disturbances. Instruct the patient to inform you immediately if they experience any of these symptoms.

Place a wheal of 1% lidocaine subcutaneously over the fracture site. Allow 1 to 2 minutes for the anesthetic to take effect. Slowly insert and advance the 23 gauge needle attached to the lidocaine-filled syringe through the skin wheal and aimed at the fracture site.

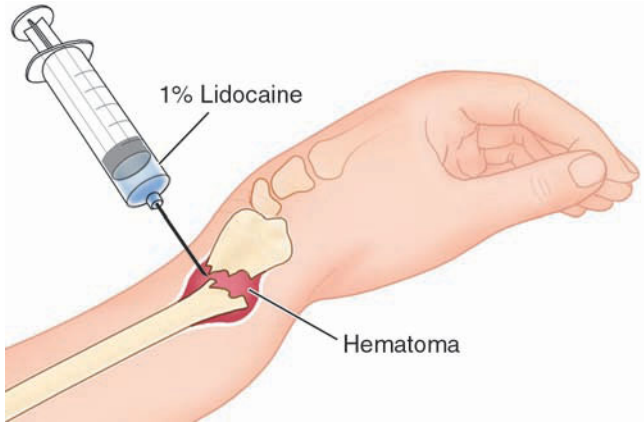


FIGURE 125-1. The hematoma block. The needle is inserted into the hematoma near the fracture fragments. Local anesthetic solution is injected into the hematoma.

Continue to slowly advance the needle toward and into the expected location of the gap between the fracture fragments (**Figure 125-1**). Aspirate with the syringe. A flash of blood indicates entry into the hematoma. If the needle strikes bone or if no flash of blood is returned, withdraw the needle and re-direct it in an attempt to enter the hematoma. Slowly inject the contents of the syringe into the hematoma. Withdraw the needle. Apply a bandage to the skin puncture site.

Some physicians reposition the needle to different areas within the hematoma and inject small amounts of the local anesthetic solution into each area. This technique distributes the local anesthetic solution to increase the efficacy of the hematoma block. Injection into multiple areas also minimizes the risk of intravascular injection of the entire dose of local anesthetic solution.

HEMATOMA BLOCK FOR INTRAARTICULAR FRACTURE-DISLOCATIONS

The procedure is identical to that described above except for the anatomic landmarks and the volume of local anesthetic solution injected. Refer to Chapter 77 for the complete details of arthrocentesis.

ULTRASOUND-GUIDED HEMATOMA BLOCK

Identify the fracture site and hematoma using ultrasound (US). Place the US probe on the patient's skin above the fracture site. Turn the US probe so its long axis is aligned with the long axis of the bone. Identify the fracture site and hematoma. Rotate the US probe 90° to visualize the short axis or cross-sectional view of the fracture site and hematoma.

Clean, prep, and sterilely drape the patient as described previously. Prepare the US probe. Apply US gel to the footprint of the US probe. Apply a sterile probe cover or a sterile glove over the US probe. Squeeze any air out of the space between the US probe and the cover. Apply sterile US gel on the probe cover.

Grasp the sterile US probe with the nondominant hand. Align the long axis of the US probe along the long axis of the bone and approximately 8 to 10 mm proximal to the fracture site. Aim the syringe containing the local anesthetic solution downward and in the direction of the fracture site. Slowly insert and advance the needle through the skin under US guidance. Advance the needle into the hematoma at the fracture site. Inject the local anesthetic solution. Remove the needle and apply a bandage to the skin puncture site.

ALTERNATIVE TECHNIQUES

Several adjuncts to the hematoma block may aid in increasing its efficacy. The addition of hyaluronidase to the local anesthetic solution has been advocated and become routine at some centers as a means of increasing the speed and efficiency of the hematoma block. The hyaluronidase breaks down the connective tissue and allows better penetration of the local anesthetic solution into the area. The evidence for the efficacy of hyaluronidase is currently lacking.[15] Based on available data, it is not currently recommend to add hyaluronidase to the local anesthetic solution. The use of ultrasound can facilitate the injection into the correct site.[16,17] Some authors recommend the use of other agents, such as anxiolytics, in combination with the hematoma block for fracture manipulation. Combining the hematoma block with nitrous oxide has shown positive results.[18]

ASSESSMENT

Reassess and document a thorough neurologic and vascular examination distal to the fracture site immediately after the injection. Assess the patient's level of pain with gentle range of motion in 10 minutes. A second injection of local anesthetic solution may be performed if required for analgesia if the patient is not experiencing any side effects or toxicity and the total combined doses do not exceed the maximum allowable limit of 4.5 mg/kg.

AFTERCARE

The extremity can be manipulated to reduce the fracture once adequate analgesia has been obtained. Splint the extremity. Perform and document another neurologic and vascular examination of the extremity after any manipulation and splinting. Instruct the patient to immediately return to the Emergency Department for severe pain, significant swelling, numbness, paresthesias, or pallor of the extremity. Arrange appropriate follow-up with an Orthopedic Surgeon. Prescribe analgesics as appropriate.

COMPLICATIONS

The complications associated with a hematoma block are rare. These include a compartment syndrome, local anesthetic toxicity, and osteomyelitis.[19–25] The early signs of local anesthetic toxicity include circumoral and tongue numbness, dizziness, lightheadedness, mental status decline, tinnitus, and visual disturbances. The cardiovascular toxic effects include asystole, atrioventricular blocks, bradycardia, cardiac depression, dysrhythmias, and hypotension. The neurologic toxic effects include agitation, coma, confusion, headaches, seizures, and possibly death. Seizures associated with local anesthetic toxicity are usually short lasting and respond to barbiturates, benzodiazepines, and propofol. Please refer to Chapters 123 and 127 for the complete details regarding local anesthetic complications and toxicity. Introducing bacteria into a previously closed fracture and injury to vascular structures are also potential complications. These can be minimized or eliminated by using strict aseptic technique and carefully identifying the anatomic landmarks.

SUMMARY

A hematoma block is an effective technique to facilitate manipulation of extremity fractures and intraarticular fracture-dislocations in adults and children. It may also be performed purely for

analgesia when no manipulation is required. Complications are rare if proper techniques are used. The procedure requires fewer Emergency Department resources than procedural sedation or a Bier block. Consider performing a hematoma block when procedural sedation is impractical or contraindicated. Patient preference should also be considered. Many patients would likely prefer a shorter Emergency Department stay with a hematoma block rather than a much longer one involving procedural sedation and the associated risks.

126 Regional Nerve Blocks (Regional Anesthesia)

Eric F. Reichman, Jehangir Meer, and Nikesh Seth

INTRODUCTION

Regional anesthesia or regional nerve blocks are defined as infiltration of a peripheral nerve with local anesthetic agents to attenuate motor output and sensory input. It provides anesthesia to allow conditions to be treated efficiently and with minimal discomfort. Patients typically tolerate nerve blocks better than direct wound infiltration. Nerve blocks often require less local anesthetic solution than does infiltration of large wounds.

Regional anesthesia provides sensory blockade of a region without altering the normal anatomic features of the area to be repaired. It may be considered for use in the repair of extensive wounds, incision and drainage of abscesses, foreign body removal, wound exploration, burn care, fracture reduction, or pain control. Once familiar with the body's sensory innervation, the Emergency Physician can easily employ regional anesthesia techniques within the Emergency Department.

Locating and anesthetizing a peripheral nerve is accomplished in one of four ways. First is to identify the general location of the nerve using anatomy and landmarks. Infiltrate local anesthetic solution at that site and allow it to diffuse over the area. The second is to locate a nerve by using the injecting needle to elicit paresthesias. Once paresthesias are elicited, withdraw the needle 1 to 2 mm and allow the paresthesias to resolve before injecting the local anesthetic solution. A nerve stimulator can be used to accurately locate peripheral nerves with motor fiber components. Use of a nerve stimulator does not require cooperation on the part of the patient. However, due to its complexity, a physician skilled in its use is required. Nerve stimulators are rarely available in the Emergency Department. US can be used to locate nerves.

The traditional method used by Anesthesiologists to perform regional anesthesia involves a combination of surface landmarks and nerve stimulation. Over the past 10 to 15 years, ultrasound (US) has gained a prominent role in guiding nerve blocks. It offers the advantages of visualizing the nerve and the needle, as well as directly visualizing the deposition of local anesthetic solution around the nerve. Several small studies have shown that Emergency Physicians can safely perform US-guided nerve blocks.[1–4]

It is common to encounter children complaining of pain in the Emergency Department. Regional anesthesia is frequently overlooked in children. Its use is increasing and serves as an excellent opportunity to minimize pain in the pediatric population.[5] It can be administered safely and effectively in these patients. A child may require intravenous or intramuscular sedation in conjunction with nerve blockade in more complicated cases. The use of nitrous oxide with pediatric patients in the Emergency Department has been found to be successful when used for forearm fracture manipulation.[6] It can also be used for other procedures. Refer to Chapter 128 regarding the use of nitrous oxide as a supplement or to perform the regional nerve block. The disadvantages of regional nerve blocks in children include the extra time required to perform the block, mandatory technical dexterity, and assistant support because the child may not remain still for the procedure.

This chapter covers regional anesthetic blocks of the head, neck, upper extremity, lower extremity, and two of the many torso blocks (**Table 126-1**). Dental blocks are discussed in Chapter 176. Refer to Chapter 123 for a more complete discussion on the properties of local anesthetic agents.

ANATOMY AND PATHOPHYSIOLOGY

There is a topographic arrangement of axons within peripheral nerves (**Figure 126-1A**).[7,8] Axons located in the outer or mantle layer innervate proximal structures. Axons in the center of the nerve or core layer innervate distal structures. Local anesthetic solution injected near a nerve diffuses from the mantle layer to the core layers. **This explains why anesthesia slowly spreads along the nerve distribution in a proximal to distal direction.**

Avoid intraneural injection when performing peripheral nerve blocks. The nerve has a tough, fibrous outer sheath that acts as a physical barrier to trap intraneural fluid (**Figure 126-1B**). Injection of local anesthetic agents into the nerve bundle will compress the fragile axons and their capillary blood supply.[9,10] This can result in axonal necrosis and permanent nerve damage. **Paresthesias elicited**

TABLE 126-1 Nerves and Anatomical Areas That Can Be Anesthetized in the Emergency Department Using a Regional Block

Head and neck	Lower extremity	Upper extremity	Torso
Supraorbital nerve block	Femoral nerve block	Brachial plexus block	Intercostal block
Supratrochlear nerve block	Saphenous nerve block	Median nerve block	Penile nerve block
Infraorbital nerve block	Lateral femoral cutaneous nerve block	Ulnar nerve block	
Mental nerve block	Obturator nerve block	Radial nerve block	
Greater occipital nerve block	Sciatic nerve block	Wrist block	
Lesser occipital nerve block	Popliteal fossa block	Digital nerve block	
Greater auricular nerve block	Common peroneal nerve block		
Scalp block	Superficial peroneal nerve block		
External ear block	Deep peroneal nerve block		
External auditory canal block	Sural nerve block		
Cervical plexus block	Posterior tibial nerve block		
	Ankle block		
	Digital nerve block		

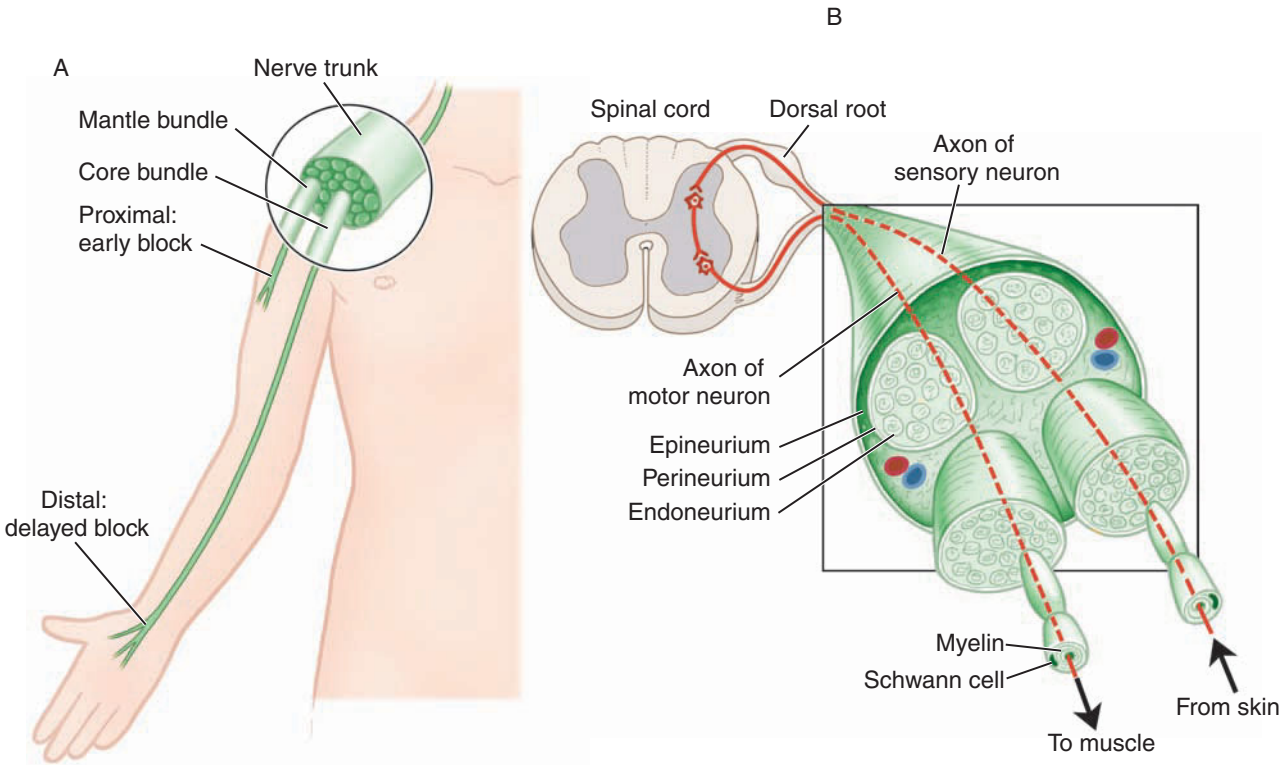


FIGURE 126-1. The anatomy and topographic arrangement of axons in a peripheral nerve. **A.** The gross anatomy of a peripheral nerve. **B.** The microscopic anatomy of a peripheral nerve.

upon needle insertion indicate that the tip of the needle is within the nerve bundle. Withdraw the needle 1 to 2 mm and allow the paresthesias to resolve, usually within 15 to 30 seconds. The anesthetic agent can be safely injected when the paresthesias resolve.

Cutaneous innervation is referenced to a segment known as a dermatome.[7] This is defined as an area of skin supplied by a single spinal or segmental nerve. This type of innervation is best represented in worms, where each body segment has its own nervous supply. The pattern of segmental innervation still holds true with some minor modifications as one moves up the phylogenetic tree. The truncal dermatomes in humans are represented as simple bands while the extremity dermatomes are serpiginous and follow the embryonic rotation of the limb buds. The most commonly used dermatomal chart is that developed by Keegan and Garrett (**Figure 126-2**).[8] Their model of the extremity dermatomes is in strips of innervation, all originating from the limb base and extending distally. This system is used in clinical medicine today.

INDICATIONS

Regional anesthesia produces profound analgesia with minimal physiologic or anatomic alteration. These techniques are especially useful in large or extensive lacerations that would otherwise require infiltration of a large and potentially toxic volume of local anesthetic solution. Nerve blocks can avoid a patient being taken to the Operating Room because the volume of local anesthetic required for extensive wound repair may require toxic doses. These techniques are also useful in cosmetic repairs where local infiltration may cause distortion of tissues or loss of anatomic landmarks making approximation and repair difficult. The necessity to palpate deep tissue for excision is also an indication for regional anesthesia.[11,12] Regional nerve blocks can be performed prior to burn care, dislocation or fracture reduction, foreign body removal, incision and drainage of abscesses, pain control, wound exploration, and wound care.

US-guided regional anesthesia offers a number of advantages when compared with the anatomic landmark. It is safer and results in fewer complications (e.g., vascular puncture, pneumothorax, and intravascular injection of local anesthetic).[13] US achieves higher rates of successful block (over 95%) and delivers a more rapid onset of anesthesia. In addition, a smaller volume of local anesthetic solution is required for the block.[13] US can eliminate the need for procedural sedation and analgesia (PSA) and its potential complications (e.g., apnea, hypoxia, and hypotension). Preprocedural fasting is not required as it is a potential requirement in PSA. US-guided nerve blocks reduce Emergency Department lengths of stay compared with patients receiving PSA.[1] It facilitates procedures in patients with higher American Society of Anesthesiology (ASA) classification scores, who would otherwise be put at higher risk for complications by the administration of PSA.

CONTRAINDICATIONS

There are few contraindications to regional anesthesia.[7,14] Absolute contraindications include injection through infected tissue, history of a bleeding disorder or a coagulopathy, or an allergy to the anesthetic agent. Relative contraindications include preexisting neurologic damage prior to the procedure. This should carefully be documented before any anesthetic injection. Additionally, patient uncooperativeness can make the procedure technically more difficult. Therefore, procedural sedation may be a necessary adjunct.[5,15] This is particularly true of the pediatric population and those with an altered mental status.[16]

There are no patient contraindications to the use of US to guide nerve blocks. Emergency Physician contraindications include the lack of familiarity and training with the procedure. Psychomotor

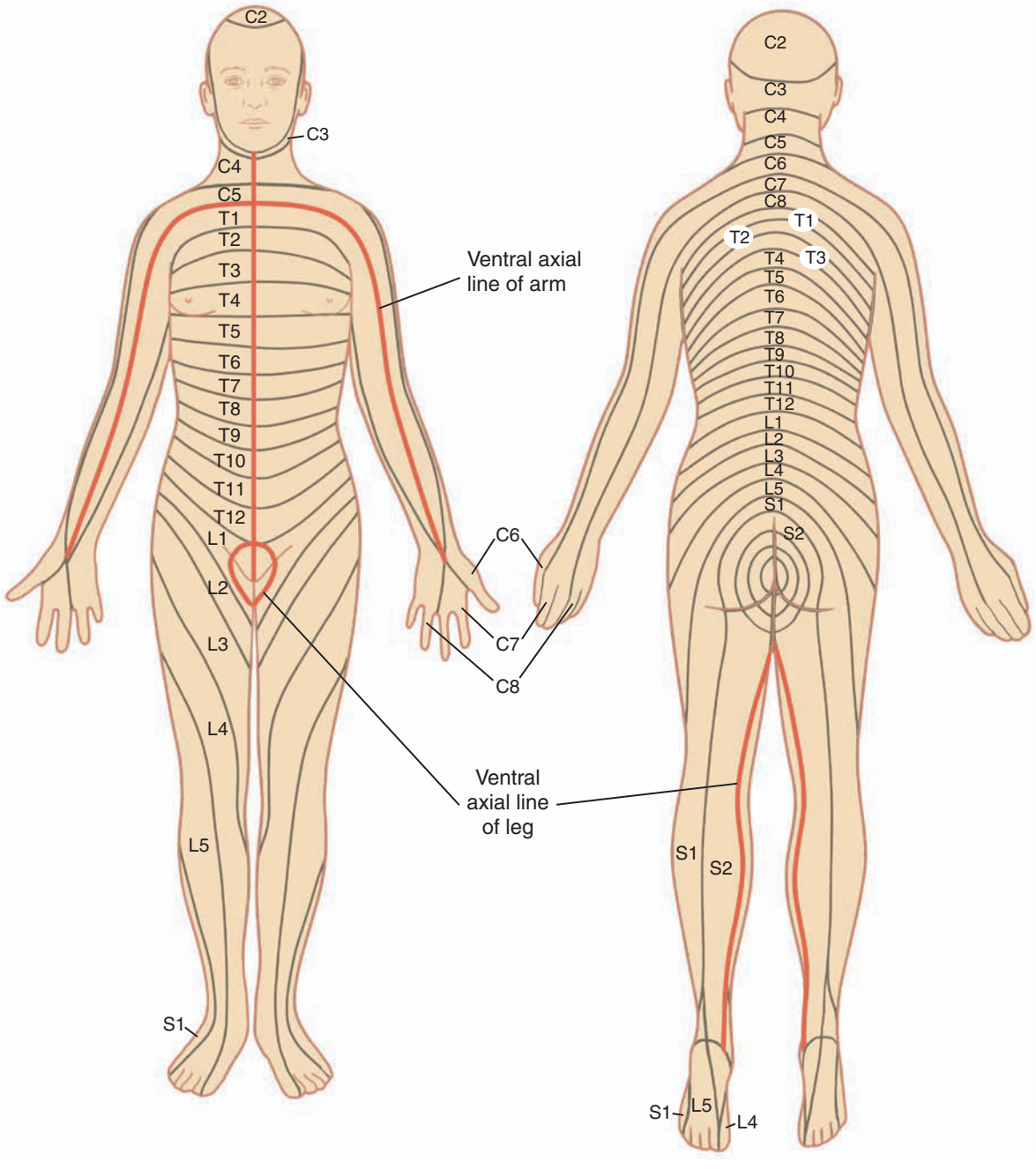


FIGURE 126-2. The dermatomal chart of the human body.

coordination and experience with US are required. Caution is advised for the novice ultrasonographer.

EQUIPMENT

Anatomic Landmark-Guided Nerve Blocks

- Sterile gloves
- Sterile drapes
- Povidone iodine or chlorhexidine solution
- Alcohol swabs
- Local anesthetic solution (**Table 126-2** and Chapter 123)
- 18 gauge needle to draw up local anesthetic solution
- 20 to 27 gauge noncutting or Quincke needles for injection, 2 inches long
- 22 to 24 gauge noncutting or Quincke spinal needles
- 1, 3, 5, 10, and 60 mL syringes
- Intravenous extension tubing

US-Guided Nerve Blocks

- Above listed supplies
- US machine
- High frequency, linear-array, US probe
- Sterile US probe cover
- Sterile US gel

TABLE 126-2 Maximum Doses of Local Anesthetic Agents

Anesthetic agent	Maximum dose (mg/kg)	Duration of action (min)
Procaine (2%)	6	15–30
Procaine (2%) with epinephrine	8	30–90
Tetracaine (0.25%)	1	120–140
Tetracaine (0.25%) with epinephrine	2	240–280
Chloroprocaine (2%)	8	15–30
Chloroprocaine (2%) with epinephrine	10	30–90
Lidocaine (1%)	3	30–120
Lidocaine (1%) with epinephrine	5	60–400
Etidocaine (0.5%)	3	30–120
Etidocaine (0.5%) with epinephrine	4	60–200
Mepivacaine (1%)	3	30–120
Mepivacaine (1%) with epinephrine	5	60–400
Bupivacaine (0.25%)	1.75	120–240
Bupivacaine (0.25%) with epinephrine	2.25	240–480
Prilocaine (4%)	5	30–60
Prilocaine (4%) with epinephrine	6	120–300

All of the required equipment is readily available in any Emergency Department. Some have a pre-prepared tray or tackle box containing all the required equipment.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Emphasize that there are few complications with this procedure. However, all possible complications should be discussed beforehand. Inform the patient of the possibility of paresthesias during the procedure and of the expected duration of action of the local anesthetic agent (**Table 126-2**). **Obtain an informed consent for the regional nerve block in addition to the procedure for which it is performed.** Ideally, the consent should be documented in the medical record and signed by the patient. Some Emergency Physicians prefer to note on the patient's chart "Indications, risks, and benefits were discussed with the patient" rather than having the patient sign a consent form. This decision is specific to each Emergency Physician, their institution, and state requirements.

Perform and document a neurological examination of the area to be anesthetized before performing regional anesthesia. Include a description of any neurological deficit in the document of informed consent for the procedure. Have the patient sign an agreement that the defect was present prior to the administration of the local anesthetic solution.

Position the patient based upon the specific regional block to be performed. Place the patient supine on a gurney or procedure table prior to the procedure in most cases. If the patient must sit upright, place the patient on an adjustable bed. The patient's comfort should be optimized to prevent unexpected complications such as vasovagal syncope.[7,17,18] Expose the area of the injection and identify the anatomic landmarks required for proper needle placement. Clean all dirt and debris from the skin. Scrub the needle insertion site with povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to delineate a sterile field.

If using US-guidance, prepare the US probe. **Always use a sterile US probe cover and sterile US gel when performing nerve blocks to prevent deep infections.** Set up a sterile field on a bedside table. Open the US probe cover set onto the sterile field. Instruct an assistant to hold the US probe upright and place standard or sterile US gel on the footprint of the US probe (**Figure 50-6A**). Apply the sterile probe cover over the US probe (**Figure 50-6B**). Smooth all the air bubbles away from the footprint of the US probe to prevent imaging artifacts. Secure the cover with rubber bands to prevent it from sliding off the US probe (**Figure 50-6C**). Place the US probe on the sterile field (**Figure 50-6D**). Apply sterile US gel onto the cover over the US probe footprint just before scanning.

TECHNIQUE

The general procedure will first be described and specifics will be addressed with each individual nerve block.

ANATOMIC LANDMARK TECHNIQUE

Position the patient. Identify the nerve or nerves to be blocked and their associated anatomic landmarks. Carefully clean and prepare the skin over the injection site in a sterile fashion. Draw up the local anesthetic solution to be injected. The amount will vary based upon the specific block. Always keep in mind the maximum allowable dose of local anesthetic (**Table 126-2**). Reidentify the anatomic landmarks. Insert the needle into the site. Withdraw the plunger to ensure that the tip of the needle is not within a blood vessel, thus avoiding intravascular injection. If paresthesias are elicited, withdraw the needle 1 to 2 mm and allow them to resolve. Inject the local anesthetic solution. Apply an appropriate bandage to the site. Allow 5 to 15 minutes for the block to take effect. Confirm that anesthesia has been achieved with pinprick prior to performing the procedure for which regional anesthesia was performed. Document the regional anesthesia procedure, the procedure for which regional anesthesia was performed, and any complications in the medical record. A sample regional anesthesia procedure note is described in **Table 126-3**.

US-GUIDED TECHNIQUE

Position and prepare the patient as described above for the anatomic landmark technique. Find the general location of the nerve using anatomic landmarks. Use US to identify the targeted nerve. Use a longitudinal needle approach for all US-guided nerve blocks. The US probe should image the nerve bundle in the short axis, allowing the entire length of the needle to be visualized as it approaches the nerve. Use a noncutting needle, such as a Quincke spinal needle, to reduce the risk of intraneural injection or nerve injury. Place the US machine on the patient's opposite side to allow the Emergency Physician to glance easily and quickly from the field to the US monitor. It is recommended to use an assistant to inject the local anesthetic solution. This allows the Emergency Physician to use their hands to hold the US probe with one hand and manipulate the needle with the other hand. Center the target nerve on the screen.

An important concept regarding the injection of local anesthetic solution around the nerve bundle is the "donut sign." This is the circumferential spread of local anesthetic solution around the nerve. This is the desired location of the local anesthetic solution around the nerve and it is usually associated with a successful block.

TABLE 126-3 A Sample Regional Anesthesia Procedure Note

After informed consent and identification of the necessary landmarks, the skin overlying _____ (location) was cleaned and prepped with povidone iodine or chlorhexidine solution. Using sterile technique, a skin wheal of local anesthetic solution was placed. A ____ gauge needle was used to anesthetize the _____ nerve with mL ____ of ____ % _____ (lidocaine, marcaine, procaine, etc.). Anesthesia was confirmed with needle pinprick testing. No complications were noted.

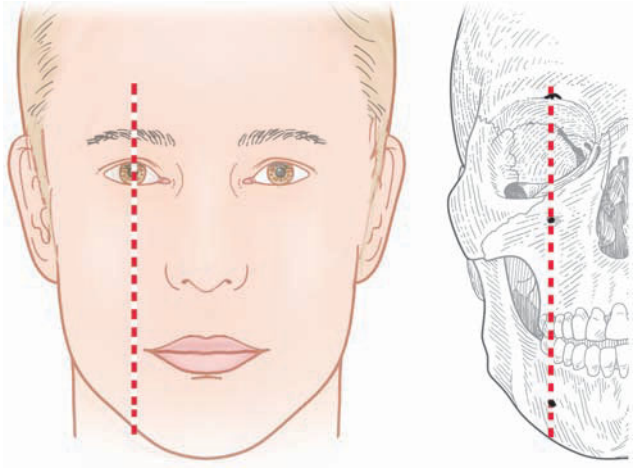


FIGURE 126-3. The supraorbital foramen, the infraorbital foramen, and the mental foramen all lie along a straight line drawn through the pupil in the midposition.

REGIONAL ANESTHESIA TECHNIQUES FOR THE HEAD AND NECK

SUPRAORBITAL NERVE BLOCK

Anatomy The supraorbital foramen lies on the supraorbital ridge along a line drawn through the pupil in the midposition (**Figures 126-3 & 126-4**). The supraorbital foramen may be palpable as an indentation. The supraorbital nerve is a branch of the ophthalmic division of the trigeminal nerve. It emerges through the supraorbital foramen, or notch, at the midline of the superior orbital ridge (**Figure 126-4A**). Its area of innervation includes the forehead, beginning at the superior orbital ridge and extending superiorly to the vertex of the scalp. It is blocked simultaneously with the supratrochlear nerve, as there is considerable overlap in their areas of innervation.

Patient Positioning Place the patient supine, or sitting, and facing the Emergency Physician.

Landmarks Identify, under the eyebrow, the superior orbital rim and the supraorbital foramen by palpation.

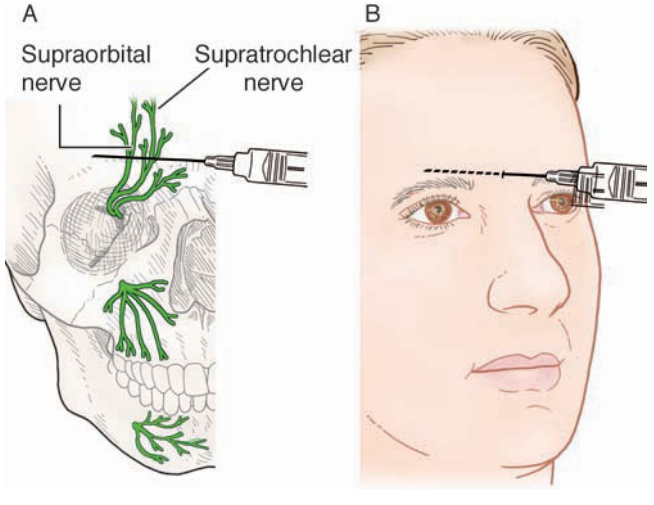


FIGURE 126-4. The supraorbital and supratrochlear nerve block. **A.** The location of the nerves. **B.** Insertion of the needle.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the midline of the forehead at the level of the eyebrow. Insert a 25 or 27 gauge needle through the skin wheal and aimed laterally (**Figure 126-4B**). Advance the needle while infiltrating subcutaneously with 3 to 5 mL of local anesthetic solution. Always maintain the needle just above the supraorbital ridge while advancing it (**Figure 126-4B**). Stop infiltrating when the needle passes the midline of the bony orbit.

Remarks This technique will anesthetize both the supraorbital and supratrochlear nerves. Infiltrate 2 mL of local anesthetic solution directly over the supraorbital foramen, or notch, if it is palpable rather than subcutaneously infiltrating above the supraorbital ridge.

SUPRATROCHLEAR NERVE BLOCK

Anatomy The supratrochlear nerve is a branch of the ophthalmic division of the trigeminal nerve. It emerges through the trochlea at the supermedial aspect of the bony orbit (**Figure 126-4A**). It provides innervation to the middle of the forehead beginning at the superior orbital ridge and extending superiorly to the vertex of the scalp. It is often blocked simultaneously with the supraorbital nerve, because there is considerable overlap in their areas of innervation.

Patient Positioning Place the patient supine, or sitting, and facing the Emergency Physician.

Landmarks Identify, under the eyebrow, the superior orbital rim by palpation.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the midline of the forehead at the level of the eyebrows. Insert a 25 or 27 gauge needle through the skin wheal, aimed laterally (**Figure 126-4B**). Advance the needle while infiltrating subcutaneously with 2 to 3 mL of local anesthetic solution. Always maintain the needle just above the supraorbital ridge while advancing it (**Figure 126-4B**). Stop infiltrating when the needle passes the midline of the bony orbit.

Remarks Stop infiltrating 1.5 cm from the skin wheal so as to block only the supratrochlear nerve.

INFRAORBITAL NERVE BLOCK, EXTRAORAL APPROACH

Anatomy The infraorbital nerve is a branch of the maxillary division of the trigeminal nerve. It emerges through the infraorbital foramen, 1 cm below the middle to medial third of the inferior orbital ridge (**Figure 126-5A**). It lies in the same plane as the supraorbital foramen and pupil that is in the midposition (**Figures 126-3 & 126-5**).

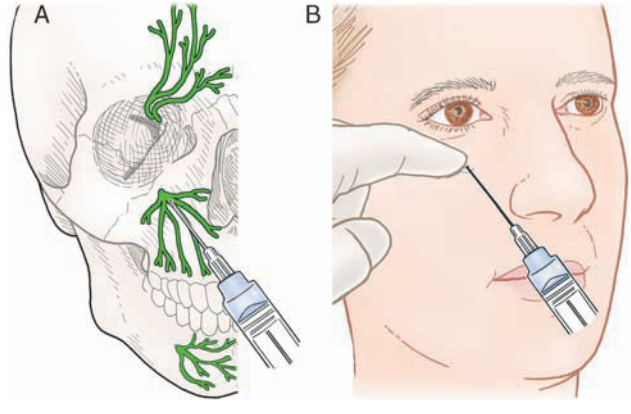


FIGURE 126-5. The extraoral approach to the infraorbital nerve block. **A.** Location of the nerve. **B.** Insertion of the needle.

The nerve exits the infraorbital foramen and travels inferiorly and medially. It provides sensory innervation to the medial cheek, nasal ala, upper lip, and the skin between the upper lip and nose. The infraorbital nerve terminates as the anterior and middle superior alveolar nerves. They provide sensory innervation to the maxillary incisors, canine, and premolar teeth, as well as their bony support and surrounding soft tissues.

Patient Positioning Place the patient supine, or sitting, and facing the Emergency Physician.

Landmarks Identify the infraorbital foramen by palpation. Significant tenderness will be elicited when the infraorbital nerve is palpated as it exits the infraorbital foramen.

Needle Insertion and Direction Insert a 25 or 27 gauge needle just above the infraorbital foramen (**Figure 126-5B**). Advance the needle until the maxilla is contacted. Inject 1 to 2 mL of local anesthetic solution.

Remarks The infraorbital nerve can be blocked intraorally. The intraoral route results in the patient experiencing less pain than the extraoral route.

INFRAORBITAL NERVE BLOCK, INTRAORAL APPROACH

Anatomy The anatomy and innervation of the infraorbital nerve is described in the previous section.

Patient Positioning Place the patient supine, or sitting, and facing the Emergency Physician.

Landmarks Identify the infraorbital foramen by palpation. It lies in a plane with the supraorbital foramen and the pupil in the midposition (**Figures 126-3 & 126-6A**).

Needle Insertion and Direction Place the index finger of the nondominant hand over the infraorbital foramen (**Figure 126-6B**). Use the nondominant thumb to retract the upper lip. Insert a 2.5 to 4.0 cm, 25 or 27 gauge needle through the mucous membranes, directed at the index finger. Advance the needle until its tip is palpable at the infraorbital foramen by the index finger. The estimated depth of needle penetration is 1.0 to 1.5 cm. Inject 2 mL of local anesthetic solution.

Remarks This is the preferred route to block the infraorbital nerve. It can also be blocked extraorally.

MENTAL NERVE BLOCK, EXTRAORAL APPROACH

Anatomy The mental nerve is a branch of the mandibular division of the trigeminal nerve. It emerges from the mental foramen. The foramen lies in a vertical plane with the supraorbital foramen, the infraorbital foramen, and the pupil that is midposition

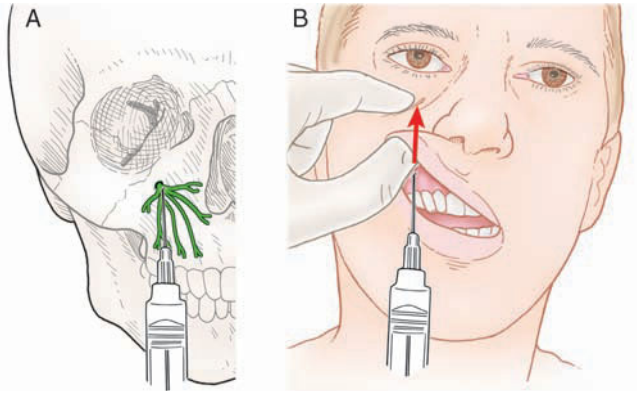


FIGURE 126-6. The intraoral approach to the infraorbital nerve block. **A.** Location of the nerve. **B.** Insertion of the needle.

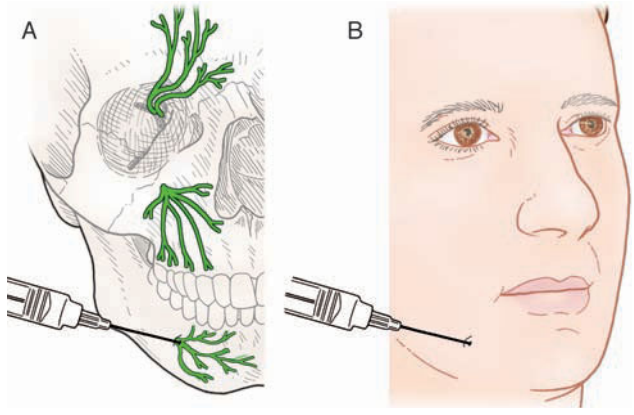


FIGURE 126-7. The extraoral approach to the mental nerve block. **A.** Location of the nerve. **B.** Insertion of the needle.

(**Figures 126-3 & 126-7**). The nerve travels inferiorly and anteriorly to provide sensory innervation to the skin of the lower lip and chin.

Patient Positioning Place the patient supine, or sitting, and facing the Emergency Physician.

Landmarks Identify the vertical plane consisting of the supraorbital foramen, the infraorbital foramen, and the midposition pupil. Identify the point where the vertical plane crosses the middle of the body of the mandible (**Figure 126-7A**). This is where the mental nerve exits the mental foramen.

Needle Insertion and Direction Insert a 25 or 27 gauge needle at the above identified landmark (**Figure 126-7B**). Place a skin wheal of local anesthetic solution at this intersection. Advance the needle through the skin wheal until the mandible is contacted. Inject 1 to 2 mL of local anesthetic solution.

Remarks This nerve can also be blocked intraorally.

MENTAL NERVE BLOCK, INTRAORAL APPROACH

Anatomy The anatomy and innervation of the mental nerve is described in the previous section.

Patient Positioning Place the patient supine, or sitting, and facing the Emergency Physician.

Landmarks Retract the lower lip and identify the junction of the first and second premolars. The patient's mouth may be open or closed.

Needle Insertion and Direction Insert a 25 or 27 gauge needle directed inferiorly and posteriorly through the gingival mucosa at the junction of the first and second premolars (**Figure 126-8**). Advance the needle one-third the depth of the mandibular body and contact the mandible. Inject 1 to 2 mL of local anesthetic solution.

Remarks This is the preferred approach to block the mental nerve. The intraoral route results in the patient experiencing less pain than the extraoral route.

GREATER OCCIPITAL NERVE BLOCK

Anatomy The greater occipital nerve is a branch of the dorsal ramus of the second cervical nerve. It provides sensory innervation to the posterior neck, extending superiorly to the vertex of the scalp (**Figure 126-9**). It emerges on the posterosuperior neck, just below the line connecting the external occipital protuberance and the mastoid process (**Figure 126-10**). The posterior occipital artery accompanies the greater occipital nerve.

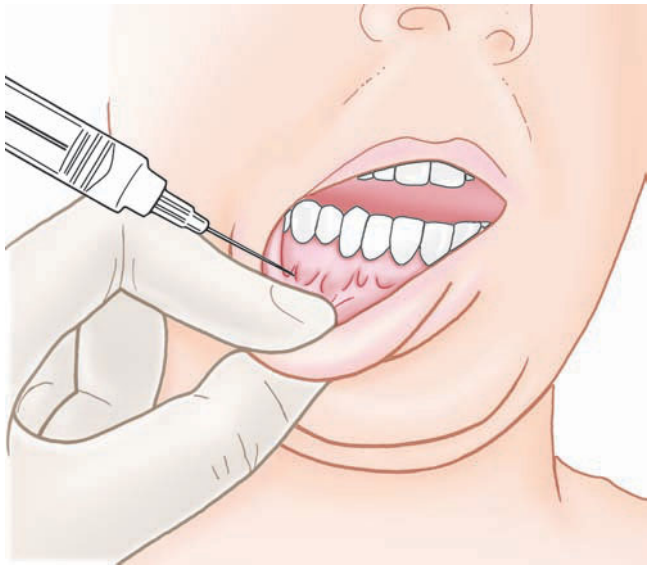


FIGURE 126-8. The intraoral approach to the mental nerve block.

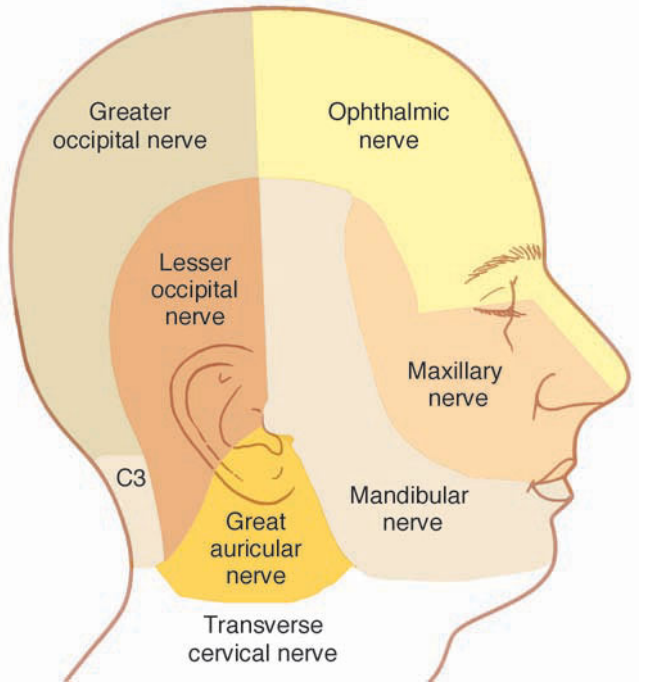


FIGURE 126-9. The cutaneous nerve supply to the face, scalp, and upper neck.

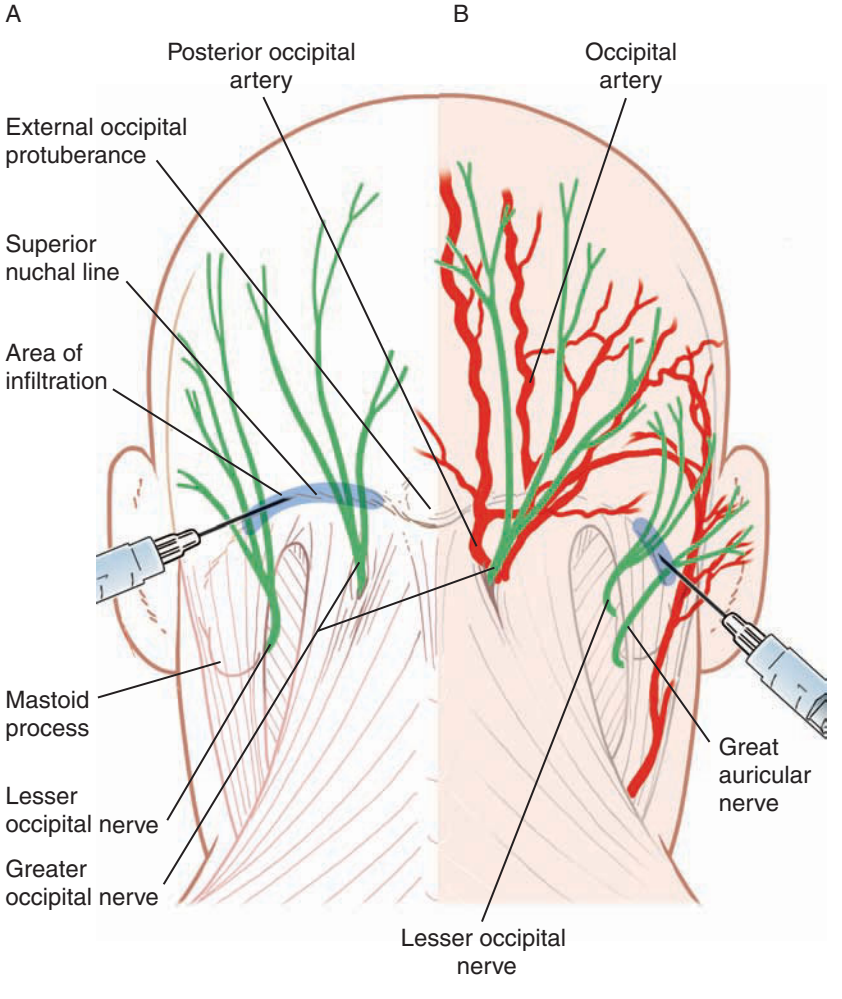


FIGURE 126-10. Regional anesthesia of the posterolateral scalp. **A.** The greater occipital nerve block. **B.** The lesser occipital and great auricular nerve blocks.

Patient Positioning Place the patient prone.

Landmarks Identify the external occipital protuberance and mastoid process by palpation (**Figure 126-10A**). Connect these landmarks with a line. Identify the occipital artery by its palpable pulse, approximately one-third the distance from the external occipital protuberance.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the pulse of the occipital artery. Insert a 25 gauge needle 1 to 2 mm to the left of the occipital artery pulse. Inject 1 mL of local anesthetic solution. Redirect the needle 1 to 2 mm to the right of the pulse and inject 1 mL of local anesthetic solution.

Remarks This block is useful for laceration repair as well as relief of occipital muscular or tension headaches. If the pulse of the posterior occipital artery is not palpable, divide the line between the external occipital protuberance and the mastoid process into thirds. Infiltrate the middle third subcutaneously with 5 to 8 mL of local anesthetic solution (**Figure 126-10A**). This technique will also anesthetize the lesser occipital nerve.

LESSER OCCIPITAL NERVE BLOCK

Anatomy The lesser occipital nerve is a branch of the cervical plexus. It provides sensory innervation to the skin and scalp between the ear and the mastoid process (**Figure 126-9**). It emerges at the middle third of the posterior border of the sternocleidomastoid muscle and travels superiorly toward the mastoid process (**Figure 126-10**).

Patient Positioning Place the patient supine or sitting with their head turned toward the side opposite that being anesthetized.

Landmarks Identify the mastoid process by palpation.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution just posterior to the mastoid process. Insert a 25 gauge needle directed anteriorly through the skin wheal. Advance the needle while infiltrating local anesthetic solution subcutaneously until the posterior ear is contacted (**Figure 126-10B**). This requires 3 to 7 mL of local anesthetic solution.

Remarks The lesser occipital nerve can be blocked at the level of the cervical plexus. Refer to the section on cervical plexus blockade below.

GREAT AURICULAR NERVE BLOCK

Anatomy The great auricular nerve is a branch of the cervical plexus. It emerges at the middle third of the posterior border of the sternocleidomastoid muscle and travels superiorly with the external jugular vein (**Figure 126-10B**). This nerve provides sensory innervation to the skin and scalp behind the ear, the posterior ear, and the lobule (**Figure 126-9**).

Patient Positioning Place the patient supine with their head turned toward the side opposite that being anesthetized.

Landmarks Identify the lobule of the ear, the mastoid process, and the sulcus behind the ear.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution just posterior to the mastoid process. Insert a 25 gauge needle directed anteriorly through the skin wheal. Advance the needle while infiltrating local anesthetic solution subcutaneously until the posterior ear is contacted (**Figure 126-10B**). This requires 3 to 7 mL of local anesthetic solution. Complete and successful anesthesia occurs within 10 minutes.

Remarks The great auricular nerve block is indicated for lacerations of the auricle, debridement, and hematoma evacuations. It is rarely performed without simultaneous blockade of the auriculotemporal nerve. The great auricular nerve can be blocked at the level of the cervical plexus. Refer to the section on cervical plexus blockade below.

SCALP BLOCK

Anatomy The scalp receives its sensory innervation from branches of the trigeminal nerve anteriorly and the cervical plexus posteriorly (**Figure 126-11**). The scalp may be anesthetized anywhere along the anterior midline to the posterior midline. This involves blocking the supratrochlear, supraorbital, auriculotemporal, lesser occipital, great auricular, and greater occipital nerves.

Patient Positioning Place the patient supine with their head turned toward the side opposite that being anesthetized.

Landmarks Identify the glabella and the external occipital protuberance by palpation.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the glabella. Insert a 25 gauge needle through the skin wheal. Infiltrate a continuous line of local anesthetic solution subcutaneously between the glabella and the external occipital protuberance (**Figure 126-11B**). This requires 15 to 20 mL of local anesthetic solution.

Remarks Infiltrate the local anesthetic solution subcutaneously along the scalp base inferior to the area in which the procedures will be performed to block only a portion of the scalp. It is useful to add epinephrine (1:200,000) to the local anesthetic solution to cause vasoconstriction and prevent excessive blood loss. Significant systemic absorption of the local anesthetic agent does not occur despite the extensive vascularity of the scalp. Scalp blocks provide anesthesia for laceration repair, drainage of superficial abscesses, and the exploration of scalp wounds. Complications are fairly rare. There is a case report of a temporary facial nerve palsy after a scalp block.[19]

EXTERNAL EAR BLOCK

Anatomy The ear is a difficult structure to anesthetize. It is innervated by a large number of sensory fibers that originate from the cervical plexus, the trigeminal nerve, and the vagus nerve. The external ear, or pinna, is innervated by the cervical plexus and the auriculotemporal branch of the trigeminal nerve (**Figures 126-9 & 126-11**).

Patient Positioning Place the patient supine or sitting upright with their head turned toward the side opposite that being anesthetized.

Landmarks Identify the angle of the mandible by palpation.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the angle of the mandible. Insert a 25 gauge needle through the skin wheal. Infiltrate local anesthetic solution subcutaneously in an anterior and superior direction, from the angle of the mandible to the superior surface of the ear, to block the auriculotemporal nerve (**Figure 126-12A**). Infiltrate local anesthetic solution subcutaneously in a posterior and superior direction, from the angle of the mandible to the superior surface of the ear, to block the great auricular and lesser occipital nerves (**Figure 126-12A**). This requires a total of 8 to 10 mL of local anesthetic solution.

Remarks Some may prefer to anesthetize the auriculotemporal nerve trunk by injecting local anesthetic solution just above the posterior aspect of the zygomatic arch (**Figure 126-12B**). It requires less local anesthetic solution and hurts less than subcutaneous infiltration. An alternative technique is to circumferentially infiltrate local anesthetic solution subcutaneously around the ear (**Figure 126-12C**).

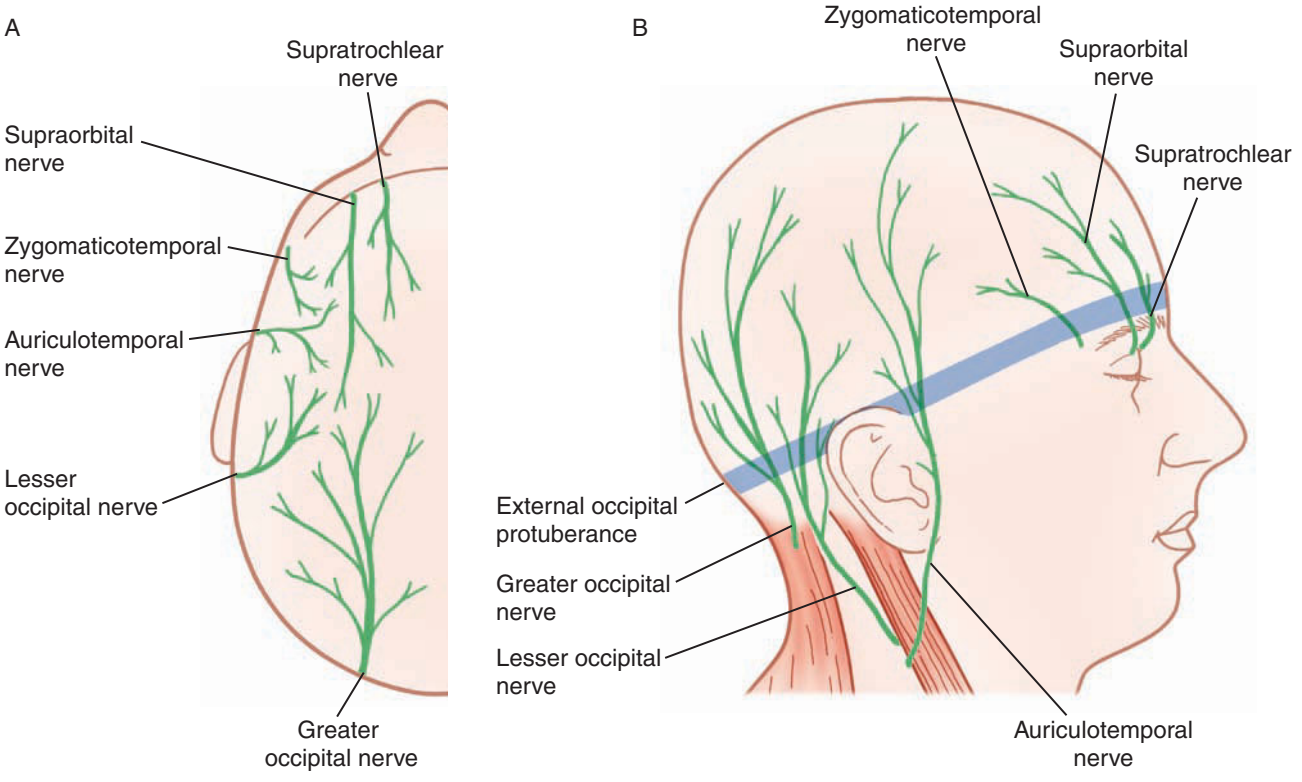


FIGURE 126-11. The scalp block. **A.** The sensory innervation of the scalp. **B.** Local anesthetic solution is injected subcutaneously along the base of the scalp.

EXTERNAL AUDITORY CANAL BLOCK

Anatomy The external auditory canal (and the tympanic membrane) receives its innervation from the auriculotemporal nerve and the vagus nerve.

Patient Positioning Place the patient sitting upright or supine with their head turned toward the side opposite that being anesthetized.

Landmarks Identify the helix, the tragus, and the lobule of the ear to be anesthetized (**Figure 126-13**).

Needle Insertion and Direction Anesthetize the external auditory canal using a four-quadrant block (**Figure 126-13**). Insert a 25 gauge needle, advance it 0.5 to 0.75 cm, and inject 1 mL of local anesthetic solution at each of the four landmarks identified in **Figure 126-13**.

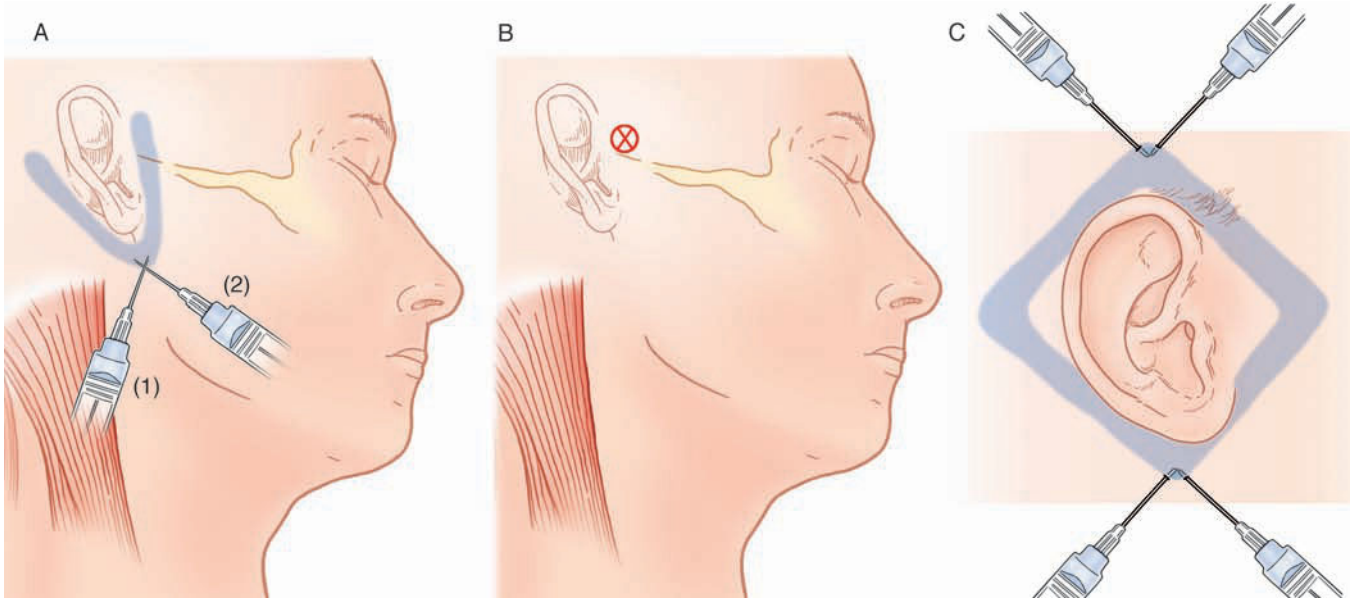


FIGURE 126-12. The external ear block. **A.** Infiltration of local anesthetic solution from the angle of the mandible to the anterior (1) and posterior (2) superior surfaces of the ear. **B.** The site for anesthetizing the trunk of the auriculotemporal nerve. **C.** An alternative method.

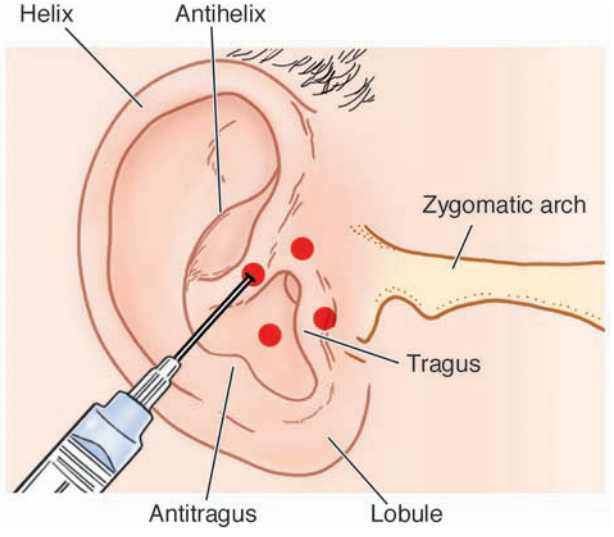


FIGURE 126-13. External auditory canal block. Inject local anesthetic solution at each of the four landmarks. This block also anesthetizes the tympanic membrane.

Remarks This block can be quite painful for the patient. The authors recommend to first anesthetize the external ear before anesthetizing the external auditory canal. This block also anesthetizes the tympanic membrane.

CERVICAL PLEXUS BLOCK

Anatomy The cervical plexus originates from the anterior rami of cervical nerves two through four. These rami form numerous loops that anastomose to form nerves that provide sensory innervation to the anterolateral neck, the scalp, the ear, and the infraclavicular area. The four nerves of the cervical plexus become superficial at the midportion of the posterior border of the sternocleidomastoid muscle and then distribute to their respective sensory areas (**Figure 126-14A**). The cervical plexus provides motor innervation to the strap muscles of the neck.

The four superficial nerves of the cervical plexus are the lesser occipital nerve, the great auricular nerve, the anterior (or transverse) cervical nerve, and the supraclavicular nerve (**Figure 126-14A**). The lesser occipital nerve travels superiorly and posteriorly to provide sensory innervation to part of the posterior surface of the upper ear and the postauricular skin. The great auricular nerve travels superiorly and anteriorly to provide sensory innervation to the skin over the posterior surface of the ear, the anterior lower half of the ear, and over the angle of the mandible. The anterior, or transverse, cervical nerve of the neck travels anteriorly to provide sensory innervation to the skin of the neck, from the inferior border of the mandible to the sternum. The supraclavicular nerves travel from the clavicle down to the second rib.

Patient Positioning Place the patient supine with their head turned toward the side opposite of that being anesthetized.

Landmarks Identify the posterior border of the sternocleidomastoid muscle by palpation. Divide this border into thirds.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the middle third of the posterior border of the sternocleidomastoid muscle. Insert a needle through the skin wheal. Infiltrate 5 to 10 mL of local anesthetic solution subcutaneously over the middle third of the posterior border of the sternocleidomastoid muscle (**Figure 126-14B**).

Remarks This block is useful when managing burns or suturing lacerations on the anterolateral neck.

REGIONAL ANESTHESIA TECHNIQUES FOR THE UPPER EXTREMITY

BRACHIAL PLEXUS BLOCK

The brachial plexus innervates the entire upper extremity. Blockade of the brachial plexus can be performed to repair tendons or extensive lacerations, to reduce fractures and dislocations, or to provide

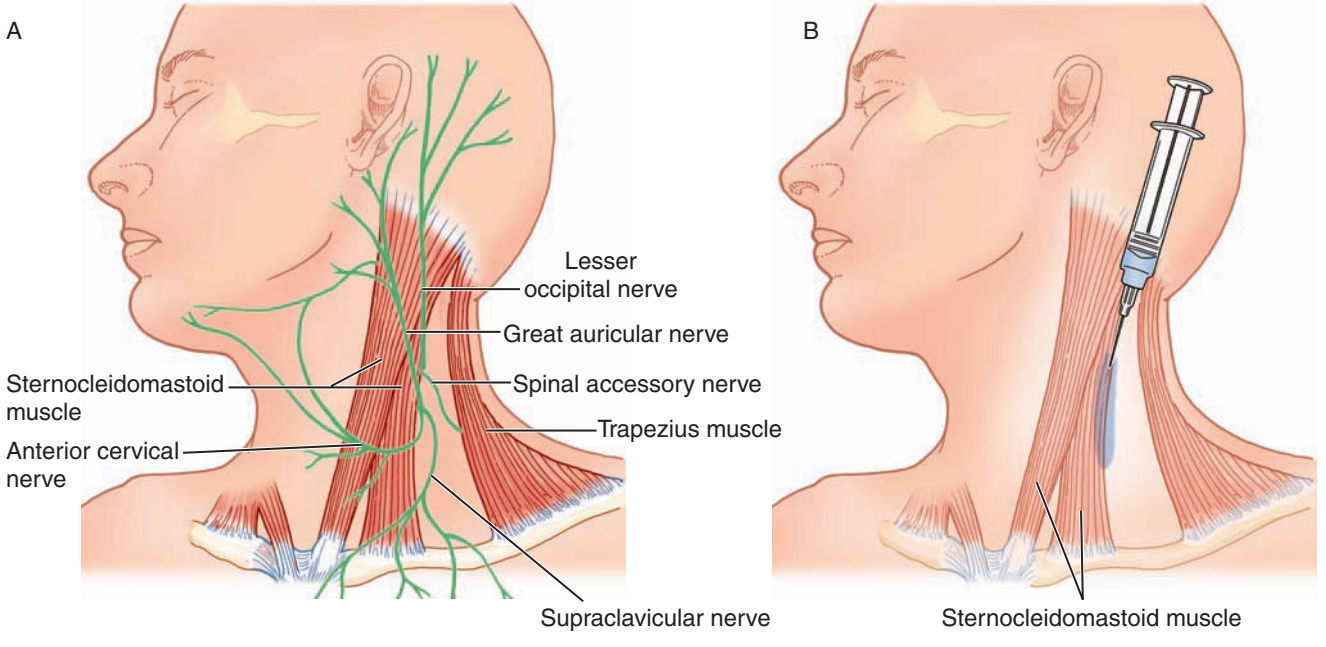


FIGURE 126-14. The cervical plexus block. **A.** The cutaneous nerves of the cervical plexus. **B.** Injection of local anesthetic solution posterior to the middle third of the sternocleidomastoid muscle.

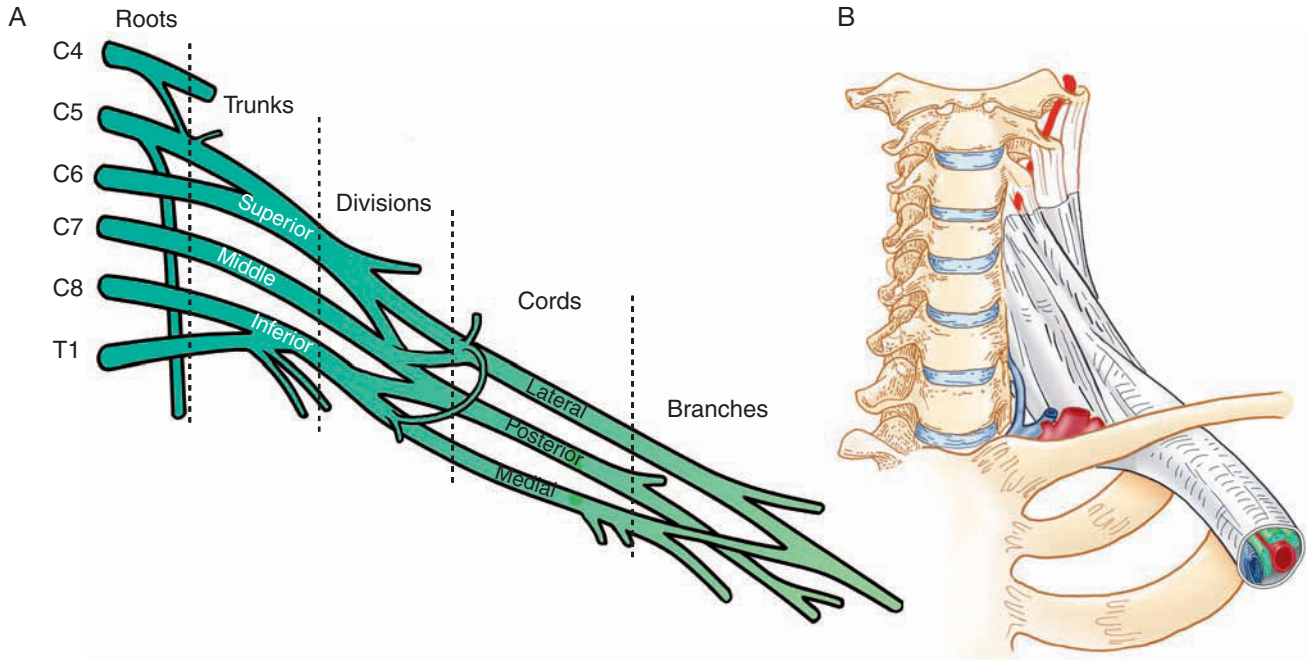


FIGURE 126-15. The brachial plexus. **A.** The anatomy of the brachial plexus. **B.** The brachial plexus is contained within a sheath. The subclavian artery and vein enter the sheath at the level of the clavicle.

anesthesia for burn care, to name a few uses. Protect the arm from injury if this procedure is to be performed by properly supporting the arm, padding the ulnar nerve and pressure points, and not extending or displacing the arm posteriorly.

The brachial plexus arises from the C5 to T1 nerve roots (**Figure 126-15**). The nerve roots fuse to form three trunks. Each trunk divides into an anterior and posterior division that then redistributes to form the lateral, medial, and posterior cords. These cords divide in the region of the axilla to form the musculocutaneous nerve, the median nerve, the ulnar nerve, the axillary nerve, the radial nerve, and several cutaneous nerves. The brachial plexus crosses the midclavicle to enter the axilla (**Figure 126-16A**).

The brachial plexus may be blocked from the supraclavicular, interscalene, infraclavicular, or axillary approach. The preferred method for the Emergency Physician is the axillary block.

BRACHIAL PLEXUS BLOCK, SUPRACLAVICULAR APPROACH

Anatomy The anatomy of the brachial plexus is described above. This approach blocks the brachial plexus at the level of the trunks, where it is most compactly arranged.

Patient Positioning Place the patient supine with their head turned 45° from the midline and toward the side opposite that being anesthetized (**Figure 126-16A**). Place the ipsilateral arm in any position of comfort for the patient.

Landmarks The subclavian artery is the main landmark. Palpate the subclavian artery immediately lateral to the clavicular head of the sternocleidomastoid muscle in the interscalene groove. Identify the midpoint of the clavicle.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution 2 cm above the midclavicle. Insert a 25 gauge needle directed caudally through the skin wheal (**Figures 126-16B & C**). Advance the needle until the patient experiences paresthesias. Withdraw the needle 1 mm and allow the paresthesias to resolve. Aspirate to ensure that the tip of the needle is not within a blood vessel. Inject 40 mL of local anesthetic solution. Reduce the volume based upon the patient's body size and the maximal allowable dose to prevent toxicity.

US-Guided Block Place the US probe in an oblique coronal plane above the clavicle and lateral to the sternocleidomastoid muscle (**Figure 126-16D**). Locate the subclavian artery. It is a pulsatile, round, and hypoechoic structure in cross section. The trunks of the brachial plexus are located adjacent to the subclavian artery (**Figure 126-16E**). Posterior to the subclavian artery lies the first rib, and the pleural line can be seen sliding in real time. Use color/power Doppler to confirm the location of the subclavian artery and any branches or take-offs, all of which must be avoided (**Figure 126-16F**). Anesthetize the skin. Position the spinal needle lateral to the US probe and parallel to its long axis. Slowly insert and advance the needle. Visualize the entire length of the needle as it is introduced through the subcutaneous tissue toward the brachial plexus. Advance the needle through the nerve sheath. Aspirate to ensure the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of anesthetic around the nerves. If it is satisfactory, inject the remainder of the local anesthetic solution to achieve the "donut sign" (**Figure 126-16G**). If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks This block is characterized by a quick onset of anesthesia and a complete block. A high volume of anesthetic is required with a quick onset of anesthesia. There is no chance of missing peripheral or proximal nerve branches because of failure of the local anesthetic solution to spread along the sheath of the brachial plexus. Unfortunately, this technique is difficult to teach and to master without considerable experience. This technique has a high incidence of an iatrogenic pneumothorax, reportedly up to 6%. Other complications include blockade of the phrenic nerve, subclavian artery puncture, and Horner's syndrome. Unintentional intravascular injection can result in high blood levels of the local anesthetic agent.

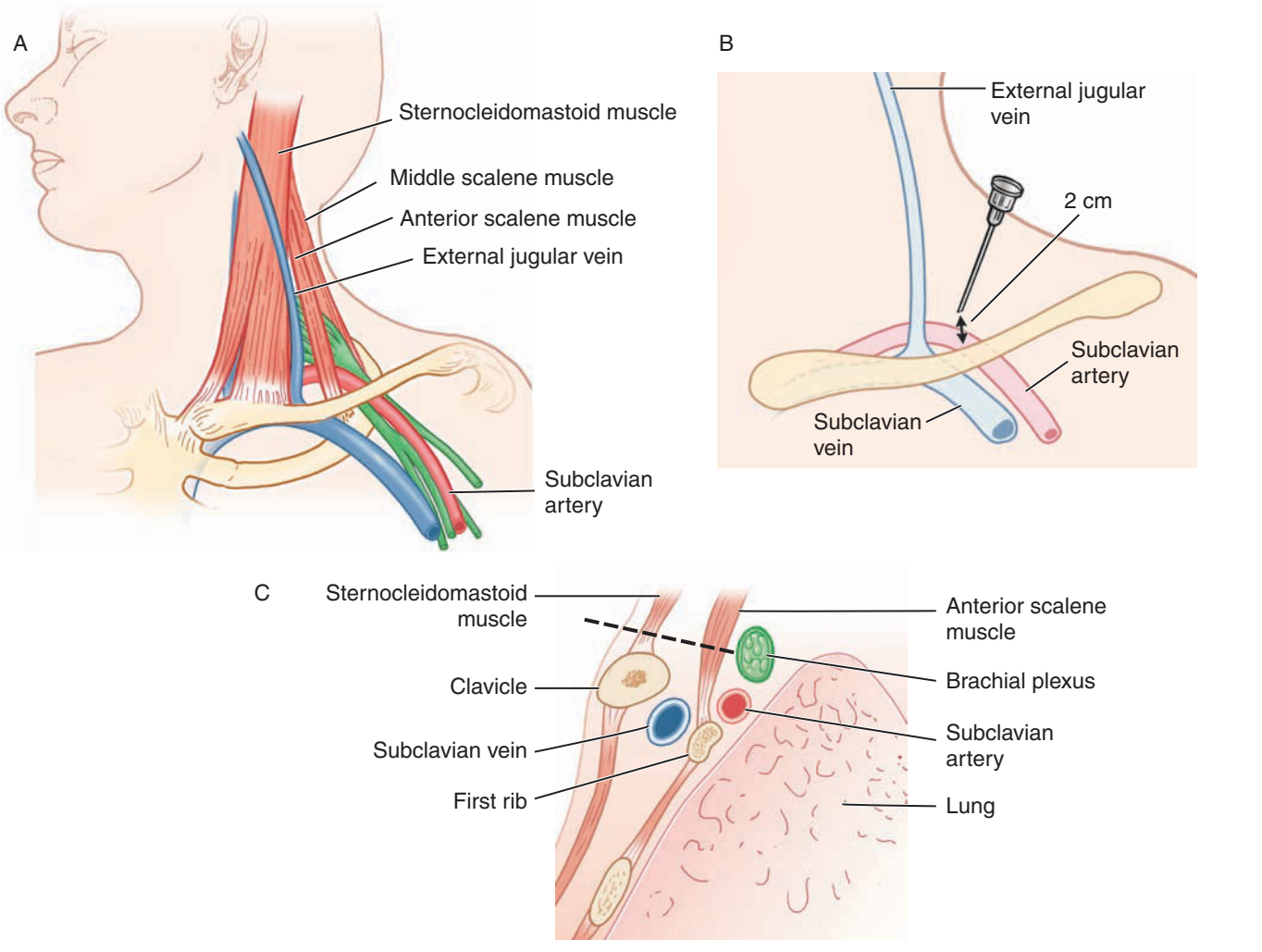


FIGURE 126-16. The supraclavicular approach to the brachial plexus block. **A.** The course of the brachial plexus. **B.** The needle is inserted perpendicular to the skin and 2 cm superior to the middle of the clavicle. **C.** Sagittal section demonstrating the trajectory of the needle (*dotted line*). **D.** US probe and needle placement. **E.** The supraclavicular brachial plexus (*arrowheads*) is adjacent to the subclavian artery (SA). The first rib is denoted by the arrows.

BRACHIAL PLEXUS BLOCK, INTERSCALENE APPROACH

Anatomy The anatomy of the brachial plexus is described above. This approach blocks the brachial plexus at the level of the trunks (**Figure 126-17A**).

Patient Positioning Place the patient supine with their head turned 45° from midline and toward the side opposite that being anesthetized (**Figure 126-17A**). Place the ipsilateral arm in any position of comfort for the patient.

Landmarks Identify the posterior border of the clavicular head of the sternocleidomastoid muscle by palpation. Move the palpating

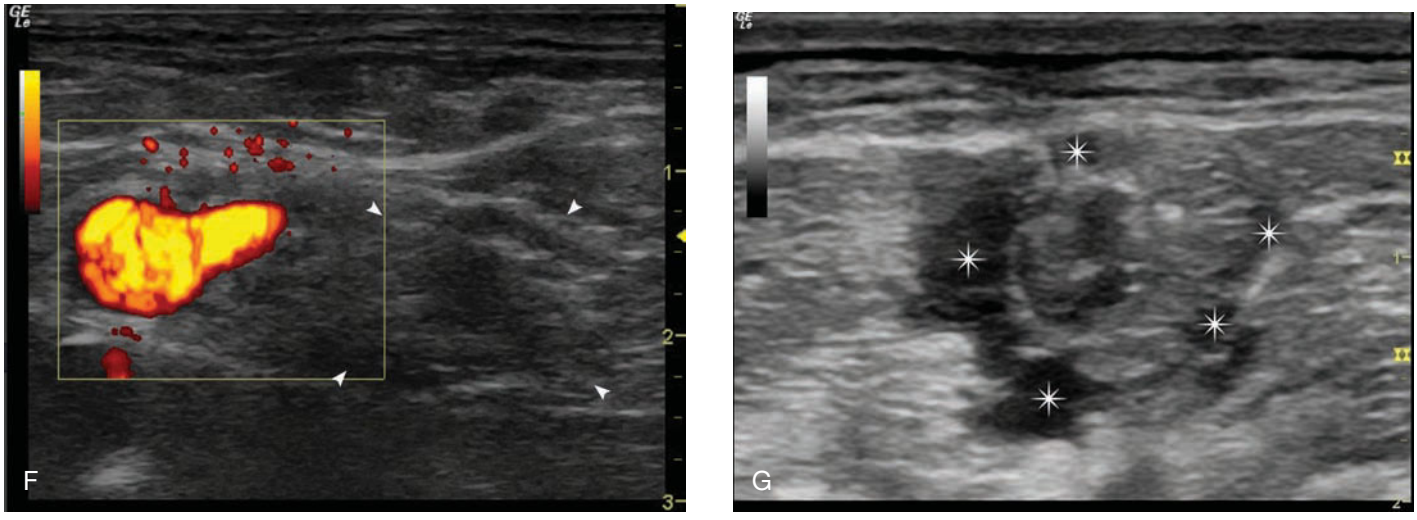


FIGURE 126-16. (*continued*) **F.** Color Doppler of the supraclavicular brachial plexus (*arrowheads*). The subclavian artery and a branch are visible in color. **G.** The "donut sign." Local anesthetic solution (*) surrounds the nerve bundles.

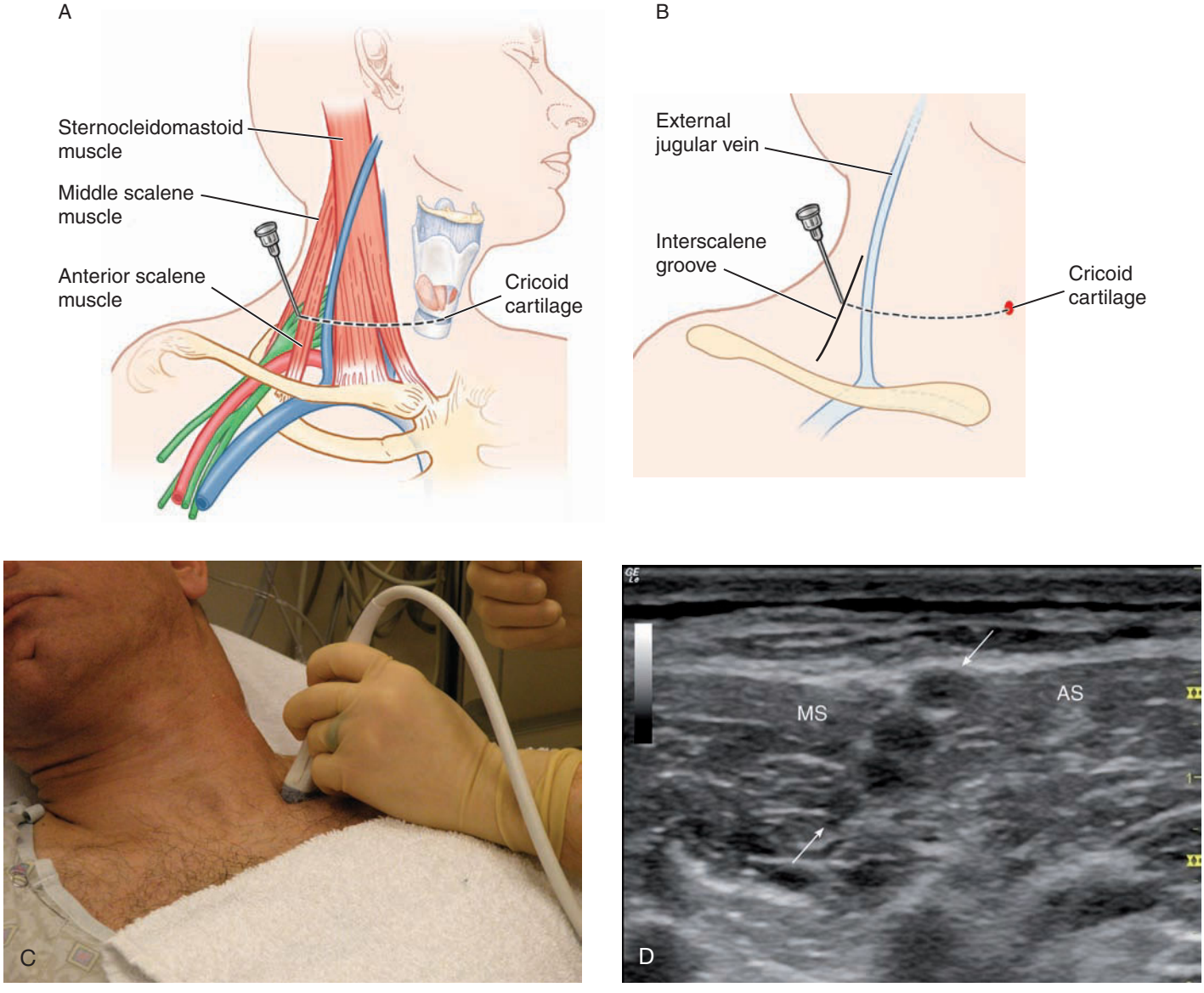


FIGURE 126-17. The interscalene approach to the brachial plexus block. **A.** The anatomy of the region. **B.** The needle is inserted into the interscalene groove at the level of the cricoid cartilage. **C.** US probe placement. **D.** The brachial plexus (between the *arrows*) is located between the anterior scalene (AS) and the middle scalene (MS) muscles.

finger laterally until it rolls into the interscalene groove between the anterior and middle scalene muscles, at the level of the cricoid cartilage (**Figure 126-17B**).

Needle Insertion and Direction Place a skin wheal of local anesthetic solution in the interscalene groove, at the level of the cricoid cartilage. Slowly insert a 25 gauge needle through the skin wheal in a dorsal, medial, and caudal direction (**Figure 126-17B**). Advance the needle until the patient experiences paresthesias. Withdraw the needle 1 mm and allow the paresthesias to resolve. Aspirate to ensure that the tip of the needle is not within a blood vessel. Inject 30 to 40 mL of local anesthetic solution. Reduce the volume based upon the patient's body size and the maximal allowable dose to prevent toxicity.

US-Guided Block This block is performed at the level of the internal jugular vein and carotid artery in the neck. Place the US probe on the neck, less than a third of the way up from the clavicle (**Figure 126-17C**). Identify the carotid artery and internal jugular vein. Move the US probe laterally to find the muscle bellies of the anterior and middle scalene muscles (**Figure 126-17D**). Between the muscles lie the nerve roots of the brachial plexus in cross section. It is represented by hypoechoic circles within the hyperechoic rings of the nerve sheaths (**Figure 126-17D**). Use color Doppler to identify any blood vessels in the field, and note their location so as to avoid them. Anesthetize the skin. Using a posterior approach, insert the spinal needle connected by extension tubing to a 20 mL syringe filled with local anesthetic solution. Advance the needle and visualize it approaching the brachial plexus. The needle path will usually go through the middle scalene muscle. Once the brachial plexus is close to the needle tip, use a short and controlled jab to penetrate through the nerve sheath. Aspirate to verify that the needle tip is not in a blood vessel. Instruct an assistant to deliver a test dose of 1 to 2 mL of local anesthetic solution. If the anesthetic spreads around the nerves, slowly deliver the remainder of the local anesthetic solution to obtain the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks The advantages and disadvantages are similar to those of the supraclavicular approach with the exception of possibly not achieving anesthesia of the lower trunk. This may require supplementary blockade of the median and ulnar nerves. The interscalene brachial plexus block, although ideal for regional anesthesia of the shoulder, has been associated with recurrent laryngeal nerve paralysis and an almost 100% incidence of phrenic nerve paralysis.[20] This can be significant in patients with respiratory comorbidities (e.g., COPD, obesity).[21] The supraclavicular brachial plexus block is associated with lower rates of these complications.[2]

BRACHIAL PLEXUS BLOCK, AXILLARY APPROACH

Anatomy The anatomy of the axillary brachial plexus nerve block is rather simple. The neurovascular bundle is easily found at the anterior axillary fold by palpating for the pulsations of the axillary artery. The neurovascular bundle is surrounded by the fibrous axillary sheath (**Figure 126-18A**). The axillary sheath is bound medially by skin and connective tissue, anteriorly by the biceps and coracobrachialis muscles, inferiorly by the triceps muscle, and laterally by the neck of the humerus. The axillary artery is the central reference structure within the neurovascular bundle. Within the axillary sheath, the median nerve is anterior, the radial nerve is posterolateral, and the ulnar nerve is posterior to the axillary artery. The axillary vein is medial to the artery. The medial antebrachial cutaneous

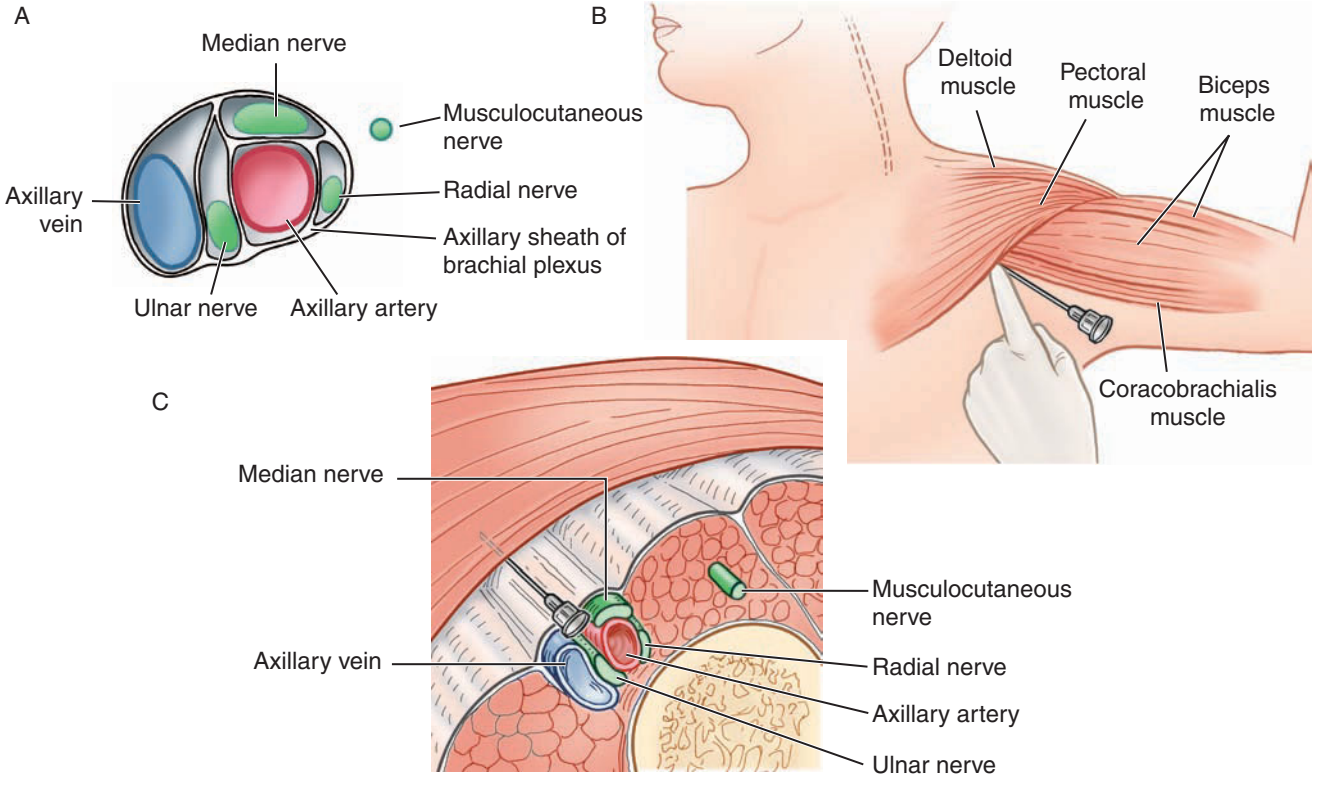
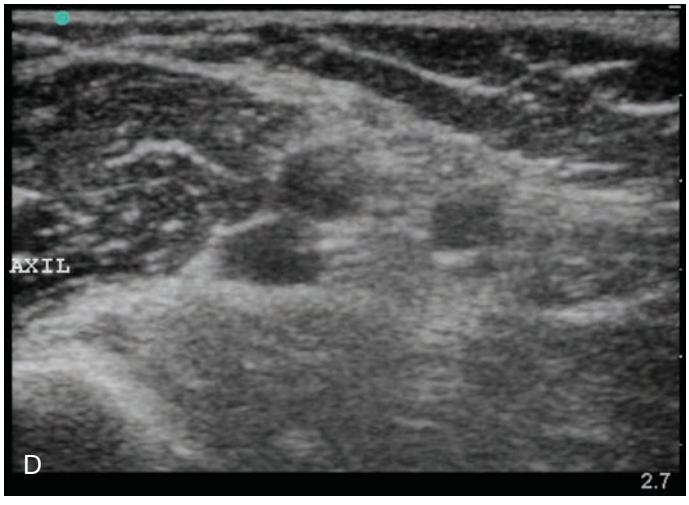
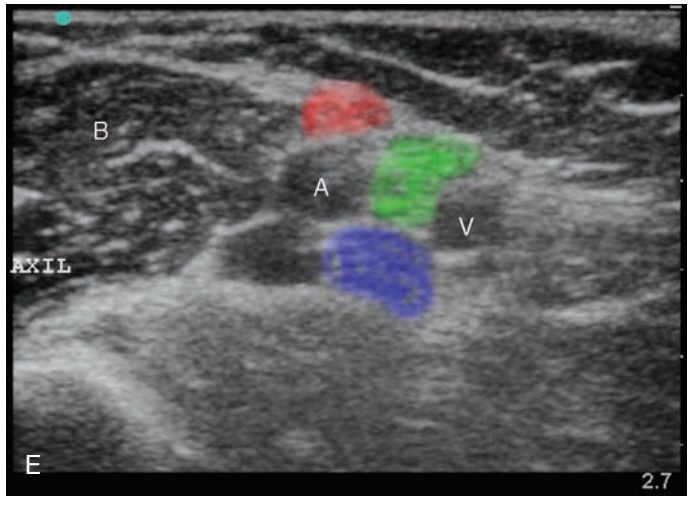


FIGURE 126-18. The axillary approach to the brachial plexus block. **A.** The topographical arrangement of the contents of the axillary sheath at the level of the blockade. **B.** The patient is positioned and the axillary artery pulse is palpated with one finger. The needle is inserted above the pulse and along the course of the axillary sheath. **C.** The needle may travel above the sheath and enter it at a higher level.







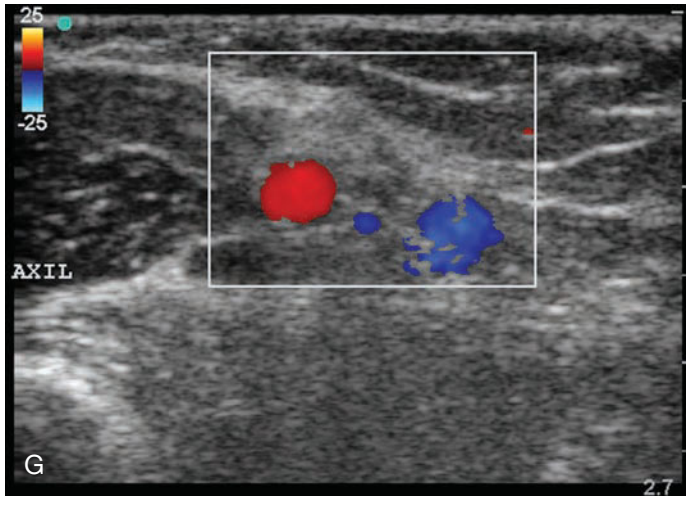


FIGURE 126-18. (*continued*) **D.** US image of the axillary brachial plexus. **E.** Same image as (**D**) with labels (A–axillary artery, B–biceps muscle, V–axillary vein, red oval–median nerve, green oval–ulnar nerve, blue oval–radial nerve). **F.** US probe and needle placement. **G.** Color Doppler of the axillary artery (red) and vein (blue).

nerve and the medial brachial cutaneous nerve are medial to the artery (**Figure 126-18A**). The only sensory nerve outside the neurovascular bundle is the musculocutaneous nerve. This nerve exits the axillary sheath as it crosses the clavicle.

Patient Positioning Place the patient supine with their head turned toward the side opposite that being anesthetized (**Figure 126-18B**). Abduct the arm 90°. Flex the elbow 90° so that the forearm is parallel to the long axis of the body and the palm is facing upward.

Landmarks Identify the brachial artery by its palpable pulse. Trace it proximally to the anterior axillary fold, formed by the pectoralis major muscle. Use the index and middle fingers of the nondominant hand to secure the neurovascular bundle (identified by the pulse) against the humerus (**Figure 126-18B**).

Needle Insertion and Direction Place the skin wheal of local anesthetic solution overlying the axillary artery pulse, just posterior to the anterior axillary fold. Insert a 22 gauge spinal needle just above the fingertip on the axillary pulse, directed toward the apex of the axilla and in the direction of the neurovascular bundle (**Figure 126-18B**). Advance the needle. A "pop" will be felt as the axillary sheath is penetrated. The correct needle position is confirmed by eliciting paresthesias, observing blood flow in the needle, or observing pulsations of the needle that match the pulse (**Figure 126-18C**). Instruct an assistant to attach the distal end of intravenous extension tubing to the hub of the needle, and the proximal end to a 60 mL syringe containing local anesthetic solution. The Emergency Physician must always maintain pressure against the neurovascular bundle with the nondominant hand while stabilizing the needle with the dominant hand. Instruct the assistant to aspirate to ensure that the tip of the needle is not within a blood vessel. Withdraw the needle 2 mm if blood flow or paresthesias are elicited.

Apply digital pressure to the neurovascular bundle just distal to the tip of the needle with the nondominant fingers. This prevents the local anesthetic solution from flowing distally. Inject the local anesthetic solution into the axillary sheath after the paresthesias have resolved and a negative aspiration has been achieved. Instruct the assistant to inject a volume of approximately 40 mL in the adult patient. This volume has been shown to consistently block the entire brachial plexus. Reduce the volume based upon the patient's body size and the maximal allowable dose to prevent toxicity. **Continue to apply digital pressure to the neurovascular bundle just distal to the needle during and after injection of the local anesthetic solution.**

Withdraw the needle while the assistant simultaneously injects 3 to 5 mL of local anesthetic solution into the subcutaneous tissue.

This blocks the medial brachial cutaneous nerve and the intercostobrachial nerve. Abduct the patient's arm 30° to 45° after the needle is withdrawn. Maintain this position, while continuing to apply digital pressure to the neurovascular bundle just distal to the needle insertion site, for 2 to 3 minutes.

US-Guided Block This block is performed at the level of the terminal branches of the brachial plexus within the axillary sheath. These branches are visualized as hyperechoic nodules around the pulsatile and hypoechoic axillary artery (**Figures 126-18D & E**). Place the US probe with the marker pointing cephalad at the superior axillary crease (**Figure 126-18F**). Locate the axillary artery and vein in cross section (**Figure 126-18G**). The musculocutaneous nerve can be seen between the biceps muscle and the coracobrachialis muscle. Use color Doppler to confirm the location of the axillary artery, vein, and any branches or take-offs (**Figure 126-18G**). Anesthetize the skin. Position the spinal needle inferior or superior to the long axis of the US probe (**Figure 126-18F**). Slowly insert and advance the needle. Visualize the entire length of the needle as it is advanced. Aim the needle between the axillary artery and vein. Advance through the nerve sheath. Aspirate to ensure the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the subclavian artery. If it is satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks The axillary approach to the brachial plexus is the most commonly used and preferred technique. The procedure is easily mastered, has no major complications, and is easily performed in the obese patient. The disadvantages of this technique include insufficient anesthesia of the shoulder and upper arm. The musculocutaneous nerve provides sensory innervation to the radial aspect of the forearm and may be missed by the local anesthetic agent. The subcutaneous infiltration of local anesthetic solution usually blocks the musculocutaneous nerve. **Proximal flow of the local anesthetic solution is required to ensure adequate anesthesia.** Abduction of the arm while maintaining pressure on the neurovascular bundle allows proximal flow of the local anesthetic solution. It also prevents the humeral head from limiting proximal spread due to compression of the brachial plexus.

BRACHIAL PLEXUS BLOCK, INFRACLAVICULAR APPROACH

This approach to the brachial plexus has many advantages and few serious complications. Unfortunately, this technique requires considerable experience on the part of the Emergency Physician and a nerve stimulator to locate the brachial plexus (**Figures 126-19A & B**). For these reasons, the anatomic landmark approach will not be described. The US-guided technique is described below.

Anatomy The anatomy of the brachial plexus is described above. This approach blocks the brachial plexus at the level of the cords (**Figure 126-15A**).

Patient Positioning Place the patient supine with their head turned 45° from midline and toward the side opposite that being anesthetized (**Figure 126-19A**). Place the ipsilateral arm extended 90°.

Landmarks Identify the middle third of the clavicle.

Infraclavicular Block This block is performed below the clavicle. The cords of the brachial plexus lie below the pectoralis major and minor muscles. They appear as distinct hyperechoic nodules positioned laterally, medially, and posteriorly around the subclavian artery (**Figures 126-19C & D**). Prep and drape the infraclavicular region. Place the US probe with the marker pointing cephalad below the clavicle, medial to the coracoid process (**Figure 126-19E**). Locate the subclavian artery (which is pulsatile) and vein in cross section. Use color Doppler to confirm the location of the subclavian artery, vein, and any branches or take-offs (**Figure 126-19F**). Anesthetize the skin. Position the spinal needle inferior or superior to the long axis of the US probe (**Figure 126-19E**). Insert and advance the needle. Visualize the entire length of the needle as it is advanced. Aim the needle between the subclavian artery and vein. Advance the needle. Continue to advance the needle through the nerve sheath. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the subclavian artery. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks This block can result in an iatrogenic pneumothorax due to the proximity of the needle to the lung apex.

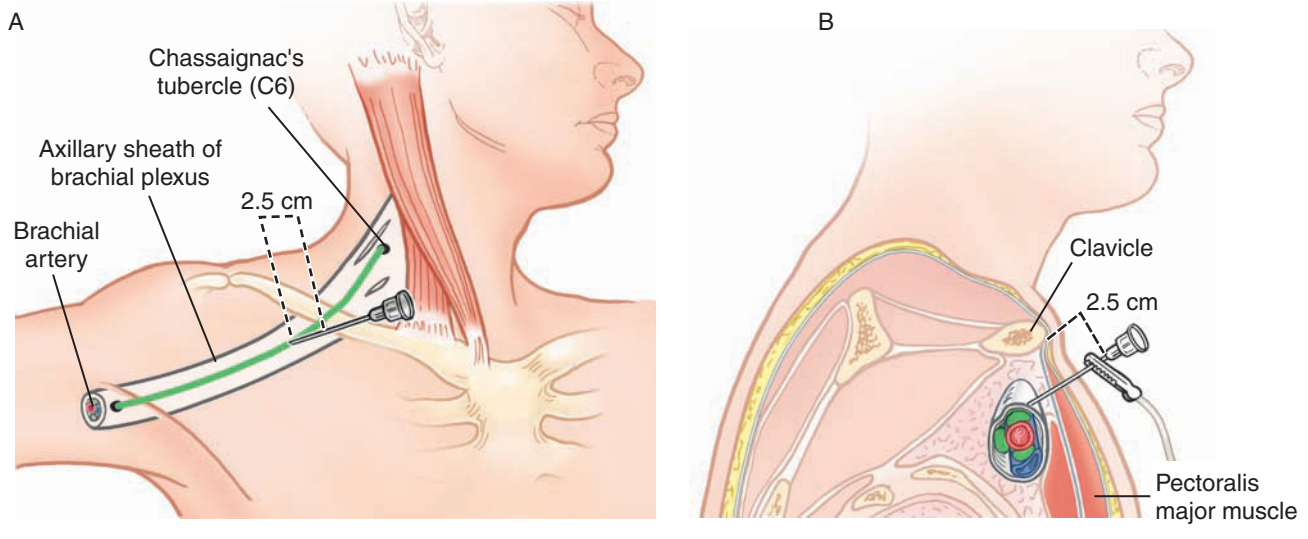
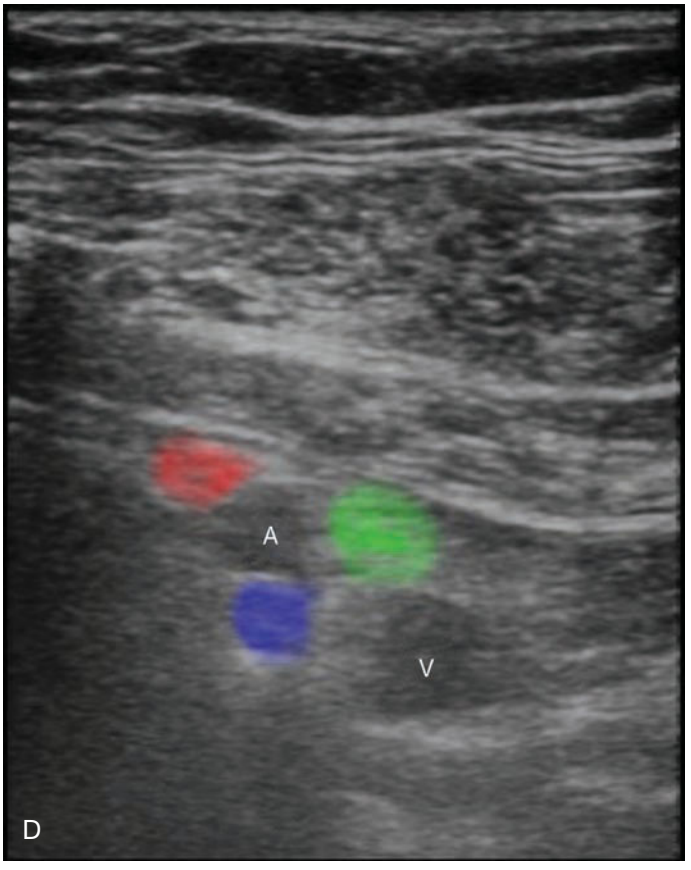


FIGURE 126-19. The infraclavicular approach to the brachial plexus block **A.** Needle insertion and direction. **B.** Sagittal section demonstrating needle insertion into the neurovascular bundle. The alligator clip is attached to a nerve stimulator.







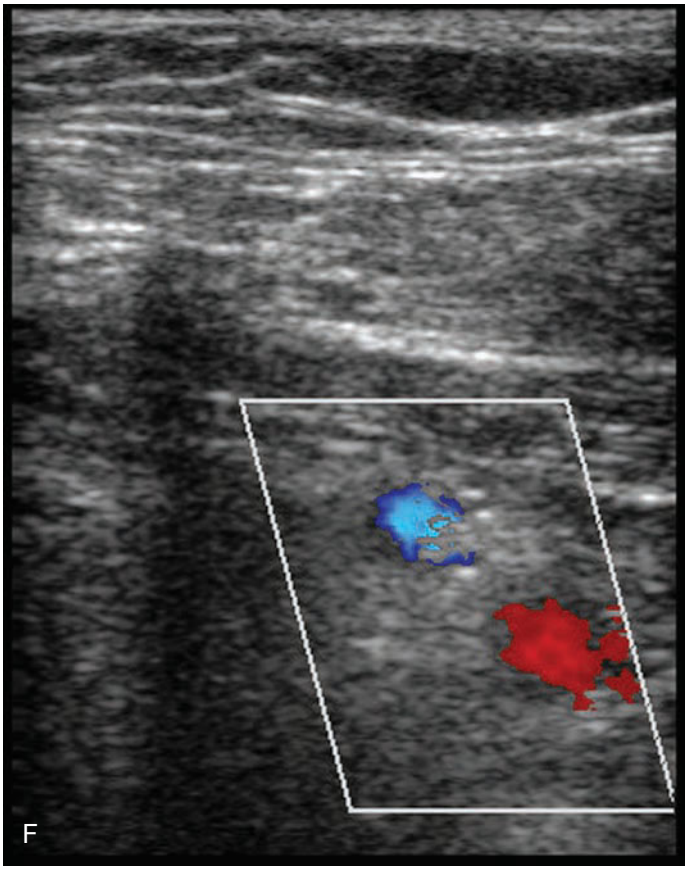


FIGURE 126-19. (*continued*) **C.** US image of the infraclavicular brachial plexus. **D.** Same image as (**C**) with labels (A–subclavian artery, V–subclavian vein, red oval–lateral cord, green oval–medial cord, blue oval–posterior cord). **E.** US probe and needle placement. The clavicle is located between the two red lines. **F.** Color Doppler of the subclavian artery (red) and vein (blue).

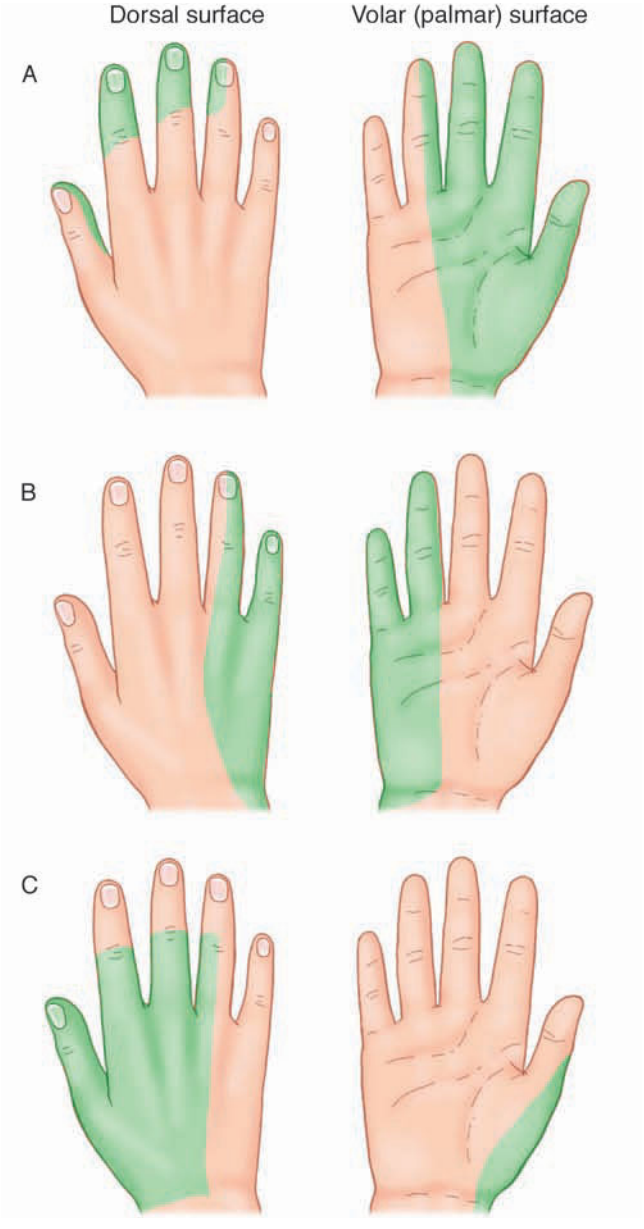


FIGURE 126-20. The sensory innervation of the hand. **A.** The median nerve. **B.** The ulnar nerve. **C.** The radial nerve.

MEDIAN NERVE BLOCK AT THE ELBOW

Anatomy The median nerve innervates all the muscles of the anterior forearm except the flexor digitorum profundus to the ring and little fingers and the flexor carpi ulnaris.[12,22,23] It innervates the thenar muscles and the lumbrical muscles to the index and middle fingers in the hand. It provides sensory innervation to the palmar aspect of the thumb, index finger, middle finger, radial portion of the ring finger, and the lateral half of the palm (**Figure 126-20A**). The median nerve provides a variable amount of sensory innervation to the dorsal distal surfaces of the lateral three and one-half fingers.[12]

Patient Positioning Place the patient supine with their arm abducted 45°, the elbow in full extension, and the hand supinated (**Figure 126-21A**).

Landmarks Identify the medial and lateral epicondyle of the humerus by palpation. Connect the epicondyles with a straight line (**Figure 126-21A**). Identify the brachial artery by palpating for its pulse just medial to the biceps tendon and over the line just drawn. Mark the site of the palpable pulse with a marker.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution just medial to the pulse, at the level of the intercondylar line. Insert a 25 gauge needle perpendicular to the skin and slowly advance it. If paresthesias are elicited, withdraw the needle 1 to 2 mm and allow the paresthesias to resolve. Inject 3 to 5 mL of local anesthetic solution. If paresthesias are not elicited, slowly move the needle in a fan-like pattern to elicit paresthesias. Withdraw the needle 1 to 2 mm, allow the paresthesias to resolve, and inject 3 to 5 mL of local anesthetic solution.

US-Guided Block Place the US probe in the crease of the antecubital fossa. Locate the pulsatile brachial artery in the middle of the antecubital fossa (**Figure 126-21B**). Anesthetize the skin medial to the brachial artery. Place the spinal needle inferior to the short axis of the US probe directly over the median nerve, which should be medial to the brachial artery. Only the tip of the needle will be visualized in this view. Insert and advance the needle until its tip is at the median nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of the local anesthetic solution around the median nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks The median nerve has no sensory branches in the forearm. Therefore, there is no advantage to blocking the median nerve at the elbow. Inserting the needle to elicit paresthesias can be quite painful for the patient. Blockade at the wrist is usually easier to perform, especially in obese patients.[9]

MEDIAN NERVE BLOCK AT THE WRIST

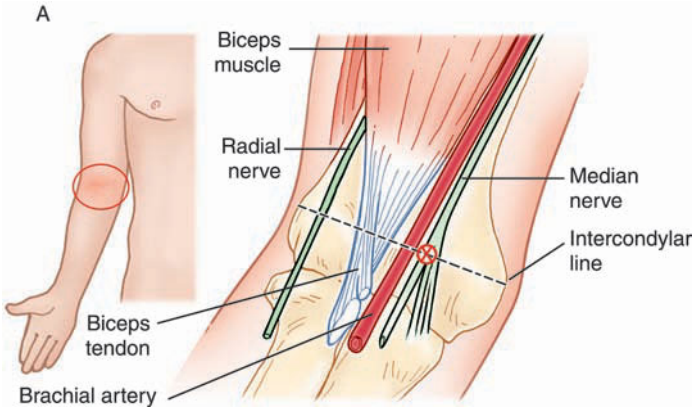
Anatomy The median nerve lies in the carpal tunnel on the volar aspect of the wrist. It is located between the tendons of the flexor carpi radialis and palmaris longus muscles (**Figure 126-21C**). The innervation of the median nerve is described in the previous section.

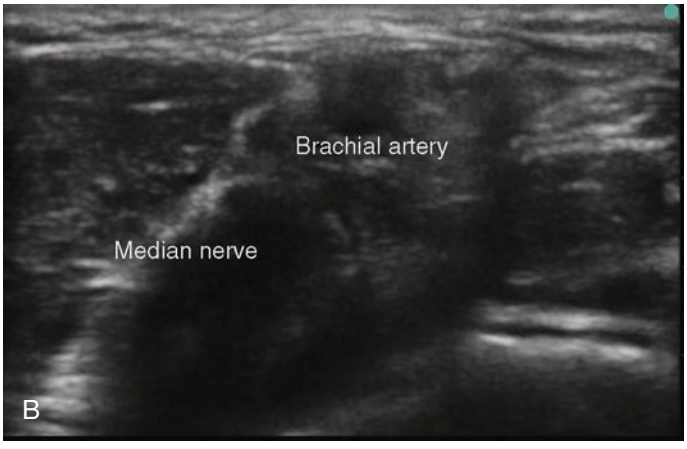
Patient Positioning Place the patient supine with their arm abducted 45°, the elbow in full extension, and the hand fully supinated (**Figure 126-21A**).

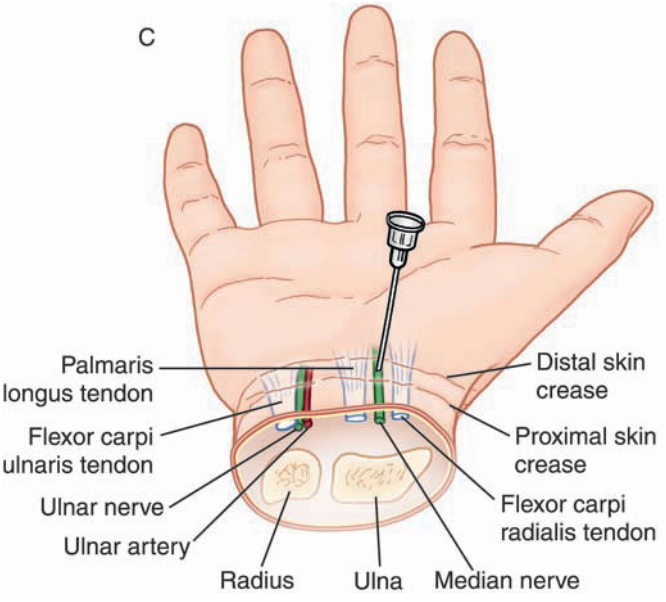
Landmarks Identify the palmaris longus tendon by flexing the patient's clenched hand against resistance. Mark the radial border of the palmaris longus tendon. Note the position of the proximal and distal wrist creases.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution along the radial border of the palmaris longus tendon, between the proximal and distal wrist creases. Insert a 25 gauge needle perpendicular to the skin wheal and advance it slowly (**Figure 126-21C**). If paresthesias are elicited, withdraw the needle 1 to 2 mm and allow them to resolve. Inject 3 to 5 mL of local anesthetic solution. If paresthesias are not elicited, inject 5 to 10 mL of local anesthetic solution. **Injection of the local anesthetic solution should not raise a skin wheal and should flow effortlessly if the needle is within the carpal tunnel.**[12]

US-Guided Block Place the US probe over the middle of the wrist with the marker pointing laterally (**Figure 126-21D**). The Palmaris longus tendon should be visible in the middle of the wrist. The median nerve is hyperechoic and directly lateral to









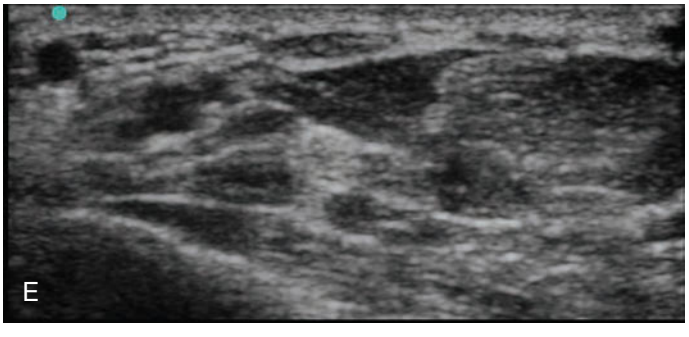


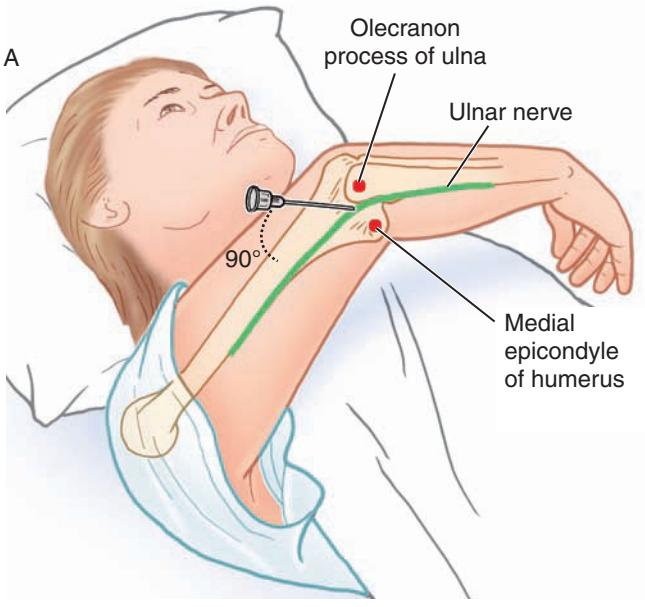
FIGURE 126-21. The median nerve block. **A.** Blockade at the level of the elbow. **B.** US image of the median nerve at the antecubital fossa. **C.** Blockade at the level of the wrist. **D.** US probe and needle placement. **E.** US image of the volar wrist. The median nerve is the round, hyperechoic structure in the center of the image.

this tendon (**Figure 126-21E**). The radial artery is lateral to the median nerve (**Figure 126-21C**). Anesthetize the skin lateral to the palmaris longus tendon. Place the needle inferior to the short axis of the US probe and directly over the median nerve (**Figure 126-21D**). Insert and advance the needle until its tip is at the median nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of the local anesthetic solution around the median nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks A small percentage of the population (10% to 15%) does not have a palmaris longus tendon. Identify the flexor carpi radialis tendon by the same method as identifying the palmaris longus tendon. Inject the local anesthetic solution 1 cm medial to the ulnar edge of the flexor carpi radialis tendon, between the proximal and distal wrist creases. The technique is otherwise as noted above.

ULNAR NERVE BLOCK AT THE ELBOW

Anatomy The ulnar nerve lies in the ulnar groove of the humerus at the elbow, between the olecranon process and medial condyle of the humerus (**Figure 126-22A**). It provides motor innervation to the flexor carpi ulnaris, the ring and little finger portion of the flexor digitorum profundus, the palmaris brevis, the hypothenar muscles, the third and fourth lumbricals, the interossei,



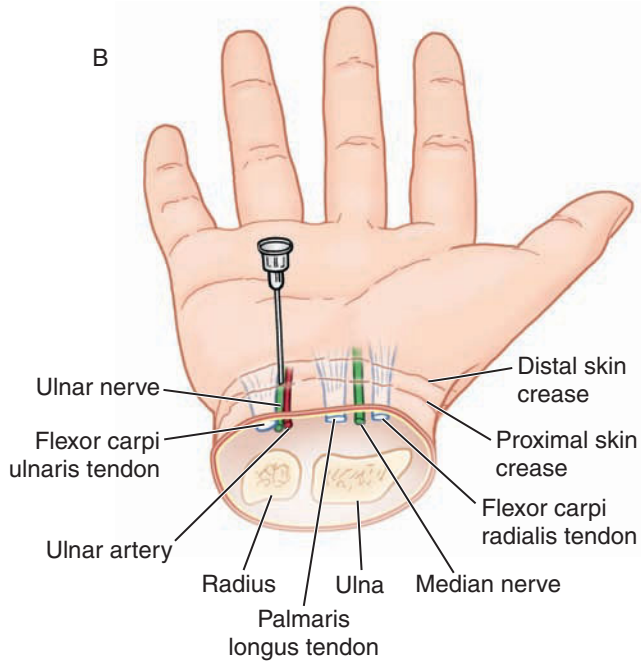






FIGURE 126-22. The ulnar nerve block. **A.** Blockade at the level of the elbow. **B.** Blockade at the level of the wrist. **C.** US probe and needle placement. **D.** US image of the volar wrist. The ulnar artery (*arrow*) is lateral to the hyperechoic ulnar nerve (in the crosshairs).

and the adductor pollicis muscles. It provides sensory innervation to the medial one-third to one-half of the palm, the palmar aspect of the ulnar half of the ring finger, and the entire little finger (**Figure 126-20B**). The ulnar nerve provides sensory innervation to the dorsomedial half of the hand, the little finger, and the ulnar half of the ring finger on the dorsal surface of the hand.[24]

Patient Positioning Place the patient supine with their elbow flexed 90° and the shoulder flexed 45° (**Figure 126-22A**).

Landmarks Identify the olecranon process and the medial epicondyle of the humerus by palpation. Palpate the groove between the olecranon process and the medial epicondyle. The ulnar nerve is located within this groove.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution 1 to 2 cm proximal to the ulnar groove. Insert a 25 gauge needle through the skin wheal and directed toward the ulnar groove. Aim the needle parallel to the ulnar groove and the course

of the nerve (**Figure 126-22A**). Advance the needle into the ulnar groove and inject 5 to 7 mL of local anesthetic solution. If paresthesias are elicited, withdraw the needle 1 mm and allow them to resolve before injecting the local anesthetic solution.

US-Guided Block Place the US probe in the crease between the olecranon process and the medial epicondyle, with the marker pointing laterally. Two hyperlucent structures should be seen, the medial epicondyle medially and the olecranon process closer to the marker. The ulnar nerve is hyperechoic and courses between these two hyperlucent structures. Anesthetize the skin. Place the needle inferior to the short axis of the US probe and directly over the ulnar nerve. Only the tip of the needle will be visualized in this view. Insert and advance the needle until its tip is at the ulnar nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the ulnar nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks The ulnar nerve has no sensory branches in the forearm and thus may be blocked at the wrist or at the elbow. Blockade of the ulnar nerve at the elbow is not recommended. A fibrous sheath surrounds the ulnar nerve at the elbow requiring intraneural injection for a successful blockade. This can lead to residual neuritis and nerve dysfunction. Blocking the ulnar nerve several centimeters above the elbow may prevent these complications. Blockade at the wrist is very reliable and does not have the associated complications as at the elbow.

ULNAR NERVE BLOCK AT THE WRIST

Anatomy The ulnar nerve lies between the distal and proximal flexor skin creases of the wrist, lateral (or radial) to the flexor carpi ulnaris tendon and medial (or ulnar) to the ulnar artery (**Figure 126-22B**). The innervation of the ulnar nerve is described in the previous section.

Patient Positioning Place the patient supine with their arm abducted 45° to 90°, the elbow fully extended, and the hand supinated (**Figure 126-22B**).

Landmarks Identify the flexor carpi ulnaris tendon by flexing the patient's clenched hand against resistance. Mark the medial aspect of the flexor carpi ulnaris tendon. Identify the ulnar artery by its palpable pulsations between the proximal and distal wrist crease. Note the position of the proximal and distal wrist creases.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution in the quadrangle defined by the proximal flexor skin crease, the distal flexor skin crease, the lateral aspect of the flexor carpi ulnaris tendon, and medial to the ulnar artery. Insert a 25 gauge needle perpendicular to the skin wheal and slowly advance it 0.5 cm (**Figure 126-22B**). If paresthesias are elicited, withdraw the needle 2 mm and allow them to resolve. Inject 2 mL of local anesthetic solution once the paresthesias resolve. If paresthesias are not elicited, inject 3 to 5 mL of local anesthetic solution.

US-Guided Block Place the US probe over the middle of the wrist with the marker pointing laterally (**Figure 126-22C**). The Palmaris longus tendon should be visible in the middle of the wrist. Move the US probe medially until the ulnar artery is visible. The ulnar nerve is hyperechoic and directly medial to the ulnar artery (**Figure 126-22D**). Anesthetize the skin medial to the ulnar artery. Position the needle inferior to the short axis of the US probe and directly over the ulnar nerve (**Figure 126-22C**). Insert and advance the needle until its tip is at the ulnar nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the ulnar nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks This is the preferred approach to block the ulnar nerve. Blockade of the ulnar nerve at the wrist is very reliable and does not have the associated complications as at the elbow.[25]

RADIAL NERVE BLOCK AT THE ELBOW

Anatomy The radial nerve and the sensory branch of the musculocutaneous nerve run together in the sulcus between the biceps and the brachioradialis muscle on the anterolateral aspect of the elbow. The radial nerve provides sensory innervation to portions of the dorsal arm and forearm, the dorsolateral half of the hand, and the dorsal proximal aspects of the thumb, index, middle, and radial half of the ring fingers (**Figure 126-20**).[12] It provides motor innervation to the muscles on the posterior aspect of the arm, forearm, and hand.

Patient Positioning Place the patient supine with their elbow flexed 15° to 30°.

Landmarks Palpate the tendon of the biceps muscle in the antecubital fossa. Identify the flexion skin crease of the elbow. Palpation of the biceps tendon is greatly facilitated by having the patient flex their elbow 90° then contract and relax their biceps muscle. Identify the medial and lateral condyles of the humerus. Draw a line between the humeral condyles (**Figure 126-23A**). This line should be located at the level of the antecubital crease.

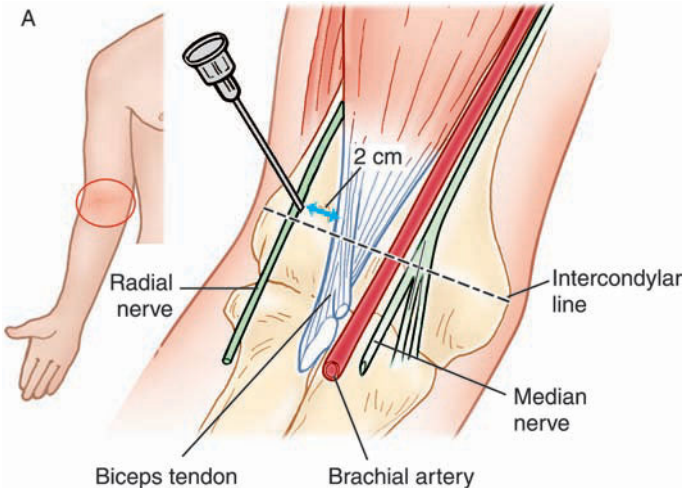
Needle Insertion and Direction Place a skin wheal of local anesthetic solution 2 cm lateral to the biceps tendon and 1 cm proximal to the antecubital crease (**Figure 126-23A**). Insert a 25 gauge needle through the skin wheal and perpendicular to the skin (**Figure 126-23A**). Advance the needle 1 to 2 cm. Probe in a fan-like pattern until paresthesias are elicited. Withdraw the needle 1 to 2 mm and allow the paresthesias to resolve. Inject 5 to 7 mL of local anesthetic solution.

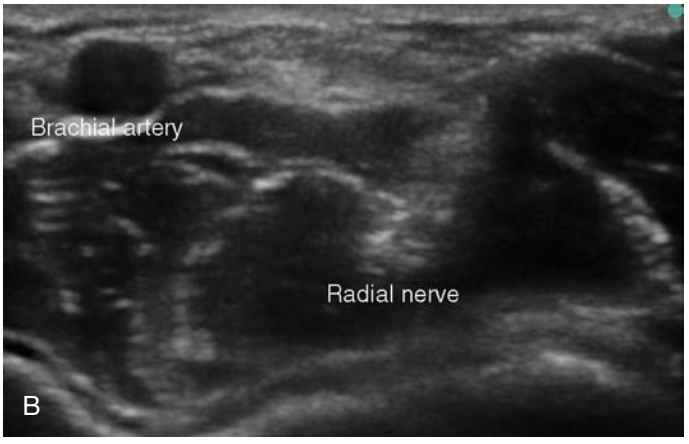
US-Guided Block Position the patient with their arm abducted 45°, the elbow in full extension, and the hand supinated. Place the US probe on the lateral aspect of the crease of the antecubital fossa. The radial nerve is lateral to the biceps tendon and the brachial artery (**Figure 126-23A**). Anesthetize the skin over the radial nerve. Place the needle inferior to the short axis of the US probe and directly over the radial nerve. Only the tip of the needle will be visualized in this view. Insert and advance the needle until its tip is at the radial nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the radial nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks Blockade of the radial nerve at the elbow is difficult, has limited applications, is painful for the patient, and often results in a large antecubital hematoma. The preferred technique is blockade at the wrist.

RADIAL NERVE BLOCK AT THE WRIST

Anatomy The radial nerve at the wrist consists of a trunk and terminal branches that arise in the forearm (**Figure 126-23C**). The innervation of the radial nerve is described in the previous section.





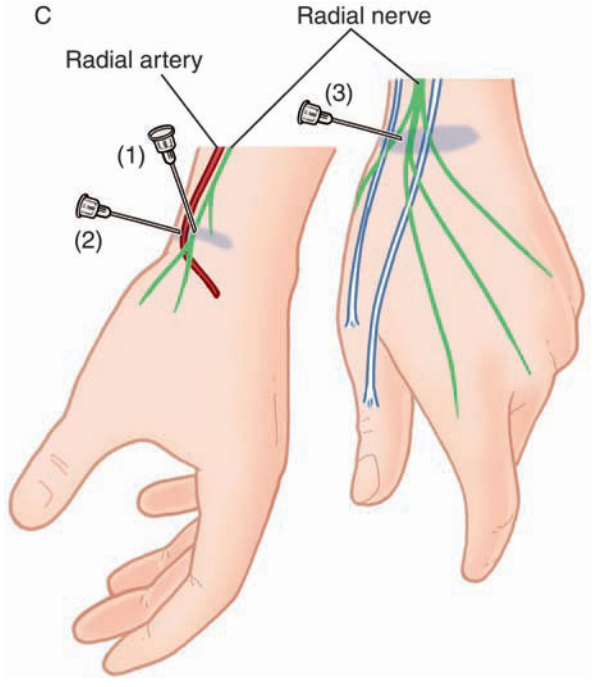




FIGURE 126-23. The radial nerve block. **A.** Blockade at the level of the elbow. **B.** US image of the radial nerve at the elbow. **C.** Blockade at the level of the wrist. The numbers represent the three injections required to anesthetize the branches of the radial nerve. **D.** US image of the wrist. The radial artery (*arrow*) is adjacent and medial to the radial nerve (in the crosshairs).

Patient Positioning Place the patient supine with their arm abducted 45°, the elbow fully extended, and the hand midway between supination and pronation (**Figure 126-23C**).

Landmarks Identify the radial artery by its pulsation at the level of the proximal wrist crease.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution 1 mm lateral to the radial pulse. Insert a 25 gauge needle 1 mm lateral to the radial pulse, through the skin wheal, and perpendicular to the skin (**Figure 126-23C**). Advance the needle 0.5 cm. If paresthesias are elicited, withdraw the needle 1 to 2 mm and allow them to resolve. Inject 2 mL of local anesthetic solution. If paresthesias are not elicited, inject 3 to 5 mL of local anesthetic solution. This will anesthetize the terminal trunk of the radial nerve. Infiltrate 5 to 7 mL of local anesthetic solution at the level of the extensor wrist crease, from the lateral aspect of the radius to the base of the fourth metacarpal (**Figure 126-23C**). This will anesthetize the terminal branches that arise in the forearm.

US-Guided Block Place the US probe over the middle of the wrist with the marker pointing laterally. The palmaris longus tendon should be visible in the middle of the wrist. Move the US probe laterally until the radial artery is visualized. The radial nerve is hyperechoic and directly lateral to the radial artery (**Figures 126-23D**).

Anesthetize the skin lateral to the radial artery and directly over the radial nerve. Place the needle inferior to the short axis of the US probe and directly over the radial nerve. Insert and advance the needle until its tip is at the radial nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the radial nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks This is the preferred technique for blockade of the radial nerve.

WRIST BLOCK

Perform the wrist block by blocking the radial, ulnar, and median nerves at the wrist. The technique for each specific nerve block was discussed previously. The wrist block provides complete anesthesia to the hand and is commonly used in hand surgery. It can be performed in the Emergency Department to provide anesthesia for burn management, foreign body removal, wound exploration, or extensive laceration repair. Wrist blockade is reliable but slow, as it requires extended time to block all three nerves at the wrist.[12]

INTERMETACARPAL NERVE BLOCK

Anatomy The principal nerves supplying the finger are the palmar digital nerves, which originate from the deep volar branches of the ulnar and median nerves in the region of the wrist. These nerves follow the artery along the lateral aspects of the bone and supply sensation to the volar skin, the interphalangeal joints, the distal finger, and the fingertip of all five digits.

Two dorsal and two palmar nerves supply each finger. These nerves run along the phalanxes in the 2, 4, 8, and 10 o'clock positions.[26] These nerves also supply the dorsal, distal aspect of the finger, including the fingertip and nail bed. The dorsal digital nerves originate from the radial and ulnar nerves that wrap around the dorsum of the hand. They supply the nail bed of the thumb and small finger and the dorsal aspect of all five digits up to the distal interphalangeal joints. The palmar and dorsal nerves need to be blocked in the case of the thumb and fifth finger.

Patient Positioning Place the patient sitting upright or supine with their hand pronated on a bedside examination table.

Landmarks Locate the web spaces and the metacarpal heads on each side of the finger to be blocked.

Needle Insertion and Direction Insert a 25 gauge needle into the dorsal aspect of the web space on one side of the digit to be anesthetized (**Figure 126-24A**). Advance the needle approximately 0.5 cm. Inject 1 mL of local anesthetic solution. Repeat the procedure on the other side of the digit to be blocked. When blocking the second and fifth digits, a half-ring block is required on the ulnar aspect of the fifth digit and radial aspect of the second digit. When blocking the thumb, infiltrate the dorsum and sides in a half-ring manner.

An alternative is the metacarpal head block. This technique can be used to anesthetize any of the fingers. Insert a 25 gauge needle perpendicular to the dorsum of the hand and adjacent to the metacarpal head on one side of the finger to be blocked (**Figure 126-24B**). Advance the needle 0.5 cm and inject 1 mL of local anesthetic solution. Repeat the procedure on the other side of the finger to be blocked. Some physicians prefer to perform this block on the volar aspect of the hand (**Figure 126-24C**). This technique is extremely painful and should be avoided.

Remarks This block produces less swelling than does the ring block. Subsequently, there is less risk of vascular compromise. This is a less painful technique than the ring block.

DIGITAL NERVE BLOCK (RING BLOCK) OF THE FINGER

Anatomy The anatomy and innervation of the digital nerves are described in the previous section.

Patient Positioning Place the patient sitting upright or supine with their hand pronated on a bedside examination table.

Landmarks Locate the dorsum of the proximal phalanx to be anesthetized.

Needle Insertion and Direction Insert a 25 gauge needle on the dorsal surface of the base of the proximal phalanx (**Figure 126-24D(1)**). Inject 1 mL of local anesthetic solution along the dorsal surface of the finger. Remove the needle and reinsert it downward, perpendicular to the phalanx and to a depth just past the base of the phalanx (**Figure 126-24D(2)**). Inject 1.0 to 1.5 mL of local anesthetic along the lateral aspect of the finger. Withdraw the needle, reinsert it on the other side of the finger to be blocked, and inject 1.0 to 1.5 mL of local anesthetic solution (**Figure 126-24D(3)**).

An alternative is the half-ring block (**Figure 126-24E**). It is a variant of the ring block (**Figure 126-24D**). Inject 1.0 to 1.5 mL of local anesthetic solution on one side of the base of the proximal phalanx to be anesthetized. Repeat this procedure on the other side of the finger. The injection of local anesthetic on one side of the finger is termed the half-ring block. It takes two half-ring blocks to anesthetize a finger.

Remarks The indications for a digital block include repair of finger lacerations and amputations, reductions of fractures and dislocations, incision and drainage of infections, removal of fingernails, and relief of pain from burns. Do not inject more than 5 mL of local anesthetic solution into a digit. Using local anesthetic agents that contain epinephrine is not recommended because the finger contains end arteries and may experience ischemia from the vasoconstrictive effects of epinephrine.

REGIONAL ANESTHESIA TECHNIQUES FOR THE TORSO

INTERCOSTAL NERVE BLOCK

Anatomy The intercostal nerves originate from the thoracic spinal cord and have four major branches (**Figure 126-25**). The first is the gray rami communicans to the sympathetic ganglion. The second branch is the posterior cutaneous nerve that supplies the paravertebral muscles and overlying skin. The third branch is the lateral cutaneous nerve that arises about the midaxillary line. It divides into an anterior and posterior division to supply most of the chest and the abdominal wall. The final branch is the terminal anterior cutaneous nerve. It supplies the anterior chest and abdominal wall adjacent to the midline. Each intercostal nerve travels within a neurovascular bundle behind the inferior border of each rib (**Figure 126-25B**). The intercostal nerve lies inferior to the intercostal vein and artery. The intercostal nerve may be blocked at several sites along its course. The most common site is at the angle of the rib. The technique described will be the blockade of the intercostal nerves at the angle of the rib.

Patient Positioning Place the patient prone with a pillow under the midabdomen to straighten the lumbar curve and increase the size of the intercostal spaces posteriorly.

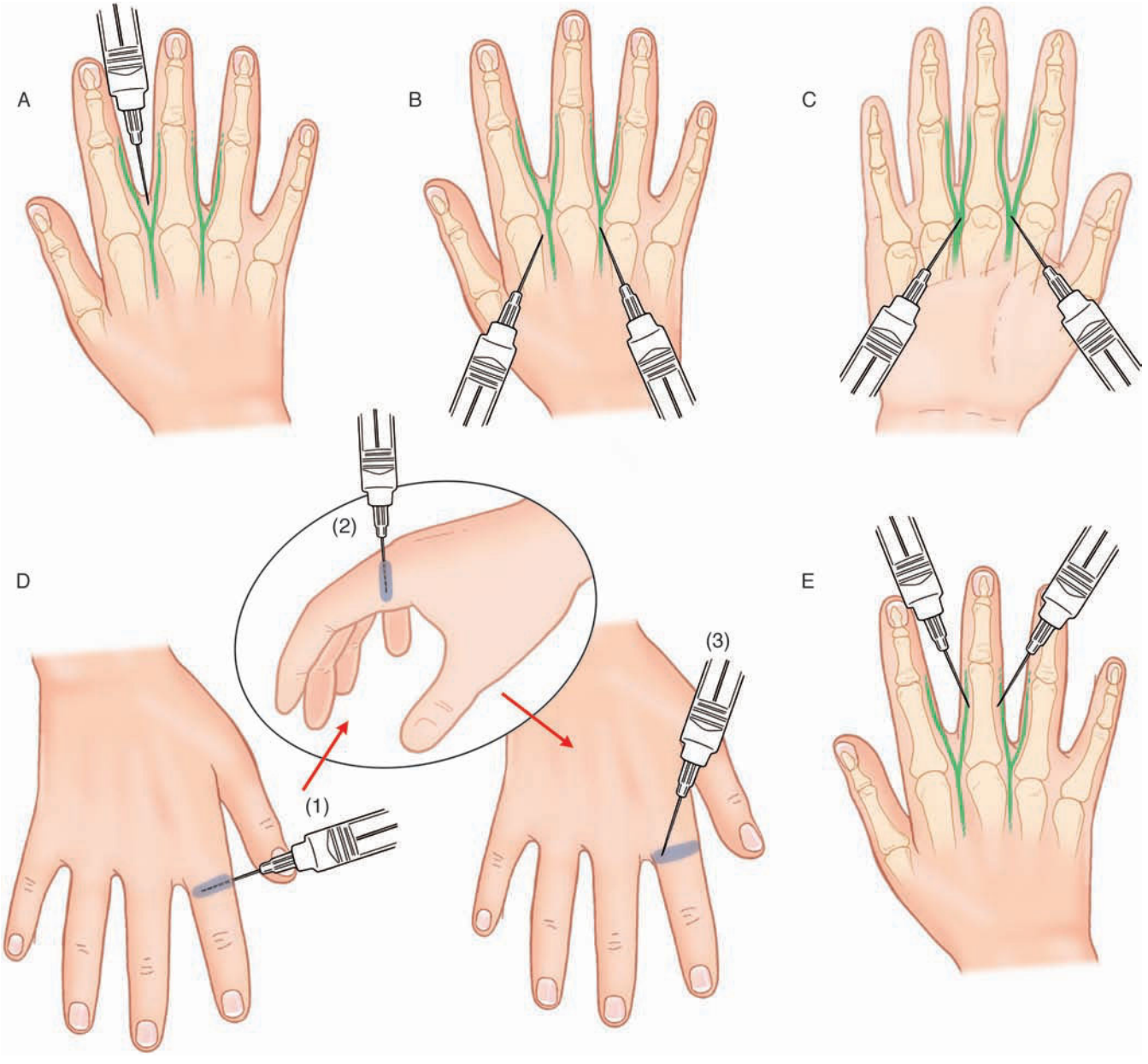


FIGURE 126-24. Techniques to anesthetize the digital nerves of the fingers. **A.** Intermetacarpal nerve block through the web space. **B.** Intermetacarpal nerve block on the dorsal surface of the hand, between the metacarpal heads. **C.** Intermetacarpal nerve block on the ventral surface of the hand, between the metacarpal heads. **D.** The ring block. **E.** The half-ring block.

Landmarks **The most important step is to correctly identify the anatomy of the patient.** Draw a line along the vertebral spines corresponding to the levels to be anesthetized. Palpate laterally from the vertebral spines to the edge of the paraspinal muscles. This is the location where the ribs are most superficial. This distance can vary from 6 to 8 cm from the midline in the average adult. Draw vertical lines parallel to the first line and along the edge of the paraspinal muscles (**Figure 126-26A**). These lines must angle slightly medially over the upper ribs to avoid the scapula. Palpate and mark the inferior edge of each rib along these two vertical lines (**Figure 126-26A**).

Needle Insertion and Direction **This procedure requires the utmost of care to prevent inducing a pneumothorax.** Inject local anesthetic solution to make a skin wheal at the intersection of the horizontal lines with the vertical paraspinal muscle lines. Use the index finger of the nondominant hand to pull the skin at the lower edge of the rib up onto the rib (**Figure 126-26B**). Grasp the syringe in the dominant hand. Insert the 25-gauge needle at a 60° angle along the tip of the nondominant index finger while the dominant hand is resting on the patient's back (**Figure 126-26C**). Advance the needle until the rib is contacted (**Figure 126-26C**, inset).

Reposition the nondominant hand so that it is resting against the patient's back and holding the needle between the thumb, index, and middle fingers (**Figure 126-26D**). Use the nondominant hand to slowly and carefully "walk" the needle off the inferior rib margin (**Figure 126-26E**). Advance the needle 3 mm with the nondominant hand (**Figure 126-26F**). **It is imperative that the needle not be advanced more than 3 mm after it is "walked" off the inferior border of the rib to prevent an iatrogenic pneumothorax.**

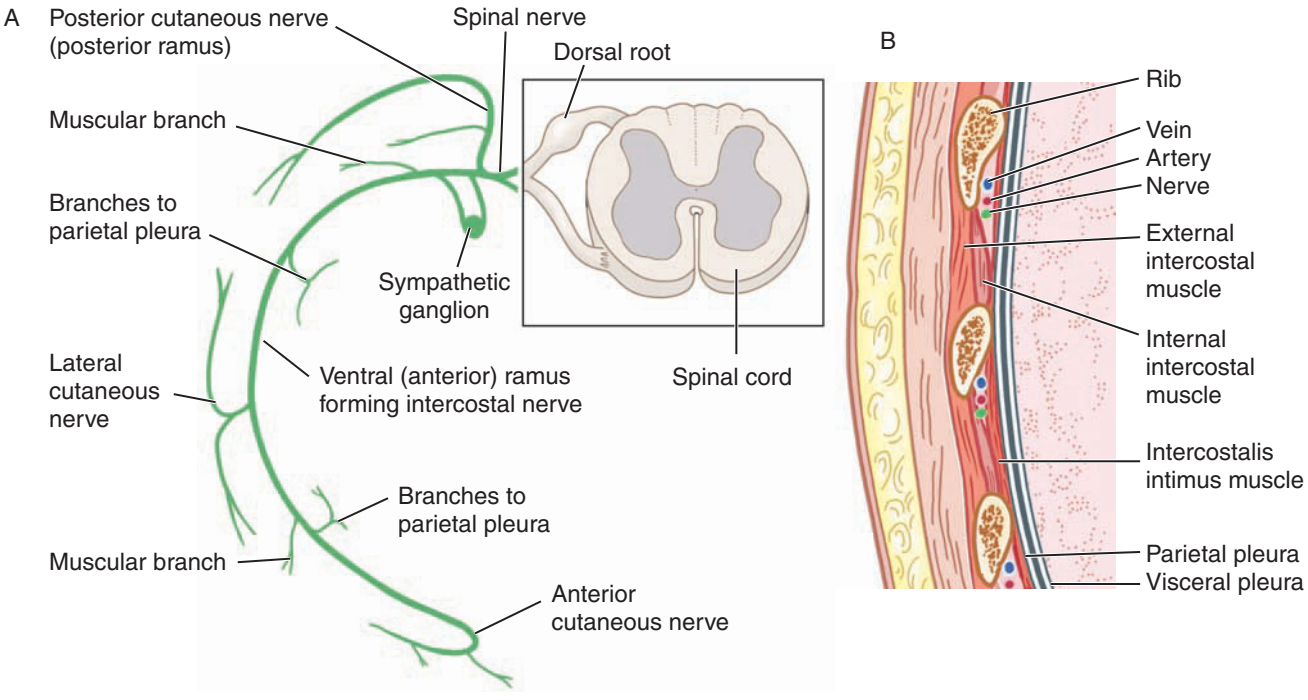


FIGURE 126-25. The intercostal nerve. **A.** The anatomy of a typical thoracic spinal nerve. **B.** Cross section through the chest wall. The intercostal nerves are contained within a neurovascular bundle that lies behind the inferior border of each rib.

Aspirate to ensure that the tip of the needle is not within a blood vessel or the lung. Inject 1 to 2 mL of local anesthetic solution (**Figure 126-26G**). Remove the needle and repeat the procedure at the other desired interspaces.

Remarks Local anesthetic solution for intercostal blocks should contain 1:200,000 or less of epinephrine. **Obtain a postprocedural upright chest radiograph to ensure that the patient does not have an iatrogenic pneumothorax.**[27]

PENILE BLOCK

The penis may be anesthetized for the purposes of circumcision, laceration repair, foreign body removal, zipper entrapment, or to perform the release of a phimosis or paraphimosis. The dorsal nerves of the penis provide sensory innervation to the penis. They emerge from under the pubis, just lateral to the symphysis, and course along the dorsal surface of the penis. These nerves are located approximately 0.5 cm from the dorsal penile midline. These nerves are blocked at the base of the penis. Refer to Chapter 146 for the complete details of the penile block.

REGIONAL ANESTHESIA TECHNIQUES FOR THE LOWER EXTREMITY

The sensory innervation of the lower extremity is illustrated in **Figure 126-27**. Note that the nerves provide patches of innervation rather than stripes of innervation beginning at the torso and extending to the foot.

FEMORAL NERVE BLOCK

Anatomy The femoral nerve is formed from the lumbar plexus. It travels in the pelvis between the iliacus and psoas major muscles. It enters the thigh below the inguinal ligament, midway between the anterior superior iliac spine and the pubic tubercle (**Figure 126-28A**). The femoral nerve lies anterior to the iliopsoas muscle and lateral to the femoral artery in the proximal thigh (**Figure 126-28B**). The femoral nerve has both sensory and motor components. It provides motor innervation to the anterior thigh muscles. It provides sensory innervation for the anterior thigh, anteromedial thigh, medial thigh, medial leg, and the medial border of the foot (**Figure 126-27**).

Patient Positioning Place the patient supine with their hip and knee extended and the leg slightly externally rotated.

Landmarks Identify the anterior superior iliac spine and the pubic tubercle by palpation. Connect these landmarks with a straight line to roughly approximate the position of the inguinal ligament. Identify the femoral artery by its palpable pulse 1 to 2 cm below the midpoint of the inguinal ligament.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution just lateral to the femoral artery pulse. Insert a 25 gauge needle through the skin wheal and perpendicular to the skin (**Figure 126-28B**). Slowly advance the needle while remaining perpendicular to the skin. The femoral nerve is identified once paresthesias are elicited. Withdraw the needle 2 mm and allow the paresthesias to resolve. Inject 15 to 20 mL of local anesthetic solution.

US-Guided Block Place the US probe along the inguinal crease, midway between the anterior superior iliac spine and the pubic tubercle (**Figure 126-28C**). Identify the femoral artery and femoral vein. The femoral nerve is hyperechoic and located 0.5 to 1 cm lateral and posterior to the common femoral artery (**Figure 126-28D**). Apply pressure with the US probe to distinguish the compressible femoral vein from the incompressible femoral artery. Use color Doppler to confirm the location of the femoral artery and any branches or take-offs. Place the needle lateral to the long axis of the US probe (**Figure 126-28C**). Slowly insert and advance the needle. Visualize the entire length of the needle as it is inserted and approaches the

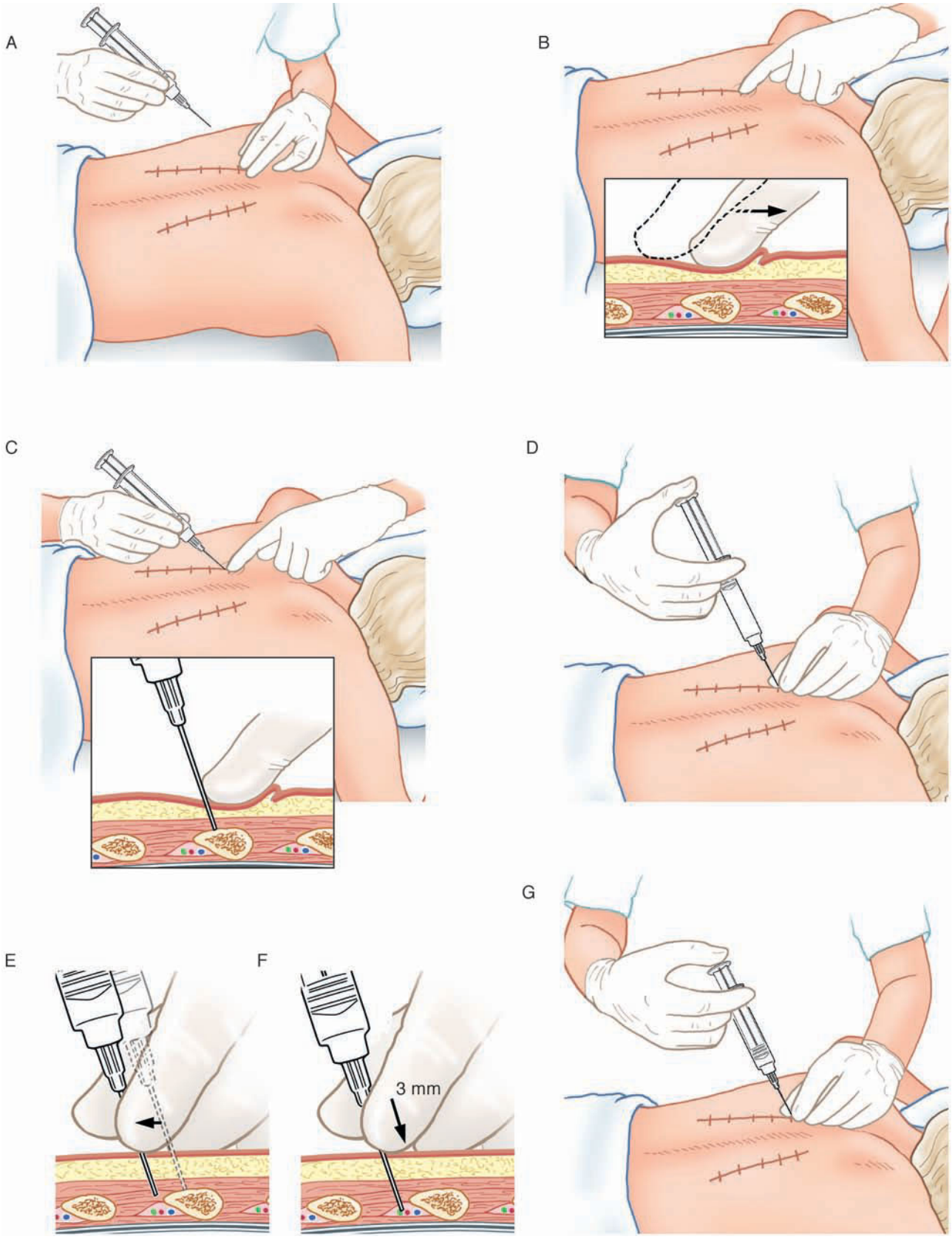


FIGURE 126-26. The intercostal nerve block. **A.** The patient is placed prone. A line is drawn along the lateral border of the paraspinal muscles. Note that the upper end is angled medially to avoid the scapula. Cross-marks are drawn to denote the inferior border of the rib and the location to perform the block. **B.** The index finger of the nondominant hand pulls the skin over-lying the inferior border of the rib upward. **C.** The dominant hand is resting against the patient. The needle is inserted at a 60° angle to the skin and advanced until the rib is contacted. **D.** The fingers of the nondominant hand grasp and stabilize the needle. **E.** The needle is "walked" off the inferior border of the rib. **F.** The needle is advanced 3 mm so that the tip is within the neurovascular bundle. **G.** Inject 1 to 2 mL of local anesthetic solution while maintaining the needle in a stable position with the nondominant hand.

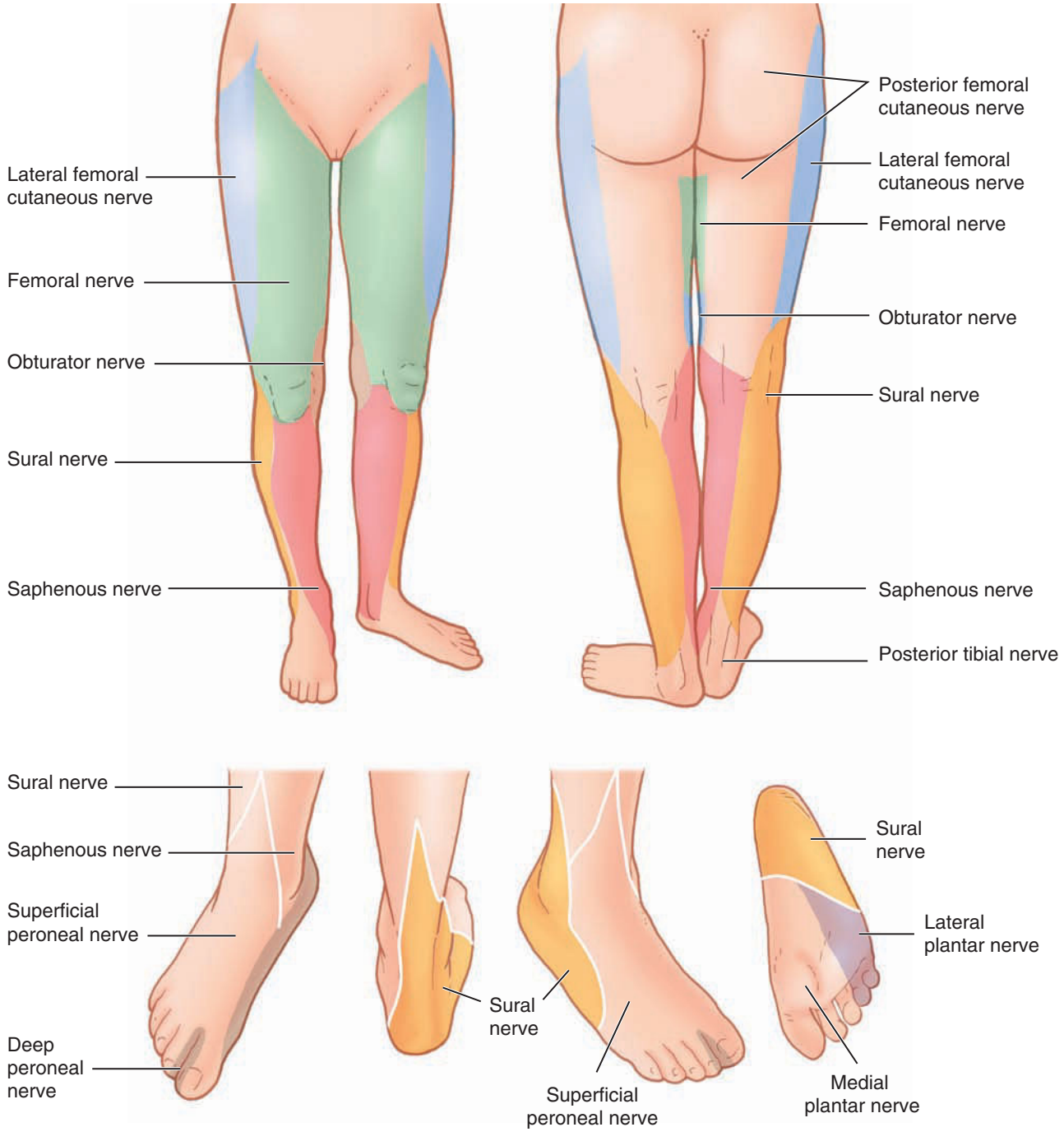


FIGURE 126-27. The sensory distribution of the cutaneous nerves of the lower extremity.

femoral nerve. Continue to advance the needle and penetrate the fascia lata and fascia iliaca so that the tip of the needle is adjacent to the femoral nerve. Aspirate to ensure that the needle tip is not in a blood vessel. Inject a test dose of 1 to 2 mL of local anesthetic solution. Watch the spread of local anesthetic solution around the femoral nerve. If satisfactory, inject the remainder of the local anesthetic solution to produce the "donut sign." If the test dose is not satisfactory, reposition the needle and inject another test dose.

Remarks The femoral nerve is contained within a fibrous sheath that is separate from the other contents (femoral artery and vein) of the femoral triangle (**Figure 126-28B**). **Paresthesias must be elicited to confirm the proper position of the tip of the needle before injecting the local anesthetic solution.** Deposition of the local anesthetic solution outside of the fibrous sheath will not result in any anesthesia except in the area of the injection.

SAPHENOUS NERVE BLOCK AT THE KNEE

Anatomy The saphenous nerve is the terminal branch of the femoral nerve. It travels across the anterior thigh in a medial direction to become superficial at the medial knee after emerging between the tendons of the gracilis and sartorius muscles (**Figure 126-29A**). It follows the great saphenous vein from above the knee to below the medial malleolus (**Figure 126-29B**). It provides sensory innervation

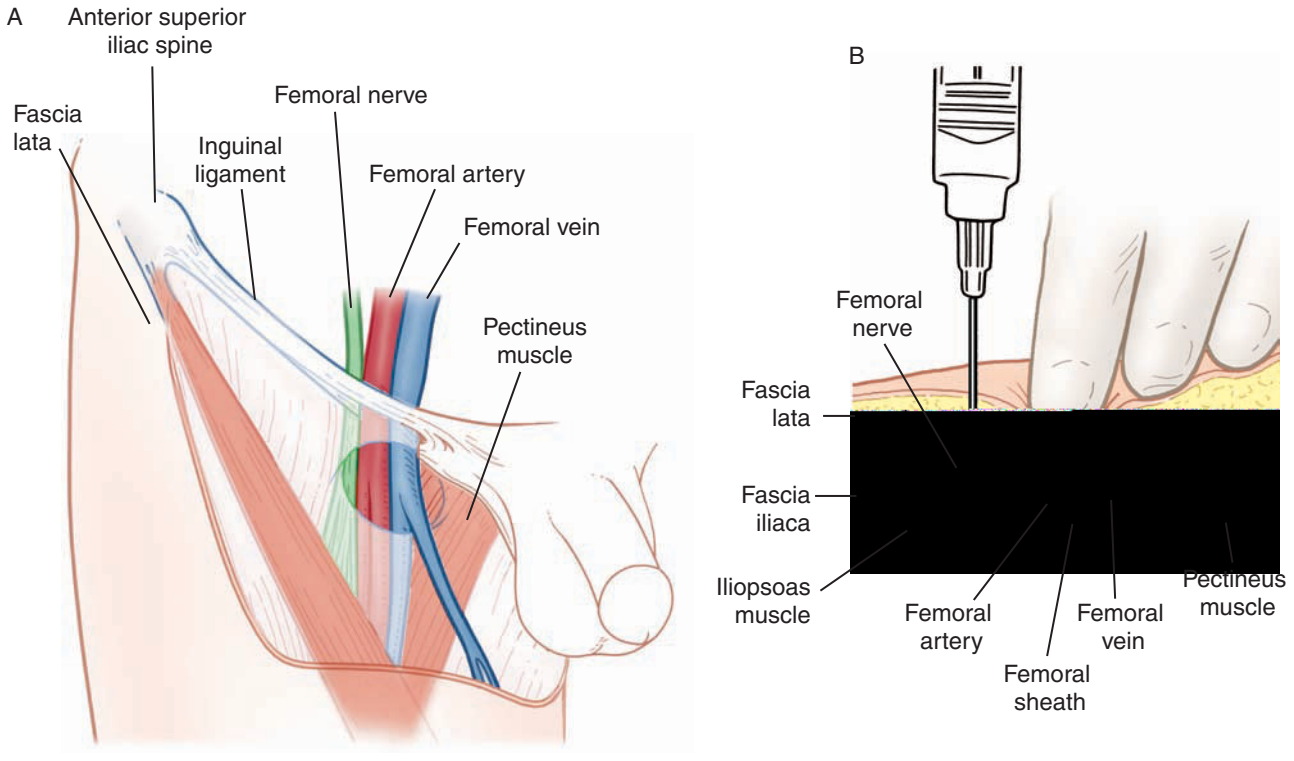


FIGURE 126-28. The femoral nerve block. **A.** The anatomy of the inguinal region. **B.** Blockade of the femoral nerve. **C.** US probe and needle placement. **D.** US image of the femoral neurovascular bundle. The femoral nerve is located within the crosshairs. (A–femoral artery, V–femoral vein)

to the anteromedial leg, medial leg, posteromedial leg, and medial border of the foot to the ball of the great toe (**Figure 126-27**). It has no motor component.

Patient Positioning Place the patient supine with their ankle supported on a pillow or blanket, the knee extended, and the leg externally rotated.

Landmarks Identify the femoral condyle above the knee or the tibial condyle below the knee by palpation.

Needle Insertion and Direction Place a skin wheal of local anesthetic solution over the posteromedial aspect of either condyle (femoral or tibial). Insert a 25 gauge needle through the skin wheal. Infiltrate 7 to 10 mL of local anesthetic solution subcutaneously in a transverse line from the posteromedial to the anteromedial aspect of either condyle (**Figure 126-29C**).

US-Guided Block Identify the femoral artery and femoral nerve at the inguinal crease (see femoral nerve block). Move the US probe

can be prevented by using appropriate techniques and care when delivering the infant.

SUMMARY

The Emergency Physician will occasionally be required to perform a delivery of a baby when the Obstetrician or Family Physician is not available or when delivery is imminent. Fortunately, births in the Emergency Department are rare and most proceed with good outcomes. Knowledge of the normal labor and delivery mechanics aids in a safe delivery and helps to identify complications. The Emergency Physician must develop strategies to treat potential complications and must be prepared to intervene.

132 Episiotomy

Francisco Orejuela

INTRODUCTION

An episiotomy is a surgical incision of the female perineum performed at the time of delivery to increase the diameter of the soft tissue pelvic outlet and facilitate a vaginal delivery. It is one of the most commonly performed surgical procedures in women in the United States, yet it is controversial.

For many decades the episiotomy was thought to provide protection to the female genital tract.[1,2] It is thought to prevent perineal tearing by substituting a straight surgical incision for a ragged spontaneous laceration that may have a worse outcome after repair. It was also believed that an episiotomy resulted in decreased postoperative pain and improved healing when compared to a tear. These original beliefs have been challenged. There is a growing body of evidence demonstrating increased injury to the pelvic floor with the routine use of an episiotomy.[3–6] A recent Cochrane database review of eight randomized controlled trials concluded that there is less posterior perineal trauma, less suturing, and fewer complications with a restrictive use versus the liberal use of an episiotomy.[7] Currently, the evidence does not support a liberal or routine use of an episiotomy.[8] These practice patterns are reflected in a steady decline in the use of an episiotomy from 1.6 million in 1992 to 716,000 in 2003.[9,10]

Nonetheless, there is a place for the episiotomy in modern obstetrics. The indications for an episiotomy today are based primarily on the clinical situation at the time of delivery. Another important reason to make an episiotomy is the prevention of a long and irregular spontaneous perineal laceration. The repair of a controlled surgical incision might be easier to repair, and the anatomical planes easier to recognize. Good clinical judgment is still the best guide to proceed or not with an episiotomy.[11]

ANATOMY AND PATHOPHYSIOLOGY

ANATOMY OF THE PERINEUM

The most critical area of the perineum is the distance from the vestibular fossa to the anus. This area is known as the pudenda, or more commonly as the perineal body. It is usually 3 to 4 cm in length in the nonpregnant woman.[10,11] The perineal body is a complex fibromuscular mass into which many structures insert. It is bordered cephalad by the rectovaginal septum (Denonvilliers' fascia), caudad by the perineal skin, anteriorly by the posterior wall of the vagina, posteriorly by the anterior wall of the anorectum, and laterally by the ischial rami.[12]

The perineal body is the center of the hub of a wheel that includes the transverse perineal muscles, the capsule of the external anal sphincter muscle, and the bulbospongiosus muscle (**Figure 132-1**). The perineal body attaches to the ischial

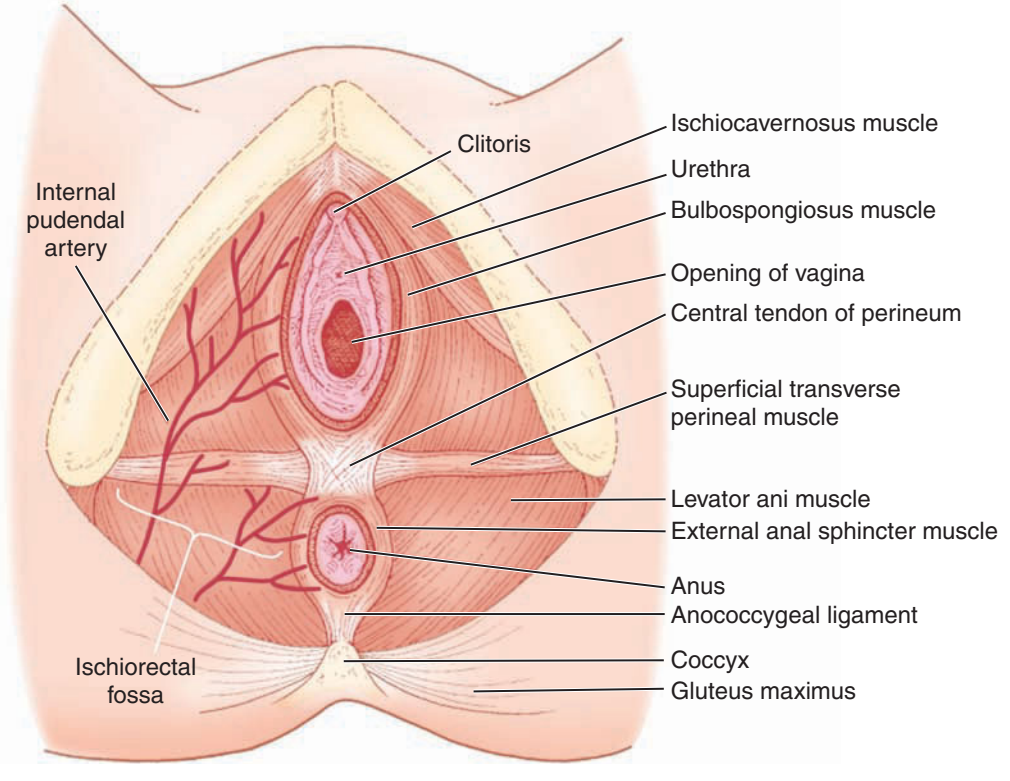


FIGURE 132-1. The anatomy of the perineum. The skin and subcutaneous tissues have been removed.

tuberosities and to the inferior pubic rami through the perineal membrane and superficial transverse perineal muscles. The bulbospongiosus muscles are located laterally to the introitus and deep to the labia majora. They insert into the inferior limit of the perineal body with the superficial transverse muscles and the subcutaneous portion of the external anal sphincter. Laterally, the bulbospongiosus muscle is attached to the muscles of the pelvic diaphragm. It is anchored posteriorly to the coccyx by the anal sphincter and anococcygeal ligament. The mediolateral episiotomy transects the superficial muscles of the perineum whereas the midline episiotomy does not.

The pudendal nerve supplies most of the innervation to the perineal body. This nerve is formed from the ventral rami of sacral spinal nerves two through four. The arterial supply is primarily derived from the internal pudendal artery, one of the branches of the anterior trunk of the internal iliac artery.[11]

TYPES OF EPISIOTOMY

An episiotomy may be performed in the midline or mediolaterally (**Figure 132-2**).[13–16] The choice between the two types of episiotomy is largely dependent upon the experience of the practitioner. Factors that influence type of episiotomy include, but are not limited to, the site of prior episiotomies, position of the presenting fetal part, the thickness or rigidity of the patient's perineum, and the obstetric perception of an impending severe laceration that risks a fourth-degree extension. A mediolateral incision may be prudent when an extended episiotomy is required or when the risk of a fourth-degree laceration is significant.[17–19] **Never perform a lateral (Figure 132-2A) or a Schuchardt (Figure 132-2D) episiotomy in the Emergency Department.** These are associated with significant complications.[13]

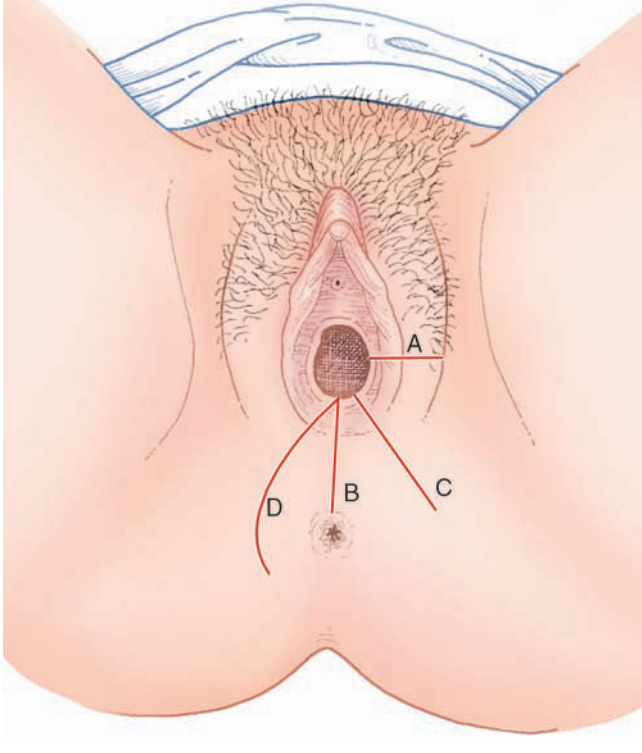


FIGURE 132-2. The types of episiotomies. **A.** Lateral. **B.** Midline. **C.** Mediolateral. **D.** Schuchardt.

MIDLINE EPISIOTOMY

The midline episiotomy is a surgical incision made in the midline of the perineal body, starting from the vaginal orifice toward the anus (**Figure 132-2B**). The incision transects the central tendinous portion of the perineal body and usually extends to the level of the transverse perineal muscle (**Figure 132-1**). This is the most common type of episiotomy performed in the United States. The midline episiotomy is easy to perform and to repair. It is associated with quicker healing, less pain and postpartum discomfort since no muscle belly is transected, and less blood loss than the other types of episiotomies. Compared to mediolateral episiotomies, there is an increased risk of third-degree and fourth-degree extensions with the midline episiotomy.

MEDIOLATERAL EPISIOTOMY

The mediolateral episiotomy is preferred outside the United States.[20] The mediolateral episiotomy is a surgical incision made from the midline of the posterior vaginal orifice obliquely toward the ischial tuberosity (**Figure 132-2C**). The anatomic structures transected from superficial to deep are the skin, the subcutaneous tissues, the bulbospongiosus muscle, the superficial transverse perineal muscle, and a portion of the levator ani muscle and fascia.

The mediolateral episiotomy is the preferred technique as it is associated with a decreased risk of extension to the anal sphincter (third-degree laceration) and the rectum (fourth-degree laceration), especially when combined with an operative vaginal delivery.[21] The disadvantages of the mediolateral episiotomy are the increased blood loss, higher degree of difficulty to repair, and increased postpartum discomfort.[6,17,22,23] It may also result in faulty healing, anatomical deformities, and dyspareunia. The adequate surgical repair of these structures requires a good understanding of the anatomy of the perineum, and is technically more challenging.

EXTENSION OF AN EPISIOTOMY

The classification of perineal lacerations most often used in the United States is quite simple.[24] A first-degree laceration is a superficial laceration of the vaginal mucosa or perineal body not requiring suturing. A second-degree laceration or episiotomy involves the vaginal mucosa and/or perineal skin and subcutaneous tissue. It requires suture closure. The third-degree laceration or episiotomy is an extension of the laceration to involve any part of the capsule or anal sphincter muscle. Finally, the fourth-degree laceration or episiotomy is an extension to include involvement of the rectal mucosa.

INDICATIONS

The rate of episiotomy decreases as one travels the continuum from Obstetrician to Family Practitioner to Certified Nurse Midwife to lay Midwife. The indications for episiotomy are more largely based on expert consensus than in evidence-based criteria. The indications depend on the clinical picture at the time of delivery. Most practitioners consider the performance of an episiotomy to be appropriate in situations of fetal distress or maternal disease requiring urgent delivery.[8] Deliveries necessitating greater space accommodation for effective delivery are also indications for an episiotomy. These situations include shoulder dystocia, breech delivery, forceps or vacuum extractions, occiput posterior positions, and cases of imminent perineal rupture.[25] Other indications include too small of a perineal body with a high likelihood of a large spontaneous laceration, contracted outlet syndrome, face presentations, and extensive fetal head extension. It is commonly believed

that an episiotomy safely aids in shortening the second stage of labor and reduces trauma to the pelvic floor musculature.[4] More perineal and pelvic tissue injury is noted with a precipitous labor; thus a timely episiotomy is critical.[1]

CONTRAINDICATIONS

Contraindications to performing an episiotomy include rectal or perineal lesions, prior or concurrent fistulae, inflammatory bowel disease, prior rectal surgery, or prior anal surgery.[26] Maternal diseases that impair healing such as autoimmune disorders (e.g., SLE, rheumatoid arthritis), HIV, pregestational diabetes mellitus, and immunosuppression are relative contraindications to an episiotomy. Some authors suggest that coagulation disorders may be contraindications.[13] However, a vaginal delivery with an episiotomy is preferable to a cesarean delivery.[13] Relative contraindications specific to the midline episiotomy are a short perineum, fetal macrosomia, vaginal operative deliveries, and abnormal fetal presentation.

EQUIPMENT

- Local anesthetic solution, lidocaine or bupivacaine
- Alcohol wipes
- 16 to 18 gauge needle
- 10 mL syringe
- 22 to 25 gauge needle
- Straight Mayo scissors
- #10 scalpel blade on a handle
- Povidone iodine solution
- Sterile drapes
- Sterile gown and gloves
- Chromic or polyglycolic acid suture, 2-0 or 3-0
- Vicryl suture, 4-0 and 5-0
- Needle driver
- 23 gauge spinal needle

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient. Clean the perineum of any dirt, debris, stool, and urine. Apply povidone iodine or chlorhexidine solution and allow it to dry. Place sterile drapes beneath the buttocks, over the legs, and on the abdomen to prevent contamination from nonsterile areas.

Anesthetize the perineal body (**Figure 132-3**). Infiltrate 10 to 20 mL of local anesthetic solution directly into the perineal body, from the posterior base of the vaginal fourchette to the anus (**Figure 132-3A**). This provides safe and effective anesthesia. It may be carefully performed if the baby's head is within the vagina or crowning.

A bilateral pudendal nerve block will also provide excellent pain control (**Figure 132-3B**). It requires more time to perform and cannot be done if the baby's head is in the vagina. Arm a 10 mL syringe with a 23 gauge spinal needle and filled with local anesthetic solution. Place the nondominant index finger in the vagina and palpate the ischial spine. The ischial spines are identified as the bony protrusions located in the posterolateral region of the vaginal side wall. The sacrospinous ligament is a firm band that runs from the ischial spine to the sacrum. The pudendal nerve and artery lie between the ischial spine and ischial tuberosity. Palpate the ischial tuberosity with the nondominant thumb.

To perform the block on the maternal right side, use the right index and middle fingers to palpate the right ischial spine and guide

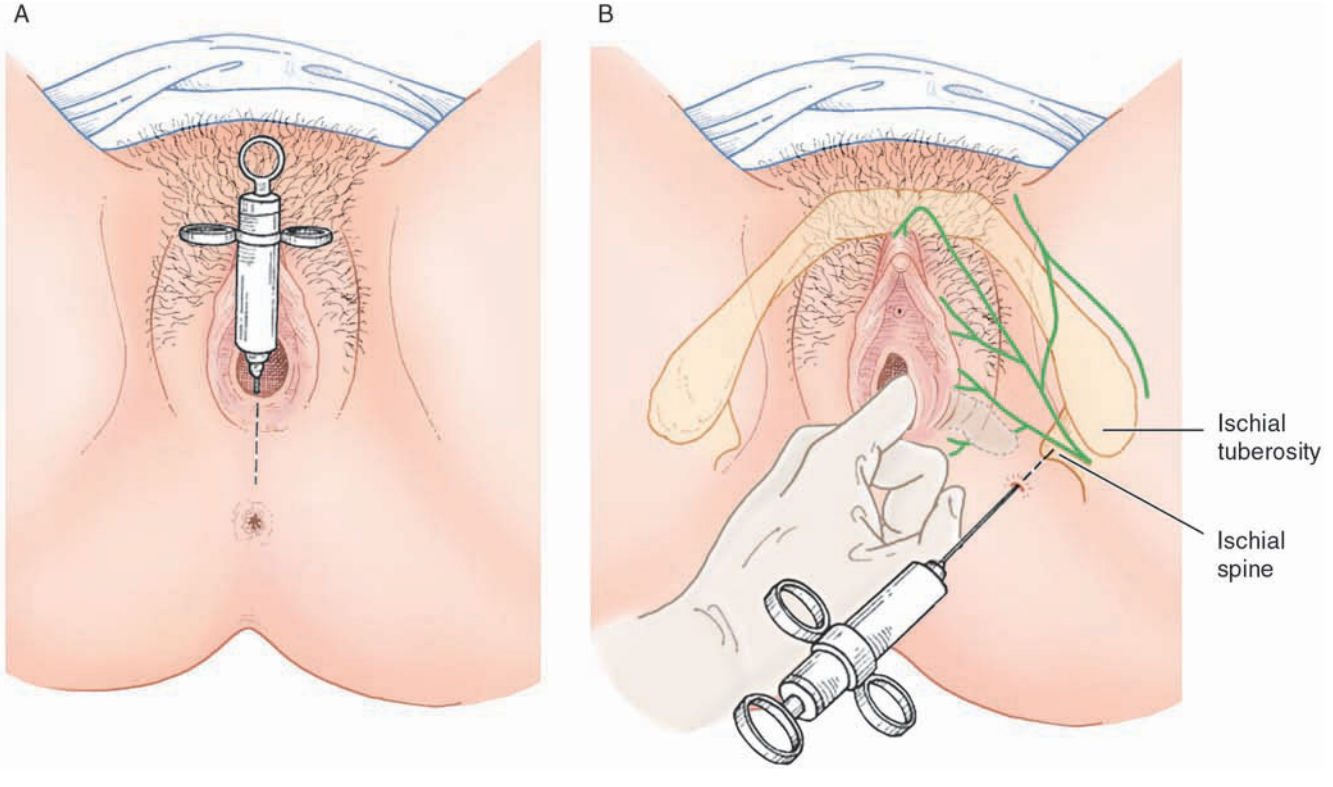


FIGURE 132-3. Anesthesia of the perineum. **A.** Local anesthetic infiltration subcutaneously from the posterior fourchette to the anus. **B.** The pudendal nerve block.

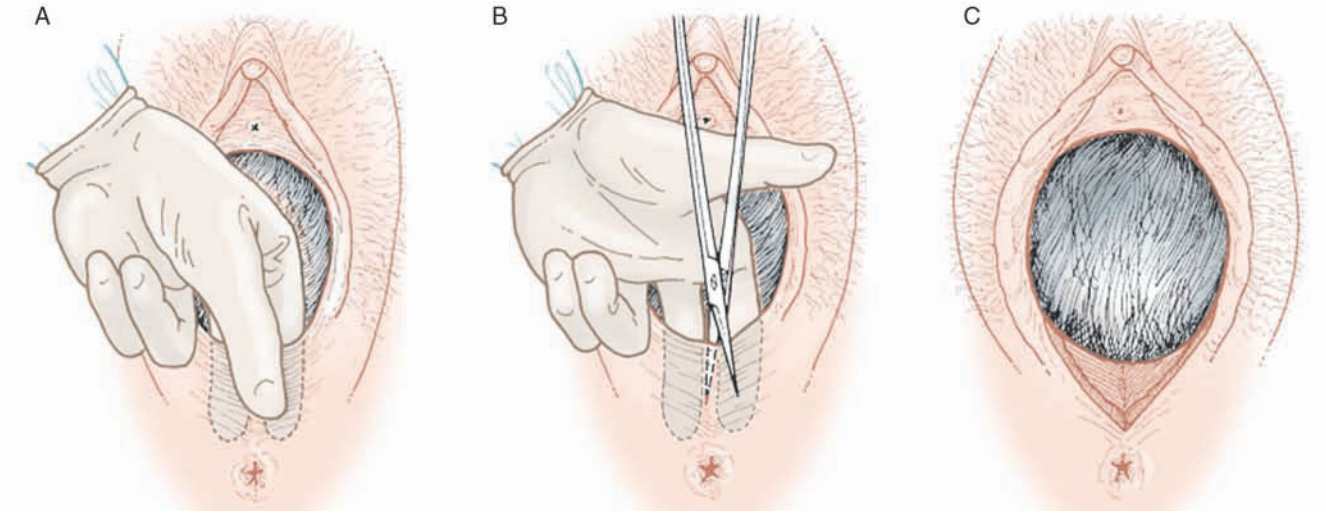


FIGURE 132-4. Performing a midline episiotomy. **A.** Place the nondominant index and middle fingers inside the introitus with the palm facing outward. **B.** Pull the perineal body away from the fetus and insert the straight Mayo scissors. Note that the blades of the Mayo scissors are positioned between the fingers. **C.** The introitus readily opens after making the episiotomy.

the spinal needle. Use the left hand to introduce the needle. Insert the tip of the needle 1 cm medial and 1 cm posterior to the ischial spine. Advance the needle through the sacrospinous ligament. Aspirate to ensure that the injection will not be intravascular. Inject 3 to 4 mL of local anesthetic solution. Advance the needle a few millimeters and inject another 3 to 5 mL of local anesthetic solution. Repeat the procedure on the contralateral side.

Occasionally, a cutaneous branch of the inferior anal nerve can innervate the area surrounding the anus. The infiltration of a local anesthetic solution will be required.[11]

TECHNIQUES

Place the index and middle fingers of the nondominant hand into the patient's introitus, with the palm of the hand facing outward (**Figure 132-4A**). Pull the perineal body away from the fetal presenting part to protect the fetus from injury (**Figure 132-4B**). Use a #10 scalpel blade, a #15 scalpel blade, or a straight Mayo scissors to make the incision. **The editor recommend using only the Mayo scissors. A scalpel can cause significant injury to the fetus, the mother, and/or the Emergency Physician.**

Insert the Mayo scissors so that one blade lies along the skin and the other is inside the introitus, between the index and middle fingers, and against the vaginal mucosa (Figure 132-4B). Allow the maximum descent of the fetal presenting part and moderate distension of the perineum before making the incision to avoid a third-degree or fourth-degree laceration. **Make the incision** when the perineum is bulging and when approximately 4 cm of fetal scalp is visible during a contraction unless early delivery is indicated.[1,22] Extend the incision 2 to 3 cm vertically up the vaginal mucosa. The introitus will readily open after making the episiotomy (**Figure 132-4C**).

MIDLINE EPISIOTOMY

Make the incision vertically in the midline of the perineal body, from the midpoint of the posterior vaginal orifice to the capsule of the anal sphincter (**Figure 132-4**). The incision length depends upon the perineal length. **Make it of sufficient length to increase the area of the introitus for successful delivery of the presenting part without compromising the anal sphincter. The incision must include the tendinous central portion of the perineal body.** This involves (in order of progression from anterior to posterior) the muscular attachments of the bulbospongiosus muscle, the superficial transverse perineal muscle, a portion of the levator ani muscle, and the capsule of the anal sphincter muscle.[8] **The most important aspect of the midline episiotomy is extension of the incision upward into the vaginal mucosal and past the hymenal ring.** This releases any constriction and allows maximal room for the presenting part of the fetus.

MEDIOLATERAL EPISIOTOMY

Make an incision at a 45° angle to the midline of the posterior vaginal orifice, from the inferior portion of the hymenal ring toward the ischial tuberosity (**Figure 132-2C**). The length of the incision is less critical than that for a median episiotomy. Longer incisions require a more extensive repair. The side to which the episiotomy is performed is generally the same as the handedness of the operator.[1] Make the incision at approximately 5 o'clock for left-handed dominants or at 7 o'clock for right-handed dominants. If the incision is not deep enough, there will be too little tissue relaxation and a second incision will be necessary. This second incision increases the risk of a zigzag line after healing.[11] The anatomic structures incised and requiring repair (in progression from superficial to deep) are the skin and subcutaneous tissues, the bulbospongiosus muscle, the superficial transverse perinei muscle, and a portion of the levator ani muscle and its fascia.

ASSESSMENT

Carefully examine the vagina, cervix, and lower uterine segment for any signs of injury or laceration immediately following delivery of the infant and placenta. Do not begin repairing the episiotomy until after the delivery of the placenta. The repair may be compromised if manual removal of the placenta or intravaginal procedures must be performed after the episiotomy is reconstructed. Assess the incision for extension (third-degree or fourth-degree). Identify any site of excessive bleeding and immediately control it with a Vicryl ligature. Perform a digital rectal examination to rule

out a fourth-degree extension or button-holing (a laceration through to the rectal mucosa which is not contiguous with the episiotomy).

MIDLINE EPISIOTOMY REPAIR TECHNIQUES

The midline episiotomy repair is an easier approximation than the mediolateral episiotomy as the incision is symmetrically situated in the perineal tissue.[21,27,28] The choice of suture is physician-dependent.[28] There are several options for episiotomy closure with limited data to suggest the superiority of one single type of material. The principal disadvantage of chromic is the rapid loss of tensile strength, increased wound breakdown, and increased initial pain.[24] The derivatives of polyglycolic acid, Vicryl and Dexon, have about a 20% reduction in short-term pain but causes perineal irritation. They frequently require removal during the puerperium. There are now monofilament absorbable sutures or more rapidly absorbable polyglactin derivates that combine both desirable characteristics of strength and rapid disappearance.[8] Use a round needle to close all layers except the capsule and skin to minimize the risk of a subcutaneous hematoma.

VAGINAL MUCOSA REPAIR

Repair the vaginal mucosa first (**Figure 132-5**). Use 3-0 suture on a noncutting needle. Place the initial suture superior to the apex of the vaginal incision to incorporate any retracted vessels. Tie the suture at the apex of the incision securely. Approximate the wound edges with a running subcuticular stitch (**Figure 132-5A**) or a running simple stitch (**Figure 132-5B**). Place a running locked stitch (**Figure 132-5C**) if there are any concerns about hemostasis. Continue the suture to the hymenal ring. **Do not allow the needle to enter through the rectal mucosa as this can result in the formation of a rectovaginal fistula.**

Place each stitch to bring together the mucous membrane of the vagina and the tissue between the vagina and rectum. This method of suturing provides for hemostasis, eliminates dead space, and decreases the risk of subsequent infection. Extend the continuous suture by one to two stitches past the hymenal ring and to the edge of the skin. Place the final suture to incorporate the subcutaneous tissue but not the skin. Finish reapproximating the skin incision with a buried knot.

The second suture is the so-called "crown suture." It is placed at the base of the sutured vaginal wound. Insert the needle into the immediate subcutaneous tissue, perpendicular to the skin, and angled deeply to approximate the edges of the bulbospongiosus muscle and its fascia. It is important to evaluate the perineal body at this time. If there is a big defect, close it with interrupted sutures to prevent leaving any open dead space. Close the remainder of the incision with the one-suture (**Figure 132-6**) or the two-suture technique (**Figure 132-7**).

ONE-SUTURE TECHNIQUE

The one-suture technique utilizes one strand of suture to close the entire episiotomy (**Figure 132-6**). Close the vaginal mucosa, as described previously, with a running stitch (**Figure 132-6A**). Approximate the hymeneal ring. Continue the running stitch to approximate the perineal body (**Figure 132-6B**). Continue the running stitch until the bottom of the episiotomy is reached. Place a running subcuticular stitch from the bottom of the episiotomy upward to the hymenal ring (**Figure 132-6C**). Finish approximating the skin incision with a buried knot at the hymenal ring.

TWO-SUTURE TECHNIQUE

This technique utilizes two strands of suture to close the episiotomy (**Figure 132-7**). Close the vaginal mucosa, as described

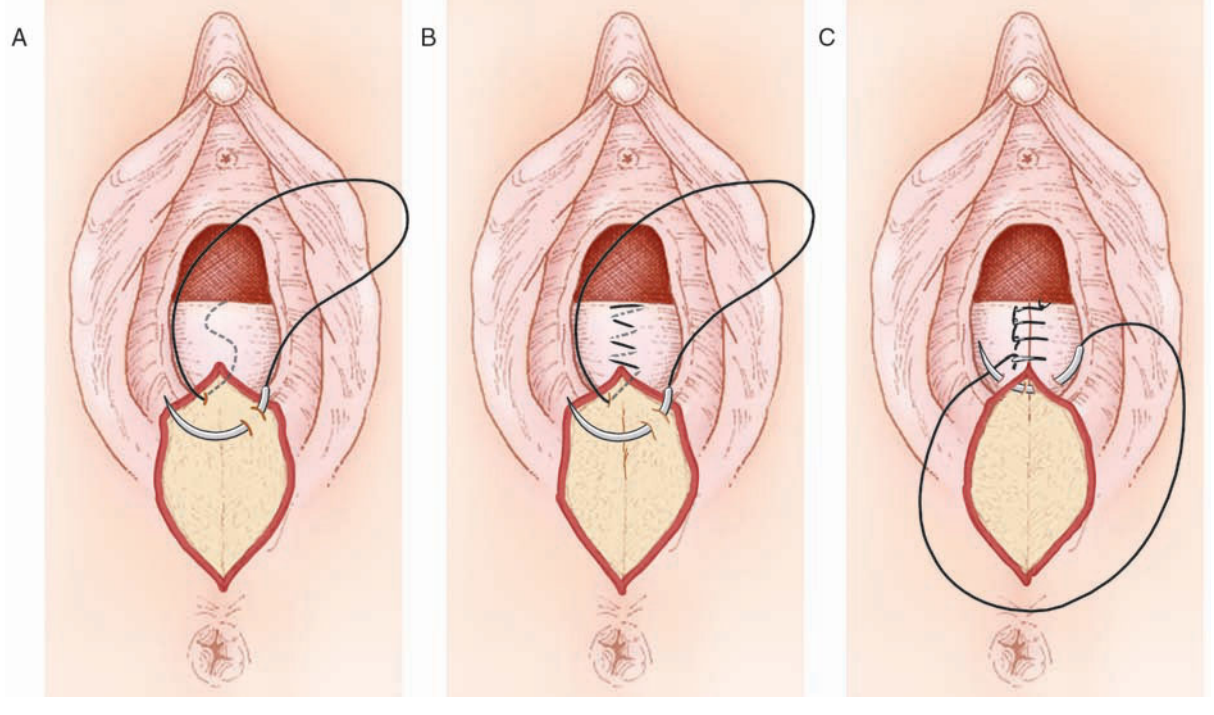


FIGURE 132-5. Methods of closing the vaginal mucosa. **A.** The running subcuticular stitch. **B.** The running simple stitch. **C.** The running locked stitch.

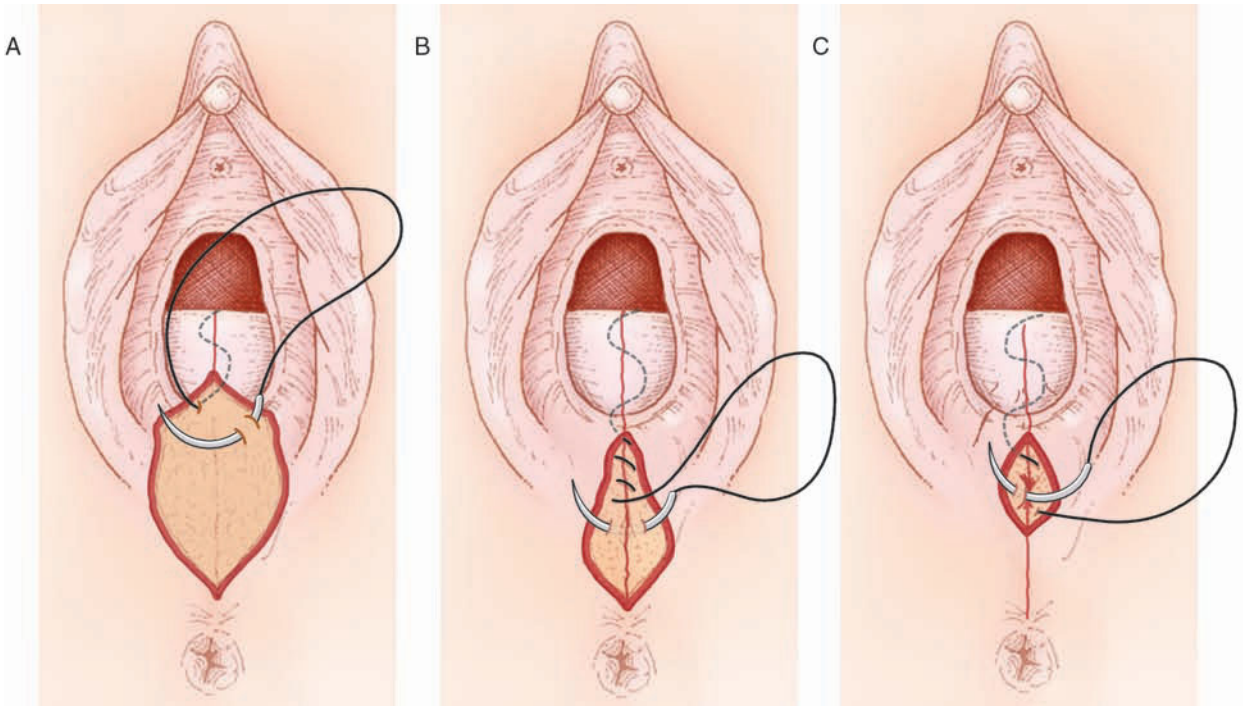


FIGURE 132-6. The one-suture technique to close an episiotomy. **A.** Approximate the vaginal mucosa with a running stitch. **B.** Approximate the hymenal ring followed by a running stitch to approximate the perineal body. **C.** Reverse the suture direction with a running subcuticular stitch to approximate the skin.

previously, with a running stitch (**Figure 132-7A**). Approximate the hymenal ring with this first strand of suture (**Figure 132-7B**). Close the perineal body using a second strand of suture material. Place running or interrupted stitches (**Figure 132-7B**). After the perineal body is closed, use the first strand of suture to place a subcuticular running stitch to approximate the skin (**Figure 132-7C**). Finish approximating the skin incision with a buried knot.

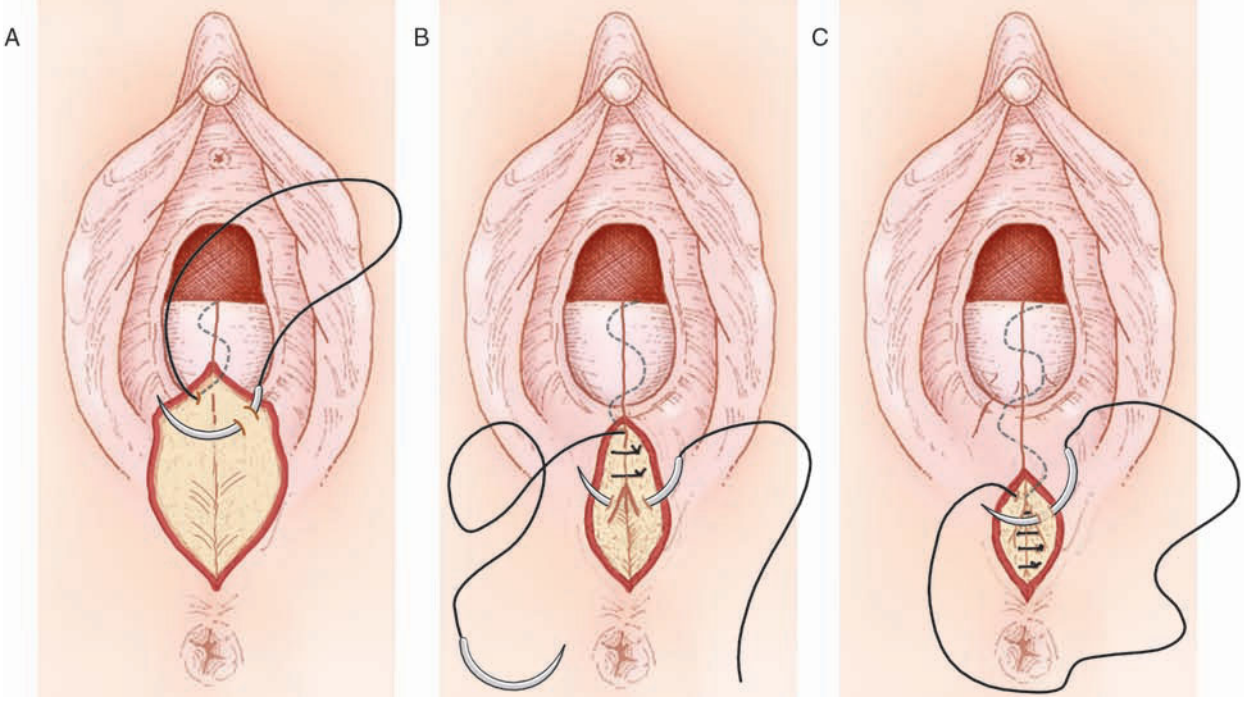


FIGURE 132-7. The two-suture technique to close an episiotomy. **A.** Approximate the vaginal mucosa with a running stitch. **B.** The hymenal ring is approximated with the first suture. The perineal body is approximated with a second suture utilizing an interrupted stitch. **C.** The first suture is continued subcutaneously to approximate the skin.

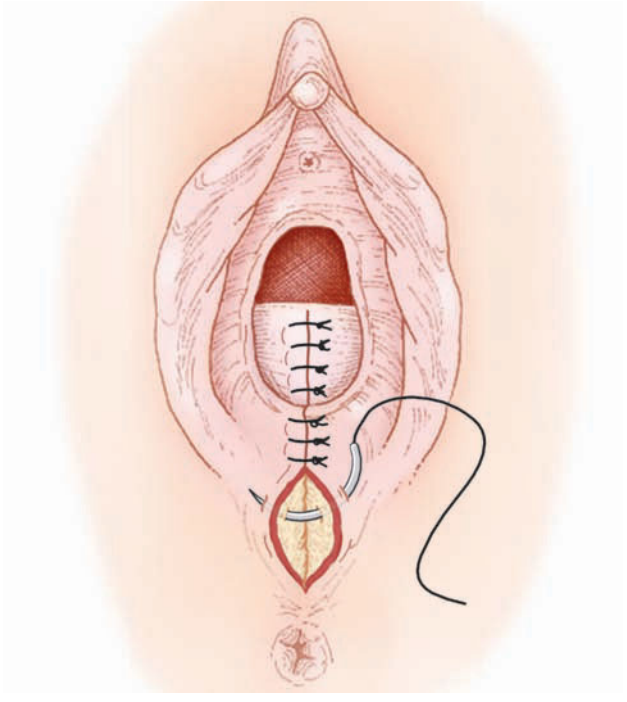


FIGURE 132-8. An alternative technique to close an episiotomy. Place simple interrupted stitches to approximate the mucosa, skin, and perineal body.

ALTERNATIVE TECHNIQUE

Approximation of an episiotomy with one or two sutures can be time consuming and difficult. An alternative is to close the episiotomy using a simple interrupted stitch (**Figure 132-8**). Take deep bites of tissue with the needle to ensure that the stitches close the subcutaneous tissues and perineal body along with the overlying vaginal mucosa and skin.

THIRD-DEGREE LACERATION REPAIR

A third-degree laceration involves the anal sphincter muscle and spares the anal mucosa. Visually inspect the anal sphincter muscle for partial lacerations. **A patient can have normal anal sphincter tone and a partial anal sphincter muscle laceration.** Repair any anal sphincter muscle lacerations as described in the following section on fourth-degree laceration repair.

FOURTH-DEGREE LACERATION REPAIR

Fourth-degree lacerations may occur as a result of a tearing of the tissues with or without an episiotomy. **These lacerations involve the anal sphincter muscle and the anal mucosa. They must be repaired to restore the normal anatomy and decrease the chance of fecal incontinence.**

A suture is placed 1 cm above the apex of the laceration, and extended through the submucosal tissue, but not through the mucosa. The mucosa is closed in a continuous running or subcuticular fashion. The suture should not penetrate the rectal mucosa, and the suture carried down to the perineal body (**Figure 132-8A**). 4-0 or 5-0 chromic gut sutures are usually used for this step, but synthetic material can also be used. A second layer over the rectal mucosa is placed, in order to reinforce the initial suture. Additionally, this suture will close the dead space between the vaginal mucosa and the rectum.

Identify both ends of the anal sphincter. They are usually retracted laterally. Use Allis clamps to grasp the edges and pull them together in the midline (**Figure 132-9A**). It is very important to incorporate the capsule of the anal sphincter in the repair and not just the muscle fibers (**Figure 132-9B**). We recommend the use of the pneumonic "**PISA**" when repairing the anal sphincter.

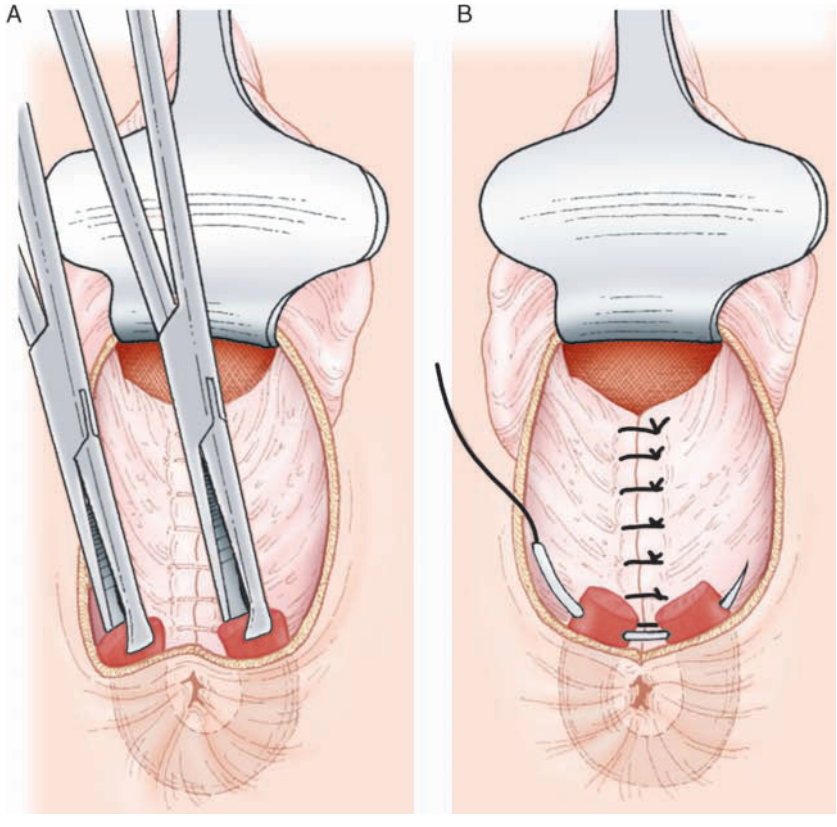


FIGURE 132-9. Repair of a fourth-degree laceration or episiotomy. **A.** Approximate the rectal submucosa and muscularis with simple interrupted sutures. Grasp the cut edges of the anal sphincter muscle with Allis clamps. **B.** Approximate the ends of the anal sphincter muscle with transfixion stitches.

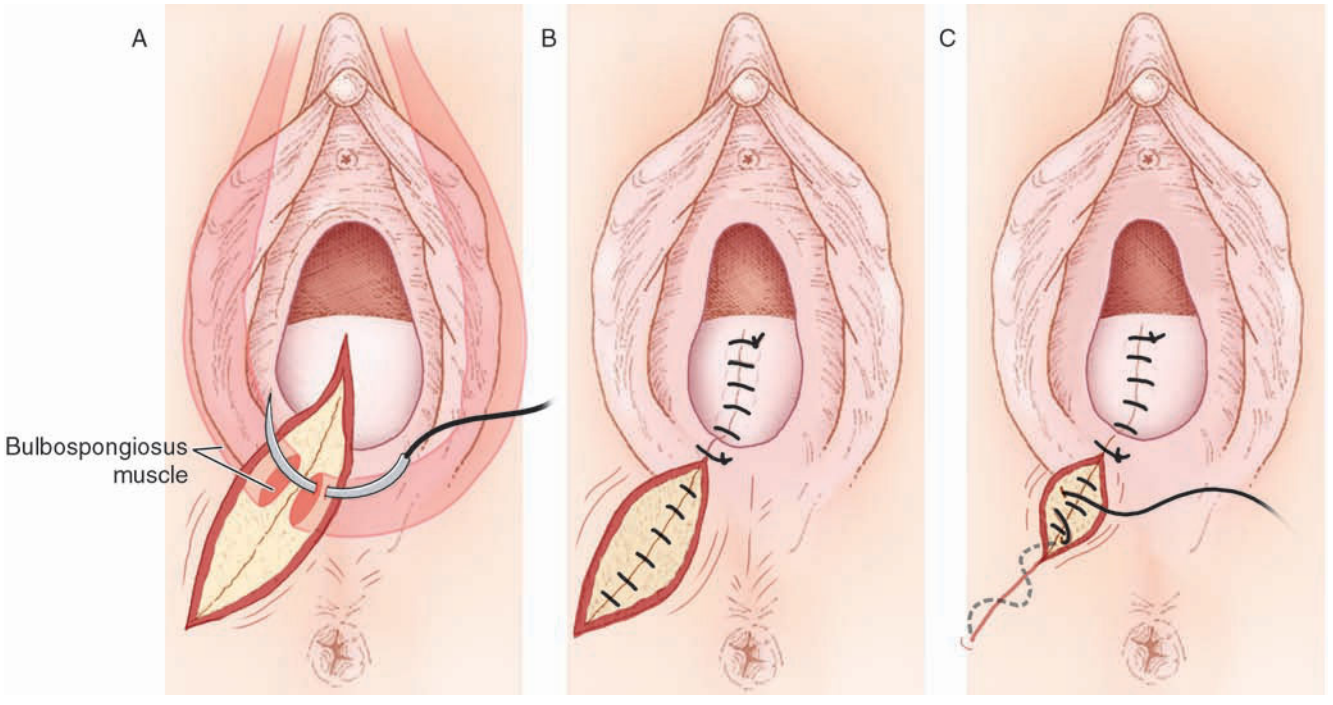


FIGURE 132-10. Repair of a mediolateral episiotomy. **A.** Find and approximate the ends of the transected bulbospongiosus muscle. **B.** Approximate the vagina and deep peroneal tissues using the one-suture or two-suture technique. **C.** Approximate the skin with running subcuticular stitches.

The use of a 2-0 polygalactic acid suture (e.g., Vicryl) on a taper needle is recommended. Initiate the repair with the **P**osterior aspect of the sphincter, which has the structure of a cylinder, at the 9 o'clock position. Next, place the most **I**nferior suture at the 6 o'clock position. Follow this with a stitch in the **S**uperior aspect at the 12 o'clock position. Finish the repair with a suture at the 3 o'clock position on the **A**nterior aspect of the sphincter.

MEDIOLATERAL EPISIOTOMY REPAIR TECHNIQUE

It is extremely important to locate and repair the transected bulbospongiosus muscle. Find and grasp the transected ends of the bulbospongiosus muscle with Allis clamps. Approximate it using 4-0 and 5-0 Vicryl sutures (**Figure 132-10A**). Approximate the vagina and deep perineal tissues using the one-suture or the two-suture technique (**Figure 132-10B**). Approximate the skin of the perineum using a running subcuticular stitch (**Figure 132-10C**).

AFTERCARE

The aftercare for a perineal incision involves perineal hygiene and adequate analgesia. The use of warm sitz baths three to four times a day in concert with the use of ice packs to the perineum will decrease inflammation and the risk of infection. Routine use of prophylactic antibiotics has never been proven effective to prevent infections after an episiotomy. Prescribe stool softeners to decrease the pain of defecation and the risk of episiotomy disruption, especially if it was associated with a third-degree or fourth-degree extension. Nonsteroidal anti-inflammatory drugs or acetaminophen provide adequate analgesia in most patients. Narcotic analgesics may be required for 24 to 72 hours, especially in cases of mediolateral episiotomies. Many Obstetricians prefer oxycodone or acetaminophen with codeine as they are not as constipating as the other narcotic analgesics. This is especially important in patients with third-degree or fourth-degree lacerations.

COMPLICATIONS

The most common complications are hemorrhage, infection, and dehiscence. Most hemorrhage can be controlled by the application of direct pressure with a sterile gauze. Place a figure-of-eight stitch in the tissues if direct pressure fails. The mediolateral episiotomy has an increased risk of hemorrhage compared to the midline episiotomy. Therefore, adequate hemostasis must be assured during the repair. Vaginal hematomas can easily form. Large or expanding vaginal hematomas usually require the incision to be opened, the hematoma drained, and the hemorrhage controlled. Small hematomas can be managed with analgesics and ice packs.

Infection usually presents 6 to 8 days after delivery. The patient usually complains of a fever, perineal pain, and a purulent discharge that may be foul smelling. Management includes local perineal care and exploration with debridement under adequate anesthesia to drain a potential abscess. Carefully examine the patient and explore the area to rule out necrotizing fasciitis.[25] Unless the patient is septic, begin intravenous antibiotics after consulting with the Obstetrician–Gynecologist and obtaining wound cultures.

Pain at the episiotomy site is common. It usually resolves in 3 to 5 days. The pain usually responds to acetaminophen and nonsteroidal anti-inflammatory drugs. If the patient is complaining of intense pain, a hematoma or an infection must be ruled out. Dyspareunia is more common with a mediolateral episiotomy.[11] Prospective studies have not found differences in the resumption of intercourse at 3 months when compared to patients without an episiotomy.[8]

Dehiscence is reported in 0.1% to 2% of episiotomies. Early closure within 1 week is preferable to the delayed closure at 2 to 3 months. It is necessary to remove all necrotic tissue and copiously irrigate

the area with a diluted povidone iodine solution. This should be followed by twice daily scrubbings of the wound with a scrub brush and povidone iodine. The wound can be repaired once it is free of exudates and begins to show granulation tissue. Intravenous antibiotics might be necessary in the presence of infection.[29] The repair procedure should be performed by a Gynecologist or a Colorectal Surgeon if the dehiscence involves the anal sphincter.

The use of a midline episiotomy may increase the risk of third-degree and fourth-degree lacerations.[30–33] A third-degree laceration is diagnosed when the capsule and/or the muscle of the anal sphincter is interrupted. A fourth-degree laceration involves the anal sphincter and the mucosa of the anus or rectum. Third-degree and fourth-degree lacerations may result in incontinence of feces, incontinence of flatus, and/or rectovaginal fistula formation if not properly repaired. Complications include increased blood loss, especially if the incision is made too early.

The midline episiotomy has been shown to be associated with an increased risk of third-degree and fourth-degree perineal lacerations in operative vaginal deliveries. Perineal and pelvic floor morbidity was greatest among women receiving a median episiotomy versus those remaining intact or sustaining spontaneous perineal tears in a study of the relationship between episiotomy and maternal morbidity. Severe lacerations were nearly 50 times more likely in parturients with midline episiotomies and over 8 times more likely in women with mediolateral episiotomies than in women who did not undergo an episiotomy.

SUMMARY

Episiotomies are not performed routinely but should be utilized on a selective basis for the appropriate indication. Surgical judgment, patient assessment, acknowledgment of surgical expertise level, and common sense should be employed. The midline episiotomy is the preferred technique for non-Obstetricians. It is easier to perform and easier to repair when compared to the mediolateral episiotomy.

133 Shoulder Dystocia Management

Eric F. Reichman and Camaran E. Roberts

INTRODUCTION

Shoulder dystocia is a rare obstetric emergency that immediately places the mother and the fetus at risk for significant morbidity and mortality. It is diagnosed when, after delivery of the fetal head, further expulsion of the fetus is prevented by impaction of the fetal shoulders within the maternal pelvis.[1] **Shoulder dystocia is considered an emergent situation that the Emergency Physician must recognize and quickly respond to by promptly delivering the fetus.**

The incidence of shoulder dystocia varies and is seen in up to 4% of cephalic spontaneous vaginal deliveries depending upon the source.[2–7] Differing definitions of shoulder dystocia may account for some of this variability. Some reports require that maneuvers for shoulder release be documented on the chart whereas others accept the Physician's clinical diagnosis of shoulder dystocia. Other definitions look at the timing of the delivery of the head, the delivery of the shoulders, or the completion of the birth. The rare occurrences of shoulder dystocia make designing prospective studies difficult, both in describing the incidence and in evaluating the efficacy of various release maneuvers.[8]

Shoulder dystocia may not be anticipated in advance. Many risk factors are associated with shoulder dystocia. However, many patients with shoulder dystocia have none of these risk factors. Emergency Physicians usually do not have knowledge of the patient's prenatal history, ultrasound reports, or previous deliveries. This makes it difficult to predict shoulder dystocia. It is imperative for the Emergency Physician to be knowledgeable and comfortable with the various release maneuvers in the event that shoulder dystocia is encountered during a precipitous delivery. When the baby is being delivered, there is not time to look up references.

ANATOMY AND PATHOPHYSIOLOGY

Shoulder dystocia is usually diagnosed after delivery of the fetal head, when the fetal shoulders fail to deliver despite standard gentle traction on the fetal head. It results from impingement of the biacromial diameter of the fetus against the maternal pubic symphysis anteriorly and the maternal sacral promontory posteriorly.[9]

Shoulder dystocia is a rare and potentially catastrophic obstetrical emergency. **The Emergency Physician must deliver the fetus quickly and without applying excessive forces that may result in fetal injury.** Always be prepared for the possibility of shoulder dystocia. Recognize the possible associated risk factors that include fetal macrosomia, maternal diabetes, a prior history of shoulder dystocia or macrosomia, prolonged second stage of labor, post-term pregnancy, multiparity, obesity, and operative vaginal delivery from the midpelvis.[9]

Fetal macrosomia is defined as fetal growth beyond a specific weight, usually 4000 to 4500 g, regardless of the fetal gestational age. The risk of shoulder dystocia is 9.2% to 24% in nondiabetic pregnant women, and 19.9% to 50% in diabetic women when birth weight is greater than 4500 g.[10] The ability to predict fetal macrosomia is limited. Shoulder dystocia can occur unexpectedly in infants of normal birth weights.[10] A simple algorithm to help determine if shoulder dystocia or fetal macrosomia may be present is shown in **Figure 133-1**.

INDICATIONS

The presence of shoulder dystocia is the unique indication for the procedures described in this chapter. They should be utilized in the approximate order described, from the least invasive and easiest to perform to the most invasive and difficult to perform.

A symphysiotomy is indicated for shoulder dystocia unresponsive to less invasive techniques and for fetal head entrapment by presumed cephalopelvic disproportion. It is an alternative to the cesarean section when a qualified Obstetrician or Surgeon is unavailable.[10] Refer to Chapter 137 for the complete details regarding a symphysiotomy.

CONTRAINDICATIONS

There are few contraindications to the release maneuvers in an emergent situation of shoulder dystocia and imminent fetal demise. The only absolute contraindication is if the procedure might endanger the mother.

The indications to perform a cesarean delivery are relative contraindications for release maneuvers. Fetal macrosomia has been associated with shoulder dystocia.[10] The American College of Obstetricians and Gynecologists (ACOG) supported the recommendation that planned cesarean delivery may be a reasonable

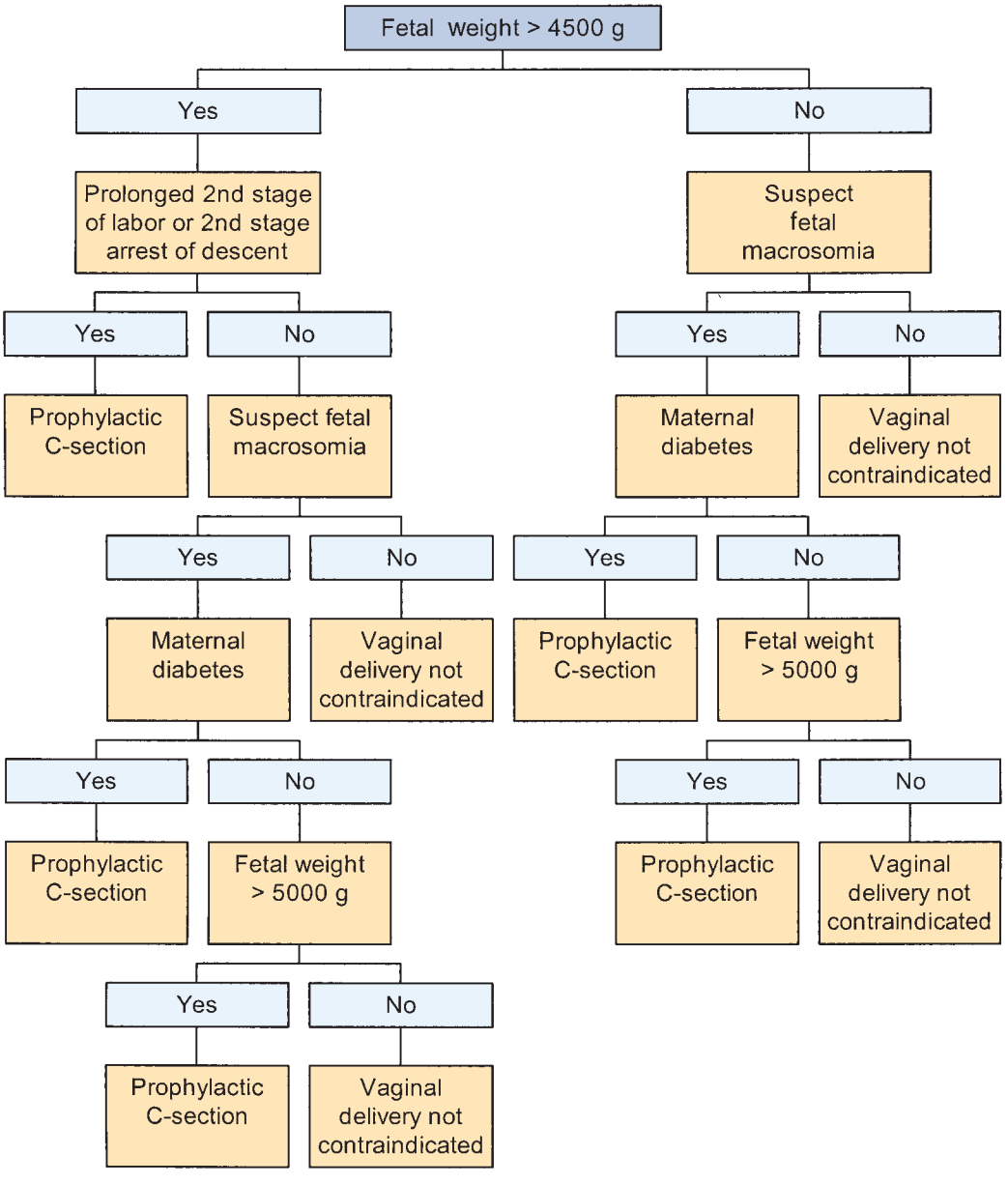


FIGURE 133-1. An algorithm providing a sequence of decisions for evaluation and anticipation of shoulder dystocia.[10]

strategy for diabetic pregnant women with estimated fetal weights exceeding 4250 to 4500 g.[8] ACOG issued guidelines on fetal macrosomia in 2001. The guidelines were based upon limited or inconsistent scientific evidence. ACOG recommended that an estimated fetal weight of more than 4500 g, a prolonged second stage of labor, or arrest of descent in the second stage of labor are indications for cesarean delivery.[10] ACOG noted that the diagnosis of fetal macrosomia is imprecise and recommended prophylactic cesarean delivery be considered with estimated fetal weights of more than 5000 g in nondiabetic pregnant women and more than 4500 g in diabetic pregnant women.[10]

EQUIPMENT

General Supplies

- Electronic fetal monitor
- Sterile towels
- Clock or timer watch
- Sterile perineal drapes
- Sterile gloves
- Chromic suture, 2-0 and 4-0
- Vicryl suture, 2-0 and 3-0
- Bulb syringe
- Clean towels/blanket for baby
- Umbilical cord clamp
- Sterile scissors to trim umbilical cord
- Infant warmer

Delivery Instrument Pack

- Bandage scissors
- Towel clips
- Two Allis forceps

- Four ring forceps
- Six straight Kocher clamps
- Straight Mayo scissors
- Two suture scissors
- Adson forceps, or other forceps with teeth
- Russian forceps, 5½ inches and 8 inches
- Gelpi retractor
- Richardson retractors, small and medium
- Army/Navy retractors
- 6 inch needle driver

Symphysiotomy

- #10 or #15 scalpel blade on a handle
- Finger guard
- Foley catheter
- Povidone iodine or chlorhexidine solution

PATIENT PREPARATION

Pain associated with the first stage of labor can be relieved with a paracervical block (Chapter 131). Inject 5 mL of local anesthetic solution into the submucosa of the lateral vaginal fornix. Repeat the injection in the contralateral lateral vaginal fornix. Pain transmission is interrupted for all visceral sensory nerve fibers from the uterus, cervix, and upper vagina. The somatosensory fibers from the perineum are not blocked. This technique is effective only during the first stage of labor and before shoulder dystocia occurs.[11,12]

A pudendal nerve block and local perineal infiltration anesthesia are usually administered just before delivery (Chapter 131).[12] Refer to Chapters 131 and 132 regarding the complete details of these anesthetic techniques. Unfortunately, these techniques must also be performed prior to the occurrence of shoulder dystocia.

The patient should already be in the lithotomy position on a bed with stirrups. Preparation begins with suspicion of fetal macrosomia by clinical examination and/or fetal ultrasonography. Retraction of the fetal head immediately after its delivery and the fetal chin against the maternal thigh (turtle sign) with difficulty suctioning the mouth may signal impending shoulder dystocia (**Figure 133-2**).

The fetal sagittal suture generally lies oblique to the maternal anteroposterior diameter with the fetal shoulders occupying the opposite oblique diameter after delivery of the fetal head (**Figure 133-3**). The shoulder may become impacted behind the pubic symphysis and impede delivery if the anterior shoulder descends in the anteroposterior diameter. Apply gentle and downward pressure on the fetal head to move the posterior shoulder into the hollow of the sacrum and deliver the anterior shoulder (**Figure 133-4**). **Resist applying excessive downward or lateral traction on the fetal head and neck.**

TECHNIQUES

Perform attempts at gentle traction coordinated with maternal expulsive efforts before attempting maneuvers to relieve shoulder dystocia. Initiate a planned sequence of events if delivery is impeded. **Avoid applying fundal pressure and discontinue maternal pushing efforts until disimpaction has occurred.** Fundal pressure and maternal pushing may further impact the fetal shoulders. Contact an Anesthesiologist for pain control. Summon extra personnel for help, with one person designated as a timekeeper. Notify a Neonatologist of the impending delivery. Maneuvers for shoulder

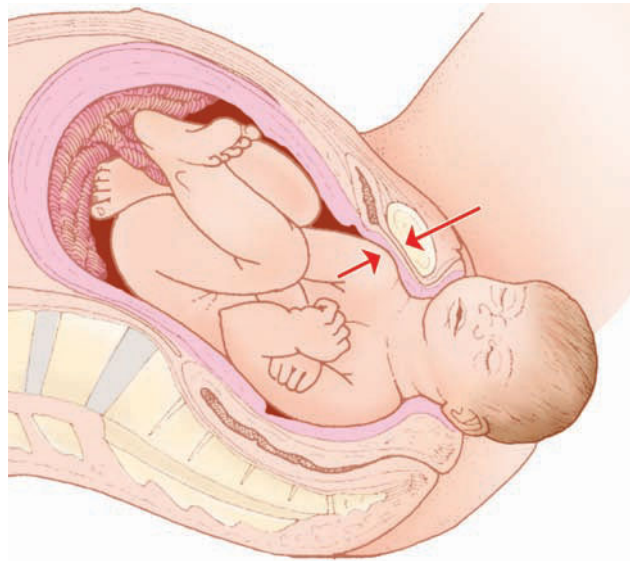


FIGURE 133-2. The head may retract toward the perineum (turtle sign) when delivery of the fetal head is not followed by delivery of the shoulders.

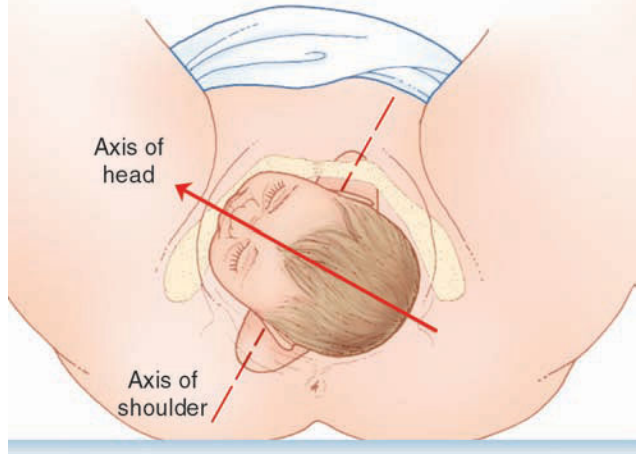


FIGURE 133-3. Restitution (external rotation) of the fetal head normally results in a natural perpendicular relationship of the head to the shoulders.

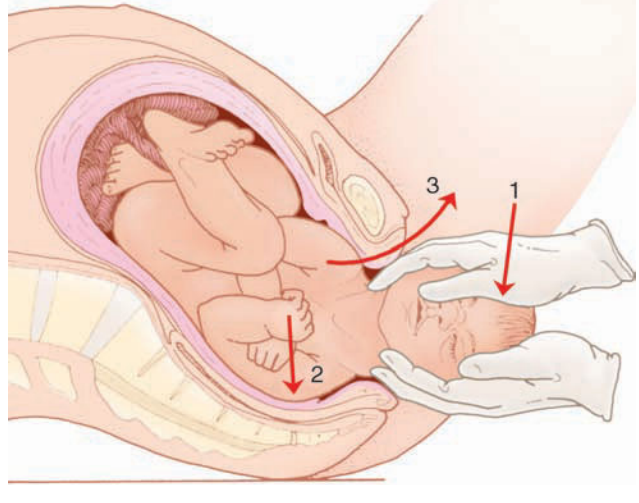


FIGURE 133-4. Apply gentle and downward pressure on the fetal head (1) to move the posterior shoulder into the hollow of the sacrum (2) and deliver the anterior shoulder (3).

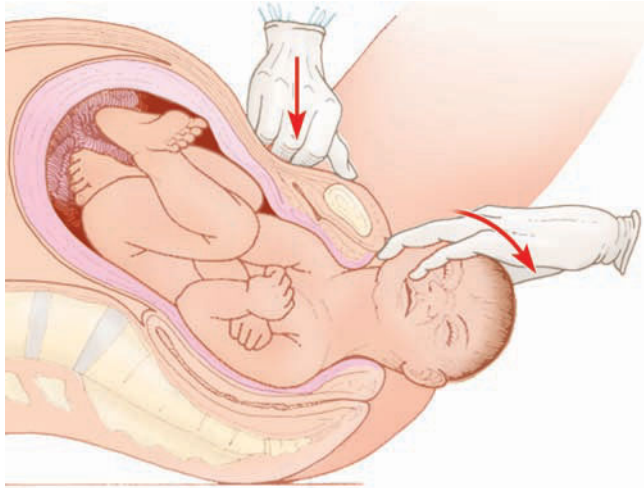


FIGURE 133-5. Moderate suprapubic pressure is applied to disimpact the fetal shoulder while gentle downward traction is applied to the fetal head.

dystocia disimpaction will be described in order of ease of implementation and from least invasive to more invasive.

SUPRAPUBIC PRESSURE

This maneuver can be used alone or in combination with the McRoberts maneuver. Apply gentle downward traction to the fetal head while an assistant simultaneously applies moderate suprapubic pressure (**Figure 133-5**). **Do not apply heavy pressure to prevent injury to the fetus's brachial plexus, neck, and spinal cord.**

McROBERTS MANEUVER

The McRoberts maneuver is easy to perform (**Figure 133-6**). Place an assistant on each side of the patient. Hyperflex the mother's thighs onto her abdomen (**Figure 133-6A**). Instruct the assistants to maintain support of the hyperflexion while simultaneously applying suprapubic pressure (**Figure 133-6B**). This results in a flattening of the maternal lumbosacral curve and a rotation of the pubic symphysis cephalad (**Figure 133-6C**). Rotation of the maternal pelvis may free the impacted anterior fetal shoulder.[7,13] This maneuver has the advantages of reducing shoulder extraction forces, brachial plexus stretching, and the incidence of clavicular fractures.[7,13] The McRoberts maneuver is effective in disimpacting the fetal shoulders in 50% to 90% of cases of shoulder dystocia.[7,13]

RUBIN MANEUVER

The Rubin maneuver is simple and may lead to the descent and delivery of the anterior fetal shoulder (**Figure 133-7**). Insert the dominant hand into the vagina. Place the fingers of the hand against the posterior aspect of the anterior fetal shoulder. Rotate the fetal shoulder counterclockwise in a small arc to approximately the 10 o'clock position. The Rubin maneuver compresses and diminishes the size of the fetal shoulder girdle to disimpact the anterior shoulder. Rotation of the anterior fetal shoulder in the opposite direction (i.e., clockwise) will open the shoulder girdle, increase the size of the shoulder girdle, and further impact the fetus.

WOOD'S CORKSCREW MANEUVER

The Wood's corkscrew maneuver (**Figure 133-8**) is an alternative to the Rubin maneuver. Insert the dominant hand into the vagina.

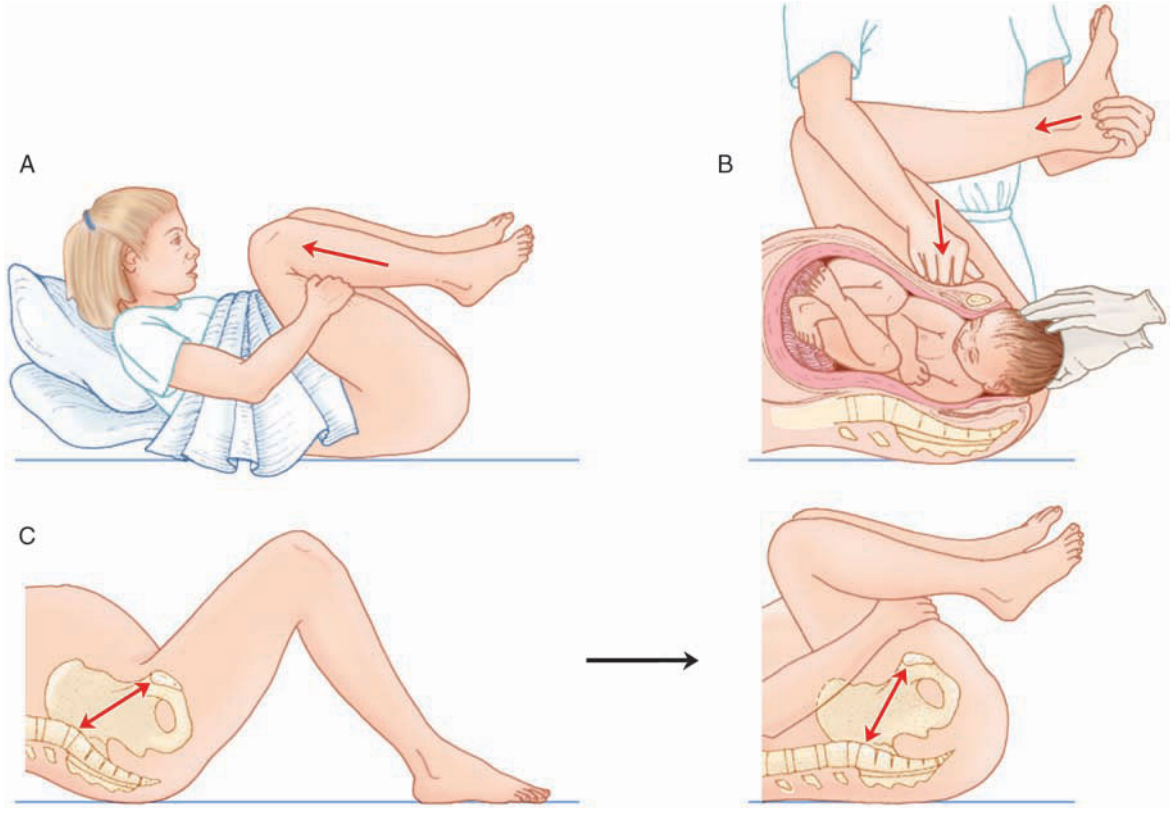


FIGURE 133-6. The McRoberts maneuver. **A.** Hyperflex the maternal thighs upon the abdomen. **B.** An assistant applies suprapubic pressure while maintaining flexion of the legs. **C.** This maneuver results in cephalad rotation of the maternal pelvis and an increase in the size of the pelvic outlet.



FIGURE 133-7. The Rubin maneuver. Rotation of the anterior shoulder counterclockwise through a small arc to the oblique position.

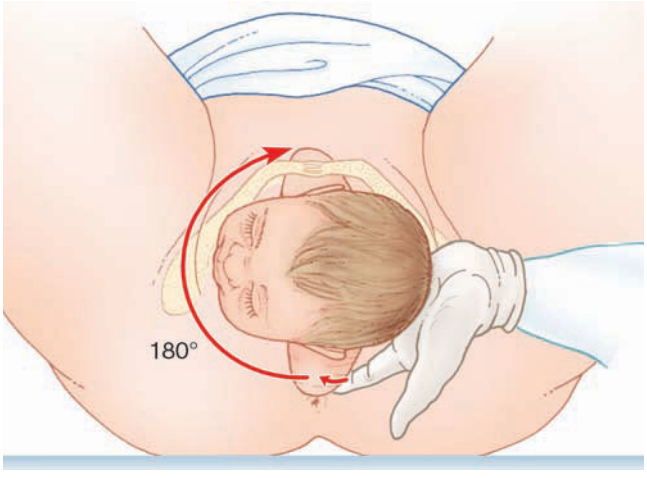


FIGURE 133-8. The Wood's corkscrew maneuver. Rotation of the posterior shoulder through a 180° arc.

Place the fingers of the hand against the posterior aspect of the posterior fetal shoulder. Gently rotate the posterior shoulder 180° clockwise (**Figure 133-8**).[15] This maneuver, like the Rubin maneuver, compresses and diminishes the size of the fetal shoulder girdle to disimpact the anterior shoulder. Rotation in the opposite direction (i.e., counterclockwise) will open the shoulder girdle, increase the size of the shoulder girdle, and further impact the fetus.

DELIVERY OF THE POSTERIOR ARM

Attempt to deliver the posterior arm if the previous maneuvers are unsuccessful (**Figure 133-9**). Insert the dominant hand into the vagina. Place the fingers of the hand against the posterior fetal humerus (**Figure 133-9A**). Sweep the fetal arm across the chest (**Figure 133-9B**). Palpate for and grasp the fetal hand (**Figure 133-9C**). Gently pull the hand along the side of the face. Continue to gently pull the hand to deliver the posterior arm and shoulder (**Figure 133-9D**). Apply gentle downward traction on the fetal head and arm while an assistant simultaneously applies suprapubic pressure to release and deliver the anterior shoulder (**Figure 133-9E**). Rotate the shoulder girdle into the oblique diameter if traction on the fetal head and arm does not deliver the anterior shoulder.[9] This will usually disimpact the anterior shoulder and allow it to be delivered. **The major disadvantage of this maneuver is that it may result in a clavicle fracture or a humerus fracture.**

DELIBERATE FRACTURE OF THE CLAVICLE

Fracture the fetal clavicle by pressing the anterior clavicle against the maternal pubic symphysis. This will decrease the rigidity and the size of the fetal shoulder girdle. Exert the pressure in a direction away from the lungs to avoid a pneumothorax. **Never use an instrument to fracture the clavicle.** It may penetrate into the thoracic cavity, cause a pneumothorax, or result in subsequent osteomyelitis if the skin is punctured.[14] The fracture will heal quickly and is much less serious than a brachial plexus injury, asphyxia, or death. This maneuver is difficult to perform.[15] It is physically and mentally difficult to deliberately fracture the clavicle of a large infant.

ZAVANELLI MANEUVER

The Zavanelli maneuver involves replacement of the fetal head followed by a cesarean section (**Figure 133-10**). The expulsed head must undergo two maneuvers to reverse the mechanisms of labor. Manually rotate the fetal head into the prerestitution position (**Figure 133-10A**). This is usually the direct occiput anterior position with full extension of the neck (**Figure 133-10B**). The second maneuver is flexion of the fetal head followed by gentle upward pressure on the head to replace it into the maternal vagina (**Figure 133-10B**). The Emergency Physician must maintain their hand in the vagina and maintain gentle pressure on the fetal head to prevent re-expulsion. The Emergency Physician, or an assistant, must keep their hand in the vagina and holding the fetal head during the entire transport to the Operating Room and until a cesarean section is performed.

This series of maneuvers decompresses the fetus. Immediately transport the mother to the Operating Room for a cesarean section. The Zavanelli maneuver was found to be successful in 84% of initial attempts and 91% of attempts when uterine relaxing anesthesia or uterine relaxing medication (usually 0.25 mg terbutaline subcutaneously) was administered.[16,17] More importantly, it was successful on the first attempt by untrained practitioners in 69% of the cases.

SYMPHYSIOTOMY

A symphysiotomy is an uncommon procedure utilized primarily in two situations. The first is shoulder dystocia unresponsive to less invasive techniques. The second is when the head of a breech delivery is trapped by presumed cephalopelvic disproportion. It serves as an alternative to the more invasive cesarean section. It is especially useful in situations where an Obstetrician or Surgeon is unavailable.[17,18] Refer to Chapter 137 for the complete details regarding a symphysiotomy.

AFTERCARE

Disimpaction of the shoulder girdle is usually followed by delivery of the infant. Clamp and cut the umbilical cord. Immediately assess and implement any resuscitative measures for the infant without delay. Deliver the placenta. Repair any lacerations, Dührssen's incisions, episiotomy incisions, perineal lacerations, and vaginal lacerations. Refer to Chapter 132 for the complete details regarding episiotomy repair. Refer to Chapter 135 for the complete details regarding postpartum hemorrhage management. Initiate uterine massage and administer intramuscular pitocin following delivery of the placenta to prevent postpartum hemorrhage. Clearly and completely document the series of events in the medical record.

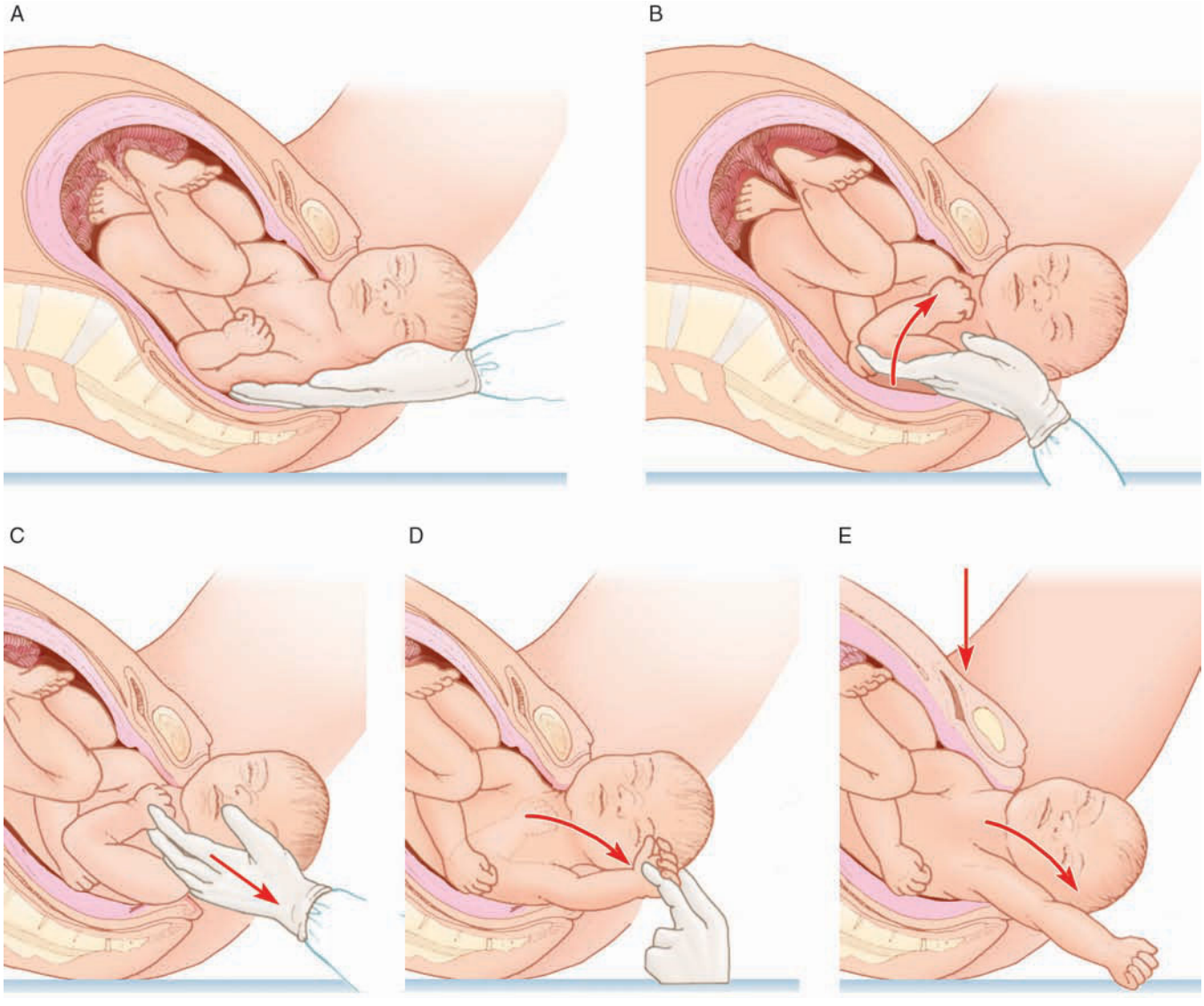


FIGURE 133-9. Delivery of the posterior arm. **A.** Insert a hand into the vagina and along the posterior fetal humerus. **B.** Sweep the fetal arm across the chest. **C.** Grasp the hand and extend the arm along the side of the face. **D.** Deliver the posterior arm and shoulder from the vagina. **E.** Apply gentle downward traction on the fetal head and arm while an assistant simultaneously applies suprapubic pressure to deliver the anterior shoulder.

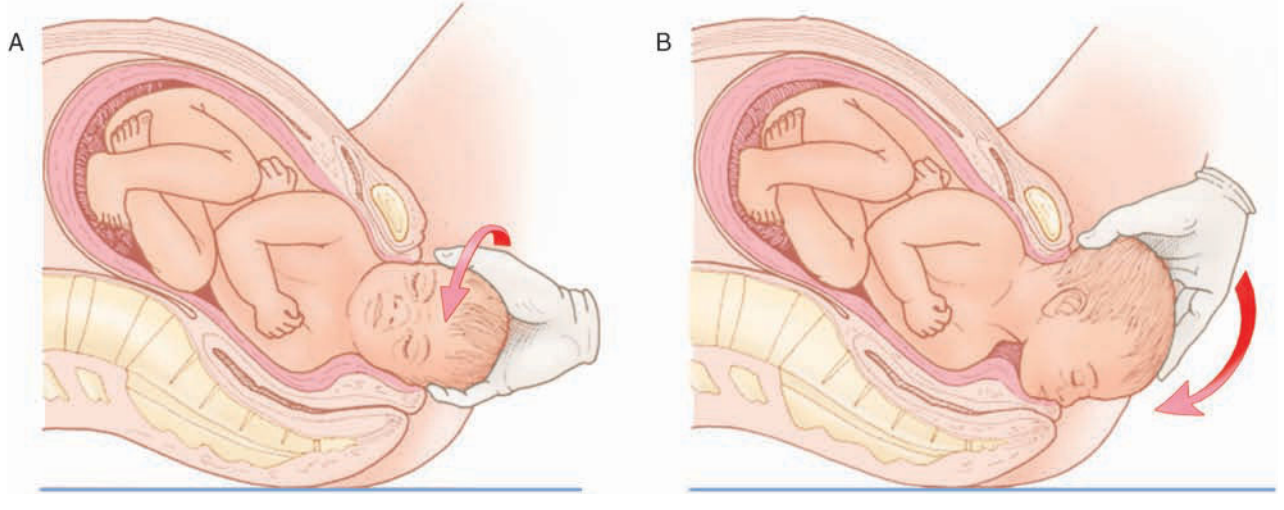


FIGURE 133-10. The Zavanelli maneuver. **A.** Manually return the fetal head to the preretitution position, if restitution has occurred. This position is usually the direct occiput anterior position. **B.** Flex the fetal head and apply gentle upward pressure to place the fetal head back into the vagina.

COMPLICATIONS

Complications can occur for both the mother and the fetus when shoulder dystocia occurs. The most common maternal complications are lower genital tract lacerations, postpartum hemorrhage (secondary to uterine atony or lacerations), and infection.[2,19]

Significant fetal morbidity and mortality is attributable to asphyxia from delayed delivery or trauma sustained during delivery.[9] Perinatal mortality ranges from 2% to 29% when shoulder dystocia occurs. Neonatal morbidity is immediately apparent in 20% of the affected infants.[2] Neonatal trauma may occur in utero secondary to chronic nerve compression from malposition and during delivery.[9] Birth trauma occurring during shoulder dystocia may include brachial plexus injuries or Erb's palsy (6% to 16%), Klumpke palsy, clavicular fractures (5% to 13%), or humeral fractures.[3,5,6,14,15,19,20]

SUMMARY

The successful management of shoulder dystocia requires considerable judgment by the clinician in a timely fashion. Warning signals such as fetal macrosomia based on clinical estimate, maternal diabetes, and labor disorders should alert the clinician to be prepared for possible shoulder dystocia. Any or all of the maneuvers described will usually resolve shoulder dystocia if performed in a methodical fashion. Begin with the simplest and least invasive maneuver and work toward the more invasive maneuvers. Reduction of the time interval from delivery of the head to delivery of the body is crucial to fetal survival.

134 Breech Delivery

Irene E. Aga

INTRODUCTION

The breech presentation exists when the cephalic pole of the fetus is positioned in a longitudinal lie and the buttocks or feet of the fetus enter the maternal pelvis before the head.[1] Management of the breech presentation in labor is an area of much trepidation and controversy, even among seasoned clinicians. A breech delivery is considered a high-risk obstetric complication that is best handled by an Obstetrician.

There are, however, unavoidable situations when a pregnant woman will present to the Emergency Department in active labor with a fetus in the breech position. A vaginal breech delivery may be the best delivery option in situations such as advanced labor, the absence of surgical assistance, the presence of an acute situation, fetal distress, or umbilical cord prolapse. Knowledge and preparedness facilitate comfort and promote success in approaching any emergent procedure. The breech delivery is no exception to this rule.

ANATOMY AND PATHOPHYSIOLOGY

The breech presentation may be associated with a variety of maternal and fetal conditions.[1,2] Maternal abnormalities that increase the risk of a breech presentation include a small pelvis and uterine anomalies. Fetal conditions associated with a breech presentation include low birth weight, prematurity, abnormal amniotic fluid volume, fetal malformations (e.g., hydrocephalus, cystic hygroma, and anencephaly), neurologic disorders, and genetic abnormalities.

Prematurity is a risk factor for a breech presentation. The incidence of breech presentations is inversely related to the fetal gestational age.[1,2] At 28 weeks of gestation, 24% of fetuses are in the breech presentation. The fetus usually turns spontaneously to a cephalic presentation so that at term, only 3% to 4% are in the breech presentation.[1,2]

There are three main types of breech presentation (**Figure 134-1**). The most common is the frank breech, accounting for 50% to 73% of breech presentations. The fetus is flexed at the hips and extended at the knees (**Figure 134-1A**). The fetus is in the "pike" position. The complete breech is the least common type and accounts for approximately 5% to 11% of breech presentations. The fetus is flexed at both the hips and the knees (**Figure 134-1B**). The footling or incomplete breech accounts for approximately 12% to 38% of breech presentations. The fetus is incompletely deflexed at one or both knees or hips (**Figure 134-1C**). This results in one or both feet presenting before the buttocks. The risks of umbilical cord prolapse and prematurity associated with the breech presentation are listed in **Table 134-1**.

A breech presentation may be suspected upon clinical examination. The abdominal examination may reveal the hardness of

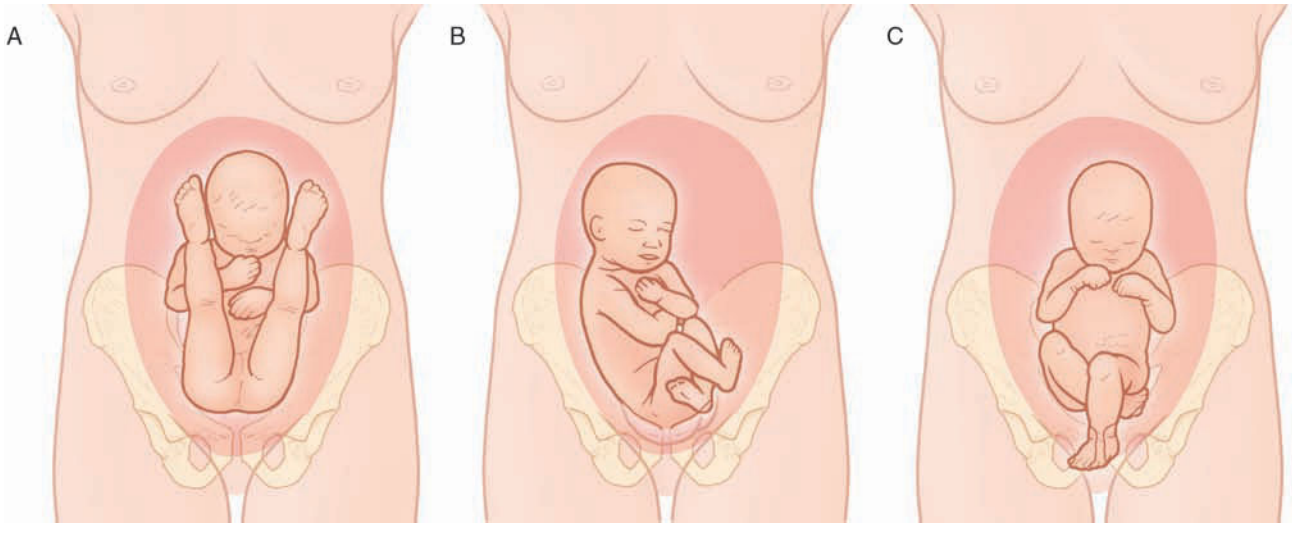


FIGURE 134-1. The main types of breech presentations. **A.** The frank breech. **B.** The complete breech. **C.** The incomplete breech.

TABLE 134-1 Breech Presentations and Associated Complications[1]

Breech presentation	Breech deliveries (%)	Umbilical cord prolapse (%)	Prematurity (%)
Frank	50–73	0.5	38
Complete	5–11	5	12
Incomplete	12–38	14	50

the fetal head palpable in the fundus rather than above the pelvic inlet. A vaginal examination can confirm this suspicion. When a breech presentation in labor is suspected, an ultrasound examination is recommended to confirm presentation and exclude a fetal abnormality.[1]

Breech delivery is divided into three categories. These include unassisted or spontaneous expulsion, partial breech extraction, and total breech extraction.[3] Unassisted or spontaneous expulsion of the fetus occurs when there is no assistance from the provider in the delivery of the infant. This generally occurs only with very premature infants or in precipitous deliveries where the baby delivers so rapidly as not to allow the provider to arrive.

Partial breech extraction is defined as spontaneous delivery of the infant to the level of the umbilicus followed by assistance from the provider. This is the usual manner of breech delivery. **Allowing the fetus to descend naturally into the pelvis avoids an increased incidence of head entrapment, deflexion of the fetal head, nuchal arms, and umbilical cord prolapse.** This is the preferred method of delivery for the Emergency Physician confronted with an actively laboring breech presentation and little hope of obtaining an Obstetrician before delivery.

Total breech extraction occurs when the provider reaches into the uterus and literally pulls or extracts the fetal feet into the vagina and through the vulva, followed by the assisted delivery of the remainder of the infant. Total breech extraction is indicated when expedient delivery is preferred in the absence of an experienced Obstetrician to perform a cesarean section and if performed for the breech presentation of a second twin, acute and profound fetal distress, and/or umbilical cord prolapse.[2]

Regardless of the mode of delivery, the breech presentation has been associated with an increased risk of cerebral palsy and perinatal mortality. Thus, failure to adopt the cephalic presentation may in some cases be a marker for some type of preexisting fetal impairment.[4] The cesarean section has been suggested as the way to reduce perinatal problems associated with the breech presentation.[5] Cesarean section has become the normal mode of breech delivery in many European countries and in North America. The rate of cesarean section for the breech presentation in the United States has increased from 12% in 1970 to 87% in 2002.[6] However, prospective and retrospective studies over the last two decades are now beginning to refute this practice.[7–10]

No consensus exists concerning the absolute preferred method of breech delivery due to the conflicting data.[11] Currently, the American College of Obstetricians and Gynecologists recommends that the decision regarding the mode of delivery should be based on the experience of the healthcare provider. It is recognized that cesarean delivery will be the preferred mode of delivery for most Physicians. Maternal morbidity and mortality are higher if an emergency cesarean delivery is performed when compared to an elective cesarean delivery. There are circumstances such as patient preference, an obstetric indication, or a precipitous delivery in which a vaginal breech delivery will be preferable.[12]

Obstetricians will often perform external cephalic version prior to the delivery date if a breech presentation is identified during prenatal visits.[1,2,10] This technique is reserved for the experienced Obstetrician as it can be associated with significant complications. External cephalic version cannot be performed if the mother is in active labor and the fetus is engaged in the maternal pelvis.

INDICATIONS

Vaginal breech delivery by the Emergency Physician is indicated when the mother is in active labor and an Obstetrician is not available to perform the delivery or a cesarean section.

CONTRAINDICATIONS

There are no agreed upon absolute contraindications to a vaginal breech delivery. Recommendations have been made based upon factors that increase morbidity and mortality in vaginal and cesarean breech deliveries.[1–3,8] Maternal risk factors for increased morbidity and mortality with a vaginal breech delivery include a small pelvis, pelvic anomalies, uterine masses, uterine malformations, and arrest of labor. Fetal risk factors for increased morbidity and mortality with a vaginal breech delivery include extremes of fetal weight, fetal head extension, prematurity, nonfrank breech, and a nonreassuring fetal heart rate pattern.

There are factors regarded as unfavorable for a vaginal breech birth.[13–15] Contraindications include placenta previa, a compromised fetal condition, a clinically inadequate maternal pelvis, and the arrest of active labor. Large infants (larger than 4000 g) and low birth weight infants (smaller than 2500 g) should not be vaginally delivered if in the breech position. The footling breech presentation can result in more complications than other breech presentations when delivered vaginally. A hyperextended fetal neck makes delivery more complicated and risks injury to the fetus. A Physician not experienced in the technique should not vaginally deliver a breech fetus.

Unfortunately, many of these conditions are not known in an emergent breech presentation. The Emergency Physician may not have the time or experience to assess these conditions. Emergent cesarean delivery is indicated if any of the conditions listed above are known and the setting permits it.

The normal progress of labor with breech presentation has not been extensively evaluated. Poor progress in the active phase of labor may be a sign of fetopelvic disproportion. Failure of the breech to descend once the cervix is completely dilated should be managed with a cesarean section.[13–15]

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Electronic fetal monitor
- Delivery instrument pack (see Chapter 131)
- Piper forceps
- Towels
- Clock or timer watch
- Sterile gowns and gloves
- Chromic or Vicryl suture, 2-0 or 3-0
- Richardson or right-angle retractors
- Ring forceps
- Straight Mayo scissors
- 8 inch needle driver
- Sterile drapes

Personnel

- Two medical practitioners if available
- Nursing personnel
- Timekeeper
- Anesthesiologist or Anesthetist if available
- Pediatric or neonatal team if available

PATIENT PREPARATION

Perform an abdominal examination and cervical examination to assess the fetal position. Apply a fetal monitor and tocodynamometer to the maternal abdomen. Perform ultrasonography if available to confirm the fetal position, to estimate fetal weight, and to evaluate for any gross fetal anomaly.

Obtain an informed consent for the delivery if possible and time permits. Epidural anesthesia or a spinal block by an Anesthesiologist is recommended if available and time permits. A pudendal nerve block with local perineal infiltration may be used as an alternative. Refer to Chapter 131 for the details regarding the pudendal nerve block. Place the mother in the lithotomy position. Scrub the perineum with povidone iodine solution, chlorhexidine solution, or antibacterial soap. The Emergency Physician should apply a mask with eye protection or goggles, a sterile gown, and sterile gloves. Apply sterile drapes to isolate the patient's perineum (**Figure 131-10**).

ASSISTED VAGINAL FRANK BREECH DELIVERY

This method is appropriate for all breech presentations. The fetus enters the maternal pelvis with the bitrochanteric diameter in an oblique position (**Figure 134-2A**). The sacrum is the point of designation for these presentations. The fetus rotates with labor and

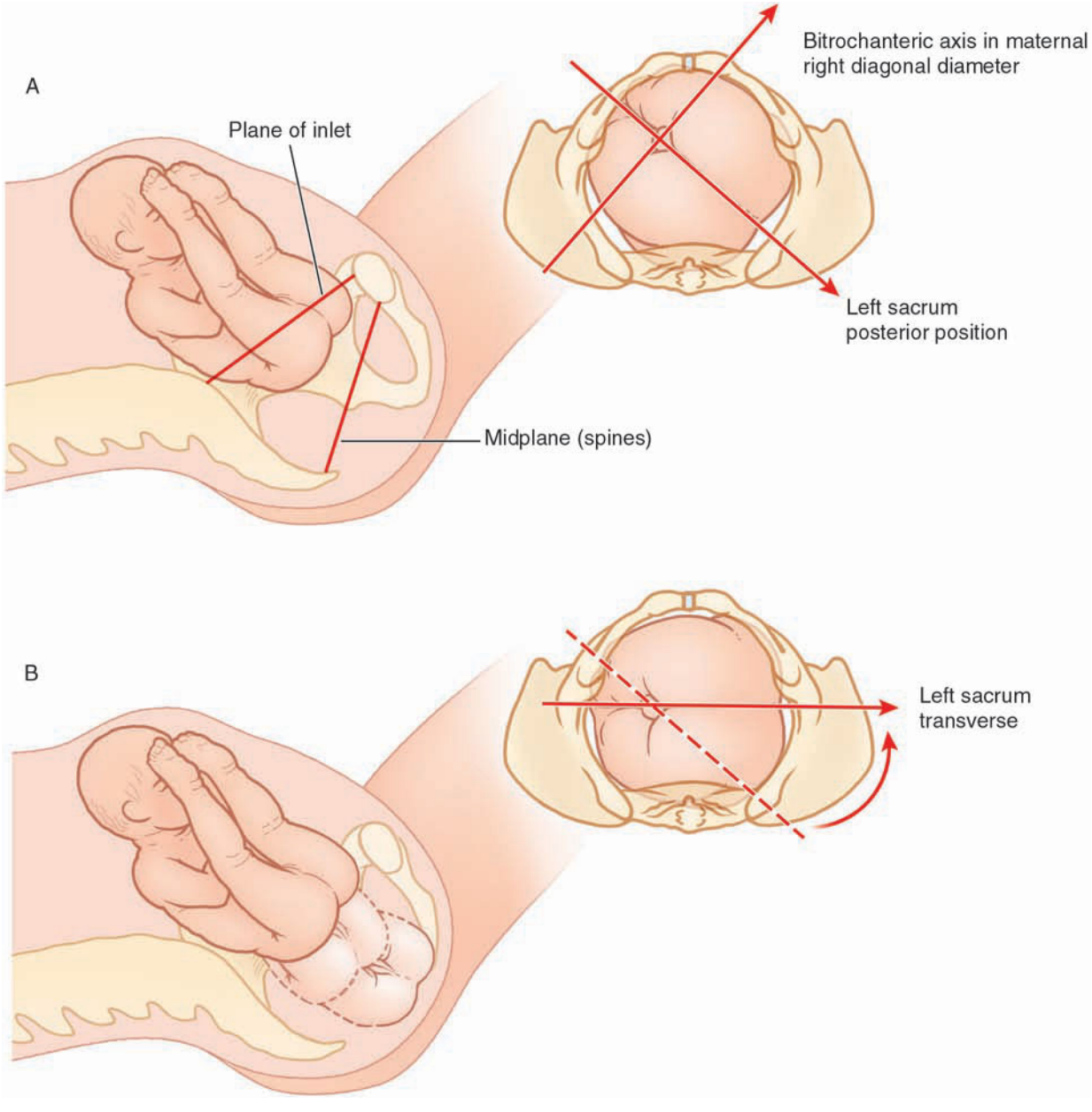


FIGURE 134-2. Breech engagement of the maternal pelvis. **A.** The bitrochanteric diameter is aligned with one of the diagonal diameters. **B.** Descent causes the bitrochanteric diameter to rotate into the anteroposterior axis and the sacrum to rotate into the transverse axis.

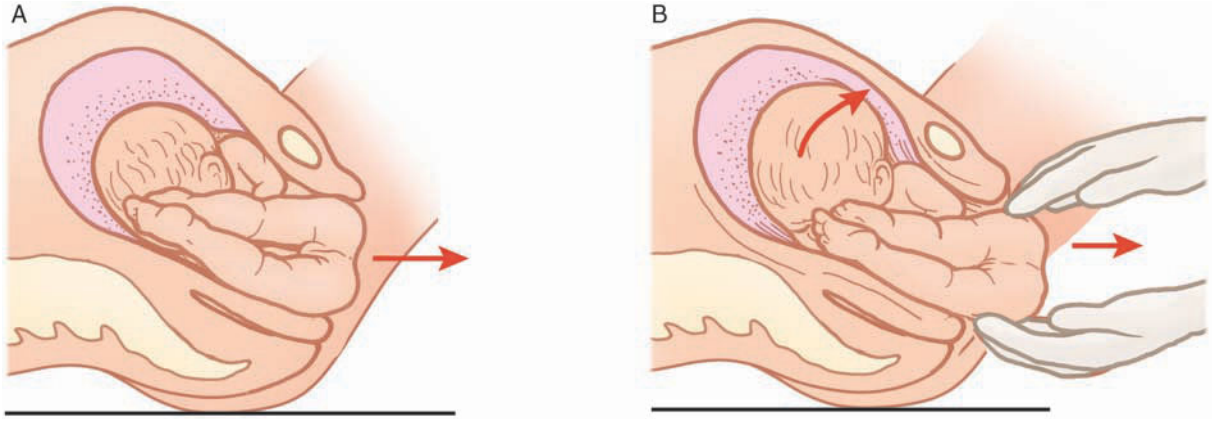


FIGURE 134-3. Delivery of the buttocks. **A.** Uterine contractions result in spontaneous emergence of the buttocks while maintaining cephalic flexion. **B.** Premature traction can result in deflexion of the vertex, head entrapment, or nuchal arms.

descent, so that the bitrochanteric diameter is in the anteroposterior axis and the sacrum is in the transverse axis (**Figure 134-2B**).

Encourage maternal "pushing" to expel the fetal buttocks (**Figure 134-3A**). Support the fetal buttocks with a toweled hand. **Do not assist with the delivery of the buttocks as they emerge (Figure 134-3B). Allow the fetus to deliver spontaneously to the level of the umbilicus with only maternal uterine propulsive efforts.** Early extraction of the buttocks increases the risk of head entrapment in a partially dilated cervix, results in deflexion of the fetal head, and increases the risk of nuchal arm entrapment. Perform a midline episiotomy when the buttocks crown. **Do not perform the episiotomy too early, as this may lead to excessive maternal blood loss.** Refer to Chapter 132 for complete details regarding an episiotomy.

Proceed with the delivery of the fetal legs when the umbilicus emerges (**Figure 134-4**). The legs will likely have delivered themselves by this time if the fetus is in the complete or incomplete breech position. Insert the fingers of the dominant hand along the long axis of the medial fetal thigh (**Figure 134-4A**). Apply laterally directed pressure on the fetal thigh to flex the knee and externally rotate the leg out and down through the vulva (**Figure 134-4A**). Simultaneously apply opposite rotation on the fetal hip and pelvis. Deliver the other leg in a similar manner (**Figure 134-4B**). **Rotation of the hip in a direction opposite the direction of knee flexion facilitates the delivery of the distal extremities. Therefore, rotate the left leg clockwise and the right leg counterclockwise.**

Prepare to deliver the fetal arms (**Figure 134-5**). Place a sterile towel around the legs and trunk of the fetus for support (**Figure 134-5A**). Continue to support the fetal body and encourage maternal pushing efforts. **Do not actively assist in the delivery until the fetal scapulae are visible. Aggressive extraction of the fetus following the delivery of the legs may cause deflexion of the vertex or nuchal entrapment of the arms.**

Proceed with active delivery of the shoulders and arms as the scapulae emerge from the vagina (**Figure 134-5**). Rotate the fetal trunk to present the anterior arm and shoulder (**Figure 134-5A**). Insert the fingers of the dominant hand longitudinally along the humerus of the presenting arm (**Figure 134-5A**). Apply traction to the humerus to flex the elbow. Sweep the arm across the chest and deliver it through the mother's vulva (**Figure 134-5B**). Rotate the fetus in a manner to bring the alternate shoulder into the anterior position (**Figure 134-5C**). Gently rotate the fetus clockwise to deliver the left arm and counterclockwise to deliver the right

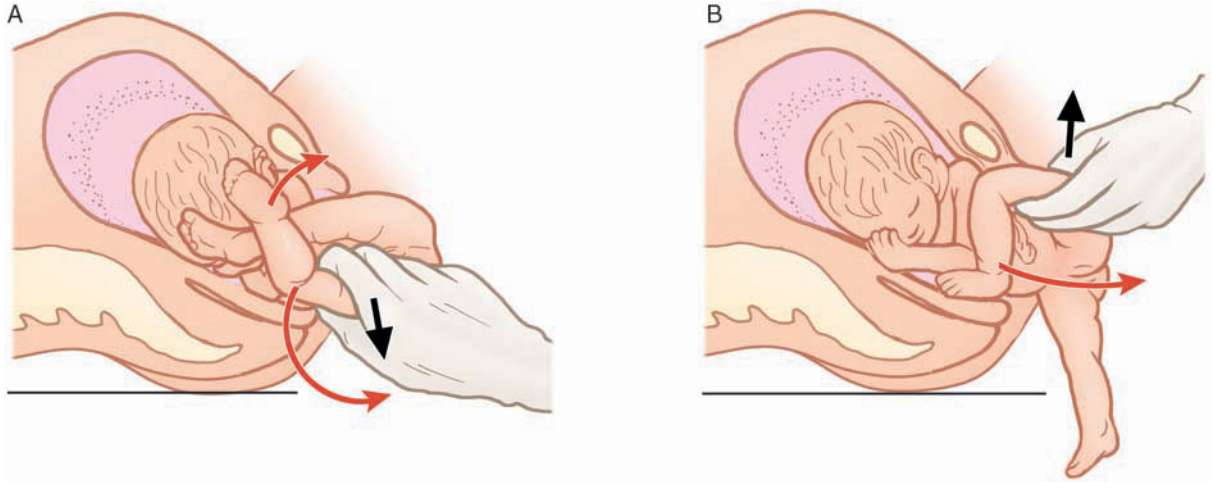


FIGURE 134-4. Delivery of the legs. **A.** Apply laterally directed pressure on the medial thigh with opposite rotation of the pelvis to deliver the leg. **B.** Repeat the procedure to deliver the other leg.

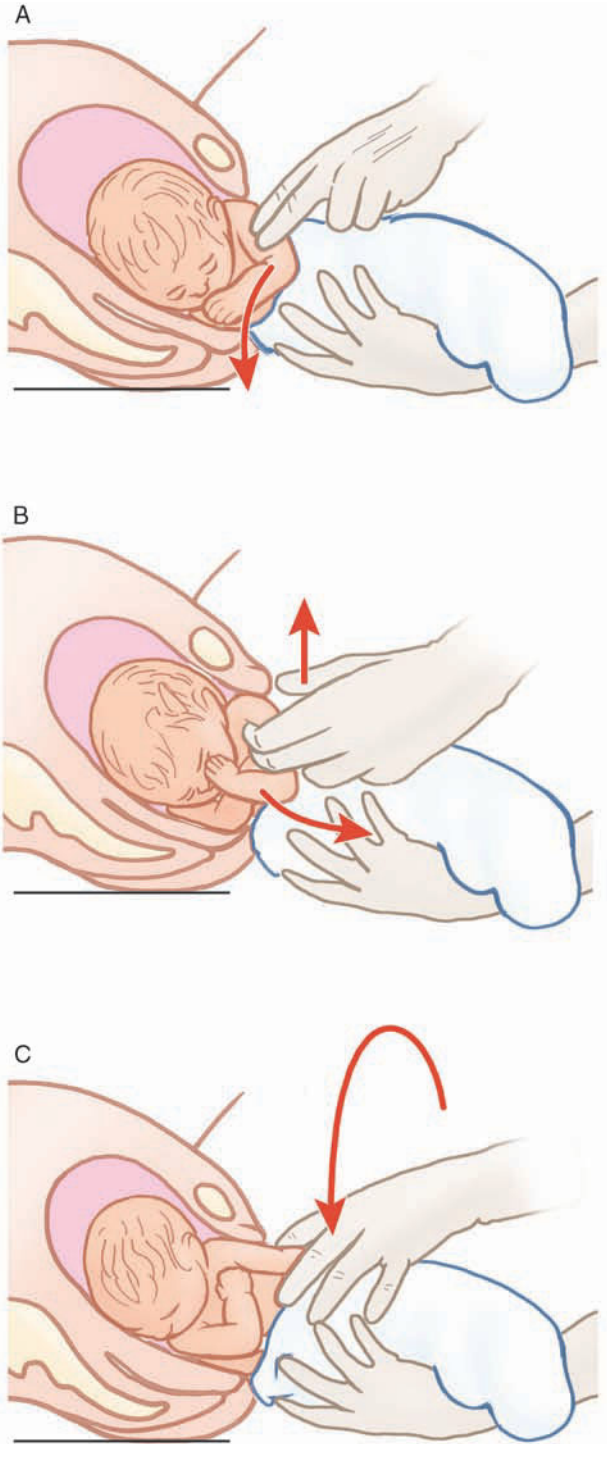


FIGURE 134-5. Delivery of the arms. **A.** Insert the dominant hand along the humerus of the anterior arm. Apply traction (*arrow*) to flex the elbow. **B.** Deliver the arm. **C.** Gently rotate the fetus so that the other arm presents anteriorly.

arm. This direction of motion prevents the arm from becoming entrapped on the neck. Repeat the procedure to deliver the second arm.

The fetal shoulders and arms may not easily deliver utilizing the above technique. Perform this alternate technique if the arms and shoulders do not deliver. Place the thumbs of both hands over the fetal posterior iliac spines and sacroiliac area. Place the palms and fingers over the fetal hips. **Apply pressure only over the iliac spines. Never grasp the fetal abdomen. The adrenal glands, kidney, liver, and spleen may be injured with excessive pressure during the delivery process.** Elevate the fetal body to deliver the posterior shoulder over the more pliable posterior perineum. Deliver the posterior arm as described above. Lower the fetal trunk. Deliver the anterior shoulder from under the maternal pubic symphysis as described above.



FIGURE 134-6. Delivery of the fetal head.

The fetal vertex will generally rotate into the anteroposterior orientation after delivery of the arms and shoulders. The fetal vertex will lie against the maternal pubic symphysis. The fetal chin will lie in the posterior aspect of the vagina and/or lower uterine segment. Wrap the fetal arms and trunk in a towel. Encourage maternal pushing efforts. The fetal head may deliver spontaneously. Note when the fetal chin and mouth appear at the posterior perineum. **Instruct the mother to stop pushing.** Suction the fetal mouth. Gently lift the infant upward to deliver the head in a controlled manner (**Figure 134-6**). **Avoid hyperextending the fetal back.**

Complete the delivery of the infant. Clamp and cut the umbilical cord. Place the infant in the warmer for examination and resuscitation. The Apgar scores for infants delivered from a breech position are generally slightly lower than from a vertex delivery. The infant may show some initial signs of short-term and generally clinically insignificant hypoxia.

DELIVERY OF THE FETAL HEAD

Cervical entrapment (inadequate cervical dilation) is a more common occurrence in the delivery of a fetus in the breech presentation. It is most frequently observed when rapid labor results in the fetal trunk being delivered through a partially dilated cervix or during the delivery of a premature breech when the fetal head is relatively larger than the fetal trunk.

The fetal head often delivers spontaneously with maternal pushing efforts, but it may occasionally fail to do so. Several options exist to aid in the delivery of the fetal head. These include manual extraction, manual extraction with the McRoberts maneuver or the Mauriceau–Smellie–Viet maneuver, forceps-assisted delivery, and Dührssen's incisions.

Adequate anesthesia is vital to the extraction of the fetal head. A pudendal block and peroneal infiltration should have been performed previously. If not, consider the administration of parenteral sedation and analgesia (Chapter 129) and local infiltration. Inhaled halogenated agents, intravenous beta-mimetics (i.e., terbutaline or ritodrine), or intravenous nitroglycerin are all useful for uterine relaxation in the event of entrapment of the after-coming head or if

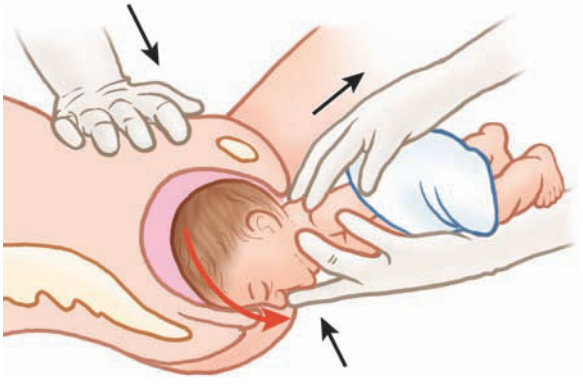


FIGURE 134-7. The Mauriceau-Smellie-Viet maneuver.

intrauterine manipulation is necessary. Utilize assistants as needed to offer adequate visualization. Gently place Richardson or Pratt retractors in the vagina to maximize the view.

McROBERTS MANEUVER

Apply the McRoberts maneuver if the fetal head does not deliver. The McRoberts maneuver is easy to perform (**Figure 133-6**). Place an assistant on each side of the patient. Hyperflex the mother's thighs onto her abdomen (**Figure 133-6A**). Instruct the assistants to maintain support of the hyperflexion while applying suprapubic pressure (**Figure 133-6B**). This results in flattening of the lumbosacral curve with rotation of the pubic symphysis cephalad (**Figure 133-6C**). Perform the manual extraction.

MAURICEAU–SMELLIE–VIET MANEUVER

Perform the Mauriceau–Smellie–Viet maneuver if the McRoberts maneuver is unsuccessful in the spontaneous delivery of the head (**Figure 134-7**). Rest the body of the infant on the dominant arm. Place the index and middle finger of the dominant hand on the fetal maxilla. Apply pressure to the maxilla to maintain the fetal head in flexion. **Do not place the fingers on the fetal mandible or in the fetal mouth.** Place the nondominant hand on the posterior aspect of the fetal neck and shoulders. Slightly elevate the fetal body from the horizontal plane.

Exert continued and gentle downward traction with both hands until the occiput moves under the mother's pubic symphysis. **Never hyperextend the fetal trunk to avoid spinal cord injuries. Never apply pressure to the mandible or the fetal mouth during this maneuver. The force applied to the mandible or mouth can dislocate the mandible.** Instruct an assistant to apply firm and gentle suprapubic pressure in conjunction with gentle downward traction by the operator. Continue this process until the head delivers.

FORCEPS-ASSISTED DELIVERY OF THE HEAD

The utilization of forceps may be warranted if none of these maneuvers is successful.[14,17] The Piper forceps have a minimal pelvic curve, allowing direct application to the fetal head. They are used solely for the delivery of an after-coming head in the breech delivery. **Forceps-assisted delivery can result in significant injury to the fetus and the mother. The use of the Piper forceps is not recommended unless the Emergency Physician has training and experience in their proper use.**

Apply the Piper forceps. Instruct an assistant to elevate the fetal trunk slightly above the horizontal plane (**Figure 134-8A**). Kneel below the fetus. Insert the forceps directly into the vagina and along the fetal head. Apply the right forceps blade. Grasp the blade in the left hand. Place the right hand along the left fetal parietal bone, between the fetal head and the right maternal pelvic side wall. Insert and apply the forceps blade. Instruct the assistant to hold the blade in this position. Apply the left forceps blade. Grasp the blade in the right hand. Place the left hand along the right fetal parietal bone, between the fetal head and the left maternal pelvic side wall. Insert

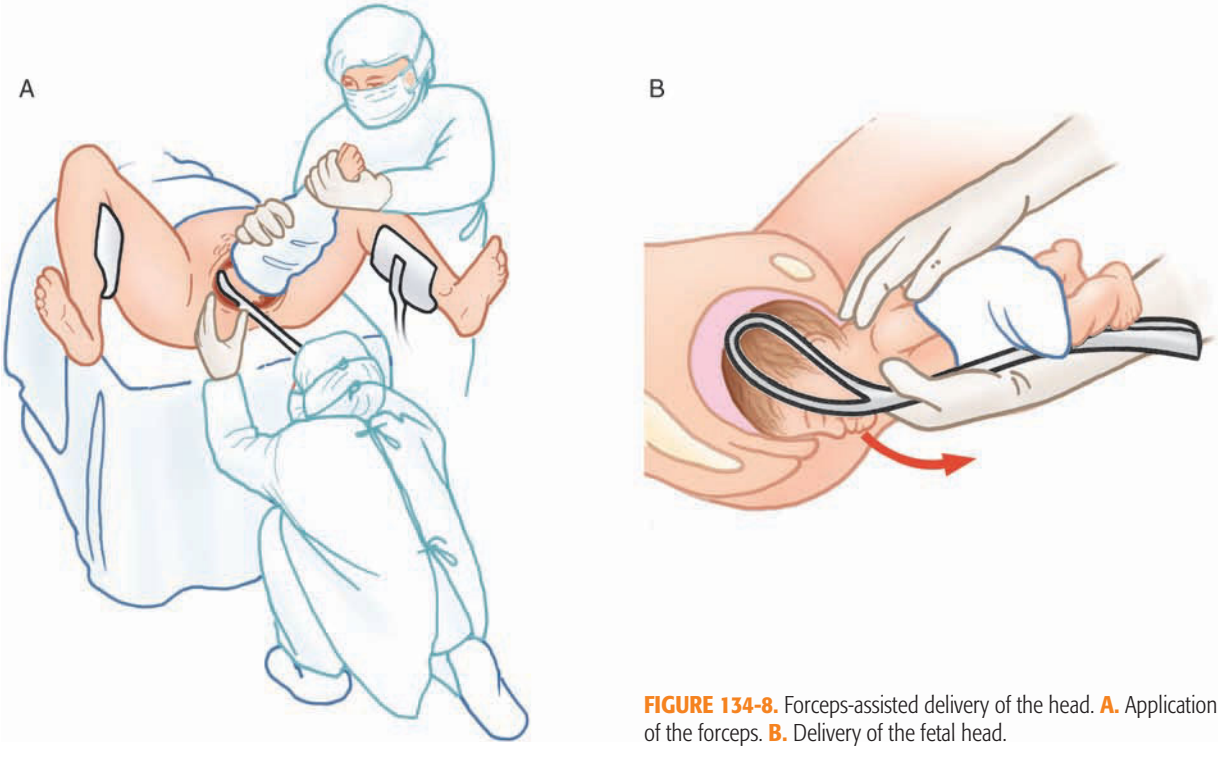


FIGURE 134-8. Forceps-assisted delivery of the head. **A.** Application of the forceps. **B.** Delivery of the fetal head.

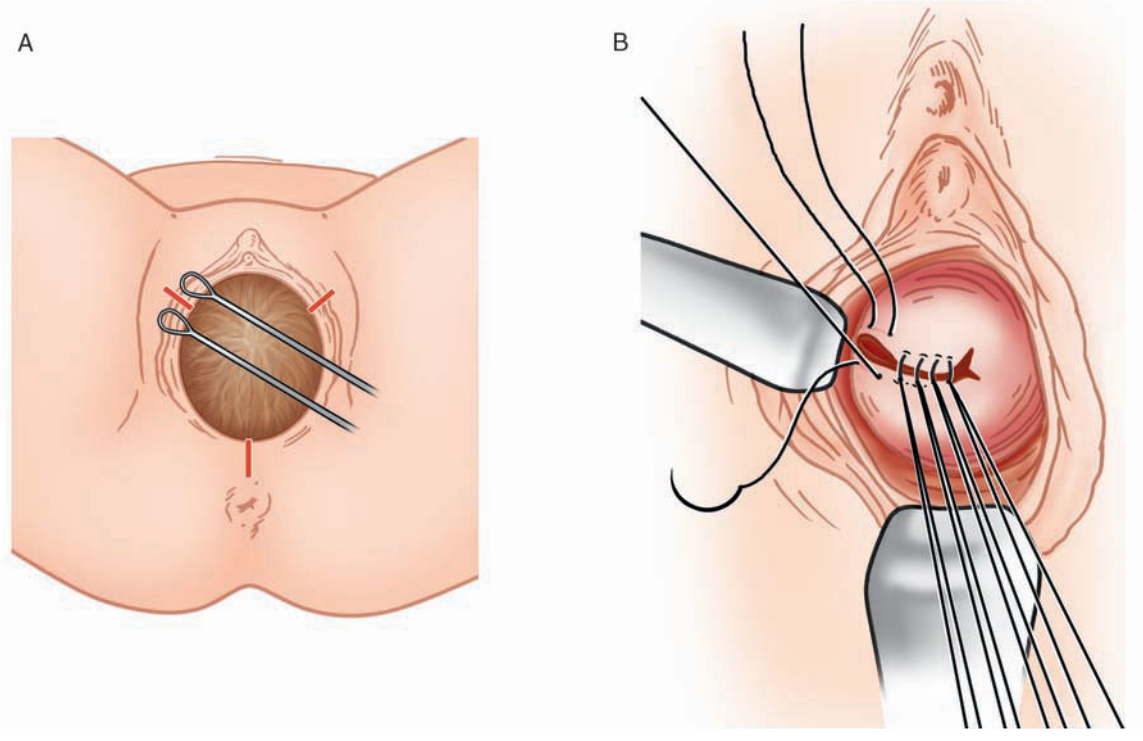


FIGURE 134-9. Dührssen's incisions. **A.** The incisions. **B.** Repair of the incisions.

and apply the forceps blade. Gently join the forceps handles while avoiding excessive pressure.

Apply gentle downward and outward traction to the forceps blades to deliver the fetal head (**Figure 134-8B**). Slowly elevate the plane of the fetal trunk toward the maternal abdomen as the fetal face delivers. **Do not hyperextend the fetal neck.** Stop the extraction as the mouth appears. Gently suction the fetal mouth. Deliver the head.

DÜHRSSEN'S INCISIONS

Perform Dührssen's incisions if the fetal head is entrapped, if other methods of extraction have failed, and if you are unfamiliar with the use of forceps. Dührssen's incisions consist of two to four incisions placed circumferentially around the cervix (**Figure 134-9**). **The two required incisions are at the 10 and 2 o'clock positions.** Additional incisions can be made at the 5, 6, and/or 7 o'clock positions. **The cervix must be more than 70% effaced and dilated more than 6 cm for the procedure to be successful and to prevent significant hemorrhage.**

Grasp two pairs of ring forceps. Grasp the cervix around the point of the incision. For example, place ring forceps at the 9 and 11 o'clock positions to make the 10 o'clock incision (**Figure 134-9A**). Make the incisions 2 to 3 cm in length with a straight Mayo scissors. Deliver the fetal head.

PERSISTENT FETAL HEAD ENTRAPMENT

The fetal head may fail deliver despite the maneuvers described above. True cephalopelvic disproportion must be differentiated from cervical entrapment (inadequate cervical dilation). The options are limited in the rare case of a true cephalopelvic disproportion. The Emergency Physician can perform a symphysiotomy (Chapter 137), the fetal body can be pushed back into the uterus and a cesarean section performed, or an experienced Obstetrician may perform a destructive procedure if the fetus is nonviable.

TOTAL BREECH EXTRACTION

Breech extraction is to be performed only in the rare instances of a second twin presenting in a breech position, extreme fetal distress without the capability of performing a cesarean section, and/or umbilical cord prolapse that does not allow time for setup or performance of a cesarean section.[2,17–19]

If available, utilize ultrasound to identify the fetal legs and feet. This will ensure you grasp the appropriate extremity. Reach into the lower uterine segment with the dominant hand and firmly grasp the fetal feet. Place the fingers around the fetus's ankles, with the index finger between the two ankles (**Figure 134-10A**). Apply continuous and firm traction in a downward and outward direction. Deliver the fetal feet and legs through the vaginal opening (**Figure 134-10A**). Continue to apply traction to deliver the fetus to the level of the buttocks (**Figure 134-10B**). Instruct an assistant to support the fetus. Perform a midline episiotomy if necessary. Deliver the fetus to the level of the umbilicus. Grasp the bony sacrum and pelvis. The remainder of the technique is as described above.

COMPLETE AND INCOMPLETE BREECH DELIVERIES

Complete and incomplete breech deliveries may occur in the same fashion as the frank vaginal breech delivery. The one exception is that one or both feet may already be extended and not require attention.[2] There is an increased risk of umbilical cord prolapse, umbilical cord entanglement, and entrapment of the after-coming head.[2,7,10] This is the basis for the recommendation for cesarean delivery in these cases.[2,7,10] However, one randomized trial reported nonfrank vaginal breech delivery to be relatively safe as well.[2,10]

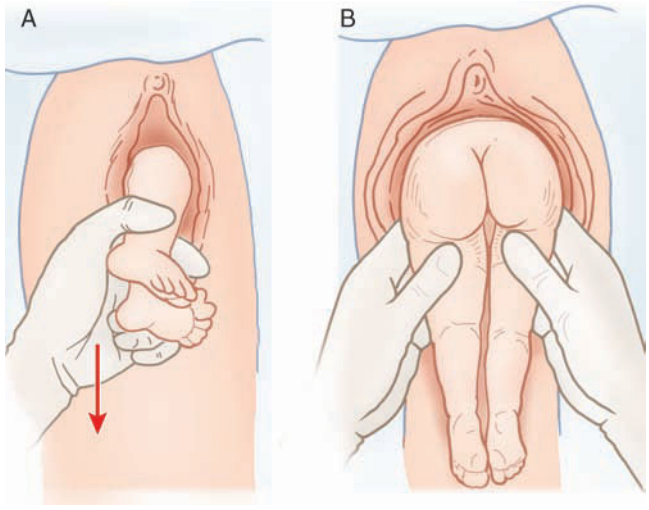


FIGURE 134-10. Breech extraction. Reach into the uterus and grasp the fetal ankles. **A.** Apply traction to deliver the feet and ankles. **B.** Delivery of the buttocks.

ASSESSMENT

The two patients must now be assessed and treated. If available, a second Physician or neonatal team can evaluate and resuscitate the infant. Determine the infant's Apgar score. Examine the infant for birth trauma and signs of prematurity (e.g., fusing of eyelids), as both correlate with perinatal morbidity and mortality.

The maternal assessment should occur simultaneously with that of the neonate. Offering reassurance to the mother while delivering the placenta and evaluating for postpartum hemorrhage is of the utmost importance.

AFTERCARE

The Apgar scores for infants delivered from a breech position are generally slightly lower than from a vertex delivery. The infant may show some initial signs of short-term and generally clinically insignificant hypoxia.

Postpartum recovery for the mother is generally uneventful. She should be observed for evidence of infection or symptomatic anemia. If regional anesthesia is used or if there is significant perineal trauma, urinary output should be monitored for the presence of urinary retention.

Deliver the placenta and repair the cervix if there are any lacerations or Dührssen's incisions. An episiotomy, perineal laceration, and/or vaginal laceration must be repaired (Chapters 132 and 135). Initiate uterine massage. Administer pitocin intramuscularly following delivery of the placenta.

It is vital that postpartum hemorrhage be managed to prevent maternal morbidity and mortality. Refer to Chapter 135 regarding the details of postpartum hemorrhage management. Grasp the base of each cervical incision or laceration to decrease the bleeding. If the distal angle is difficult to visualize, do not waste time attempting to locate it. Apply traction to the proximal edges of the incision or laceration with ring forceps. Alternatively, place 2-0 chromic, Dexon, or Vicryl sutures along the edges of the cervical incision or laceration that can be visualized. Place progressively proximal interrupted sutures until the base is completely visualized (**Figure 134-9B**). Apply traction to the sutures to better visualize the cervical incision or laceration.

COMPLICATIONS

Maternal complications associated with the performance of a vaginal breech delivery include lacerations (e.g., cervical, vaginal, and/or perineal), episiotomy extension, infection, postpartum hemorrhage, and hematomas (e.g., vaginal or pelvic).

Neonatal complications include hypoxia, anoxia (i.e., perinatal asphyxia), umbilical cord prolapse, fractures (e.g., cranial, femoral, and clavicular), cerebral hemorrhage, cephalohematomas, lacerations, brachial nerve palsy, cerebral palsy, spinal cord injuries from head hyperextension, arrest of the after-coming head, and death[1,2,7,8,10,20–25] Recent studies suggest that the occurrence of these complications may be greatly influenced by the urgency of the delivery rather than solely the method of delivery.[2] Thus, an adequately prepared Emergency Physician may not be able to prevent these complications but will less likely contribute to them.

There are complications that are unique to the breech presentation. Head entrapment is a potentially serious complication of breech delivery. The head is often the largest part of the fetus. There is no time for molding of the aftercoming breech head. If the fetal head does not deliver easily after delivery of the torso, umbilical cord compressions can contribute to fetal hypoxia, acidosis, and death. Attempts to expedite delivery can result in maternal and fetal trauma. The risk of head entrapment is especially high in the preterm infant before 30 weeks as the head is large in relation to the body.[16]

Nonfrank breech presentation has an increased incidence of umbilical cord prolapse as the presenting part may not completely occlude the cervix. The risks of umbilical cord prolapse and prematurity associated with the breech presentation are listed in **Table 134-1**.

SUMMARY

Perinatal survival is similar for the delivery of a breech infant vaginally or by cesarean section, although controversy still exists. Increased morbidity and mortality may be seen with estimated fetal weights of less than 1500 g or greater than 4000 g, single or double footling presentation, a diminished maternal pelvis, cephalic hyperextension, or in the hands of an inexperienced provider. Cesarean section is preferable in these instances if available. The Emergency Physician managing an imminent breech delivery should be well aware of not only the potential complications but also the relative indications for cesarean delivery and the techniques and tools for vaginal delivery in order to lessen the inherent risks to both patients.

135 Postpartum Hemorrhage Management

Leah W. Antoniewicz

INTRODUCTION

Postpartum hemorrhage, or excessive blood loss following delivery, is the leading cause of maternal death worldwide. It is traditionally defined as blood loss greater than 500 mL after vaginal delivery and 1000 mL after a cesarean section.[1] This is impractical because the normal blood loss is believed to be 300 to 500 mL following a vaginal delivery and 900 to 1200 mL following a cesarean section.[2] It has also been defined as blood loss that results in a decrease in

TABLE 135-1 Anatomic Sites of Postpartum Hemorrhage

Anus
Broad ligament
Cervix
Contractile tissue (previous uterine incision)
Episiotomy incisions
Lower urinary tract (periurethral area, urethra, bladder)
Noncontractile/poorly contractile tissue (lower uterine segment)
Perineum (perineal body, rectum)
Placental implantation site
Rectum
Tissue tears
Vagina (fornices, hymen, anomalous septa, side walls)

TABLE 135-2 Etiologic Associations for Postpartum Hemorrhage

Altered maternal anatomy	Operative delivery
Altered uterine contractility	Pitocin use, prolonged
Asian ethnicity	Placental abruption
Cesarean section dehiscence or rupture	Placenta previa
Chorioamnionitis	Postpartum hemorrhage history
Coagulopathy	Precipitous delivery
Compound delivery	Preeclampsia
Disseminated intravascular coagulation	Prolonged or tumultuous labor
Dührssen's incisions	Reproductive tract anomalies
Endometritis	Retained placental fragments
Episiotomy	Shoulder dystocia
Fetal scalp electrode injury	Tissue lacerations
General anesthesia	Tocolytic use
Grand multiparity	Trauma
Hispanic ethnicity	Uterine anomalies
Infection	Uterine atony
Intrauterine pressure catheter injury	Uterine inversion
Myomectomy dehiscence or rupture	Uterine leiomyomata
Occiput posterior delivery	Uterine pressure monitor injury
	Uterine rupture
	Von Willebrand's coagulopathy

the hematocrit of greater than 10 points between admission and the postpartum period, which corresponds to the 97th percentile of vaginal and 92nd percentile of cesarean deliveries.[1,2] A clinically useful definition is excessive bleeding that results in signs and/or symptoms of hypovolemia (e.g., tachycardia, hypotension, oliguria, dizziness, palpitations, syncope, and/or shortness of breath), which corresponds to a 10% or more loss in total blood volume.[3] Postpartum hemorrhage can occur at sites within or external to the genitourinary tract (**Table 135-1**).

The incidence of postpartum hemorrhage ranges from 4% to 6% of pregnancies in the United States.[3] Primary postpartum hemorrhage accounts for greater than 90% of all cases and occurs within 24 hours of delivery. It is most commonly the result of excessive bleeding from the placental implantation site (uterine atony) or trauma to the genital tract. It can be associated with a considerable drop in hematocrit and significant maternal complications. Secondary postpartum hemorrhage occurs more than 24 hours after delivery and up to 12 weeks postpartum. It is usually the result of excessive bleeding from the placental implantation site or retained products of conception, but can also be caused by an infection or coagulation defects.[3,6] This chapter reviews the pathophysiology of early postpartum hemorrhage, discusses the diagnosis and assessment of postpartum hemorrhage, and concludes with strategies for treatment.

ANATOMY AND PATHOPHYSIOLOGY

The most common causes of postpartum hemorrhage are uterine atony (70% to 90%), genital tract trauma (5% to 8%), retained products of conception (3% to 5%), and hematologic or coagulopathic abnormalities (<2%). Uterine inversion is a rare cause of postpartum hemorrhage. Risk factors for uterine atony include a prolonged third stage of labor, induced or augmented labor, high parity, an overdistended uterus, use of uterine relaxing agents, chorioamnionitis, some types of anesthesia, and previous postpartum hemorrhage.[1] Genital tract injuries include vaginal or cervical lacerations, episiotomies, vulvar or vaginal hematomas, and uterine rupture. Retention of all or part of the placenta interferes with uterine contraction, resulting in continued bleeding from the implantation site. Hematologic abnormalities include von Willebrand's disease, disseminated intravascular coagulation, and other less common inherited, congenital, or acquired disorders.

In a normal pregnancy, the plasma volume increases by approximately 40% and the red cell mass by 25% resulting in a hypervolemia of about 1500 to 2000 mL.[3,5] This compensates for typical blood losses. Visual estimates of blood loss are inaccurate, especially if blood is mixed with amniotic fluid. **Weigh all pads for an accurate assessment (1 g = 1 mL of blood).** The signs and symptoms of postpartum hemorrhage include measurable blood loss greater than 500 mL, tachycardia, hypotension, oliguria, syncope, pallor, diaphoresis, palpitations, dizziness, shortness of breath, and fatigue. Concealed hemorrhage from a vaginal hematoma, uterine rupture, or broad ligament hematoma must be suspected if the patient is symptomatic in the absence of obvious blood loss.

Patients at risk for postpartum hemorrhage require blood typed and held on admission. Leading risk factors associated with early postpartum hemorrhage in vaginal birth include prolonged third stage of labor, preeclampsia, mediolateral episiotomy, previous postpartum hemorrhage, multiple gestations, arrest of descent, and soft tissue lacerations.[1] Other risk factors are listed in **Table 135-2**. Surgical deliveries, as compared with vaginal deliveries, are often associated with increased blood loss. Inhalation anesthesia, especially with halogenated agents, increases the risk for postpartum hemorrhage and should be used sparingly in high-risk cases.[5,7] Other risk factors for postpartum hemorrhage in cesarean deliveries include chorioamnionitis, preeclampsia, protracted active phase of labor, and arrest of descent.[2]

INDICATIONS

All postpartum hemorrhage must be controlled as soon as possible to prevent maternal morbidity and mortality. The two foremost causes of postpartum hemorrhage are uterine atony and lower genital tract lacerations. Such lacerations and injuries are most common with difficult deliveries, especially operative vaginal deliveries, and with the use of an episiotomy. Carefully examine the vagina and cervix for injury immediately following delivery of the infant and placenta. If present, these factors should be noted and the possibility of postpartum hemorrhage anticipated.

CONTRAINDICATIONS

There are no absolute contraindications to the management of postpartum hemorrhage. Therapies for postpartum hemorrhage, specifically drug therapy for uterine atony, may have significant side

effects. Avoid undiluted rapid IV infusions of oxytocin which can cause hypotension. Ergots, such as methylergonovine, are potent vasoconstrictors and should be given intramuscularly. They are contraindicated in the presence of cardiac disorders, coronary artery disease, hypertensive disorders, preeclampsia, scleroderma, and Raynaud's phenomenon. Prostaglandin F (PGF) is contraindicated in patients with active asthma as it can incite severe bronchospasm in sensitive individuals.[4] It may also result in vasoconstriction of the pulmonary bed.[4] The side effects include diarrhea, fever, and tachycardia. PGE_2 (Prostin) should be avoided in hypotensive patients. Human recombinant factor VIIa is a new, expensive treatment for life-threatening hemorrhage but can cause subsequent thromboembolism.[8]

EQUIPMENT

- Sterile gown and gloves
- Face mask with eye shield or goggles
- Cap
- Povidone iodine or chlorhexidine solution
- Foley catheter
- Gauze sponges
- Sponge-tipped applicators (large)
- Sterile delivery drapes
- Alcohol swabs
- 16 to 18 gauge needle
- 10 mL syringe
- 22 to 25 gauge epidural needle for injection
- Weighted vaginal speculum or Sims retractor
- Two right angle (Heaney) retractors
- Four ring forceps
- Straight Mayo scissors or sterile scalpel
- 2-0 or 3-0 suture: polyglactin (Vicryl) or chromic gut
- SOS Bakri tamponade balloon
- Sengstaken–Blakemore tube
- Three 30 mL bulb Foley catheters
- Packing forceps

Medications

- Local anesthetic solution (lidocaine, bupivacaine, or mepivacaine)
- Oxytocin (Pitocin)
- Methylergonovine maleate (Methergine)
- 15-methyl $PGF_{2\alpha}$ (Hemabate, Carboprost)
- Misoprostol or PGE_1 (Cytotec)
- Dinoprostone or PGE_2 (Prostin)
- Factor VIIa (NovoSeven)
- 4-inch gauze soaked with 5000 U of thrombin in 5 mL of saline

PATIENT PREPARATION

The initial management must be aimed at stabilizing the mother and identifying the bleeding source. Apply bimanual compression (**Figure 135-1**), which will control most hemorrhage, and obtain help. Establish intravenous access at two sites with 16 to 18 gauge angiocatheters. Type and cross match the patient for any required blood components if not done previously. Place a Foley catheter to monitor urine output and to allow the uterus to contract. Regulate fluid intake carefully.

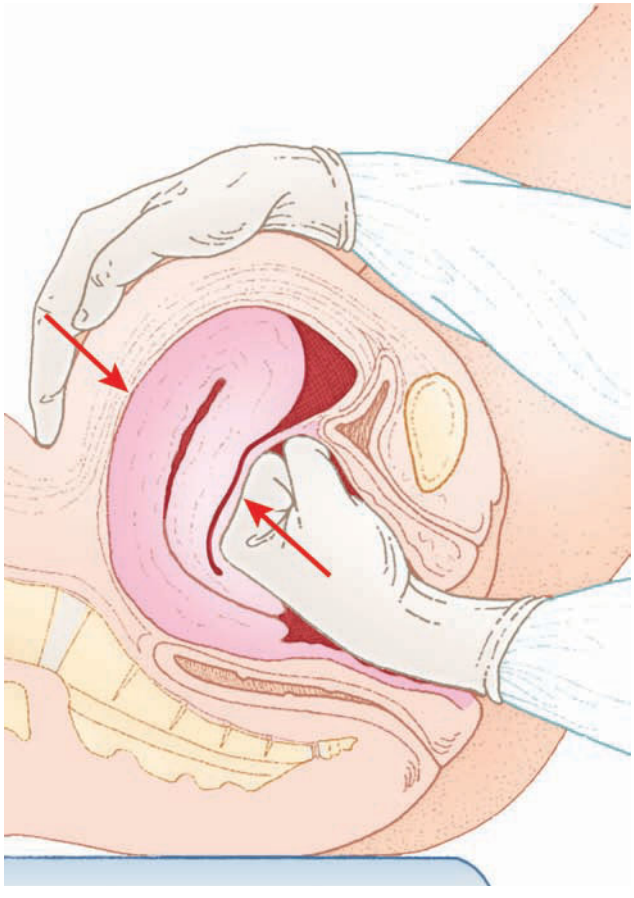


FIGURE 135-1. Bimanual uterine compression for uterine atony.

Identification of the origin or site of bleeding is critical. Uterine hypotonia is the most frequent source of hemorrhage. Therefore, uterotonics are usually administered concurrently with a complete examination of the uterus. Palpation will often exhibit a boggy, soft, and spongy uterus that may be increasing in size due to the accumulation of clots and blood within the endometrial cavity. These must be cleared to allow for adequate uterine contractions. Continued bleeding from the endometrial cavity through the cervical os is always present. A well-contracted uterus does not bleed significantly in the absence of a severe coagulopathy. Examination of the uterus is performed by palpation of the fundus with the nondominant hand and manual exploration of the uterine cavity with the other. Ultrasound may be used to ascertain the presence of placental tissue or clots that may require manual removal and/or curettage.

Continued hemorrhage with a firm uterus indicates bleeding from another source such as the lower uterine segment, the cervix, or the vagina. **Examine all areas carefully, even after hemorrhage is noted at one site, as there may be more than one source of hemorrhage.** Begin at the most distal aspects of the genital tract and work proximally.

TECHNIQUES

UTERINE ATONY

Oxytocin and fundal (transabdominal) massage should be initiated just after delivery of the placenta, which usually results in a firm, contracted (rock-like) fundus. However, the uterus may never become firm or may relax again.

Uterine atony is identified by palpating a soft and boggy uterus. Begin transabdominal uterine massage to promote uterine muscle contractions. Use one or two hands to palpate the uterus through the abdominal wall and rhythmically press downward in a circular motion. Massage in a firm but gentle manner, without pushing the uterus through the birth canal (inversion). **Avoid overly vigorous massage, as this can injure the vasculature of the broad ligament.**[5]

Initiate an oxytocin infusion at the same time as fundal massage. Inject 40 units of oxytocin into 1 L of intravenous sterile normal saline. Allow this solution to infuse over 10 minutes. Alternatively, administer 10 U of oxytocin intramuscularly. Repeat the oxytocin dose if atony persists.

Continued bleeding requires the initiation of bimanual uterine compression. Massage the posterior aspect of the uterus with the abdominal hand and the anterior aspect of the uterus through the vagina with the other hand clenched into a fist (**Figure 135-1**).[5] Use the intravaginal hand to massage the uterus against the external pressure applied by the abdominal hand. This allows for more effective uterine massage. Perform manual uterine exploration if the massage fails to control the hemorrhage. Manual uterine exploration can localize and extract any placental fragments remaining within the uterus.

Begin second-line medications to contract the uterus if bimanual massage is ineffective. **Consult an Obstetrician prior to administering any of these medications.** In the nonhypertensive patient, administer 0.2 mg of methylergonovine (Methergine) intramuscularly. This is an ergot derivative that causes uterine contraction. The dose may be repeated every 2 to 4 hours. Prostaglandin F-2 (Hemabate) is a potent stimulator of uterine contraction.[9] Administer 250 µg intramuscularly or transabdominally into the uterine musculature every 15 to 90 minutes to a maximum total dose of 2 mg. Misoprostol (Cytotec) has been widely used and is inexpensive, safe to use in patients with hypertension, and safe to use in patients with asthma. Administer 800 to 1000 µg (in 100 µg tablets) rectally. This dose may be repeated every 4 to 6 hours. Monitor the patient's temperature frequently as pyrexia can occur. Dinoprostone (Prostin) 20 mg rectal suppository is preferred over the intravaginal route as continued bleeding may expel the suppository. This may be repeated every 2 hours. Consider using 16.7 to 200 µg/kg of factor VIIa concentrate (NovoSeven) intravenously. This agent has the potential to cause intravascular clot formation with subsequent end organ damage.

Sustained bleeding requires an Obstetrician for curettage or other operative management. A discussion of these techniques is beyond the scope of this chapter. Tamponade the uterus while waiting as described below. Alternatively, consult an Interventional Radiologist, if available, to consider uterine artery embolization.

BALLOON TAMPONADE

The SOS Bakri balloon was designed to tamponade the uterus for postpartum bleeding.[10] Gently grasp the balloon with a ringed forceps. Insert it into the uterus transcervically. Hold the tubing in place at the cervical os to ensure the balloon remains above the cervix. Instill 300 to 500 mL of sterile saline to inflate the balloon. Clamp the tubing. Apply gentle traction. Secure the tube to the patient's thigh or attach a 500 mL saline bag to the tubing as a weight. Blood will drain from sites proximal to the tube. If bleeding is excessive, tamponade has failed.

If a Bakri balloon is not available, use a Sengstaken–Blakemore tube. These are often available in the Emergency Department. Insert the Sengstaken–Blakemore tube into the uterine cavity. Inflate the gastric balloon with 250 mL of sterile saline. Apply slight traction and secure the tube as described above. Flush the lumen of the Sengstaken–Blakemore tube with 10 mL of sterile saline to clear any clots or blood collected behind the balloon.

If neither of these devices is available, use Foley catheters with a 30 mL balloon. Gently grasp the distal end of the Foley catheter with ring forceps. Insert it completely into the uterus. Securely hold the catheter in place. Instruct an assistant to instill 50 to 60 mL of sterile saline into the balloon and clamp the tubing. Repeat this procedure with up to two more Foley catheters to completely fill the endometrial cavity and tamponade the hemorrhage.

UTERINE PACKING

If none of the previously mentioned devices are available or if they fail, consider packing the uterus. Tightly pack the uterus, starting at the fundus and working outwards, with 4-inch wide gauze roll (e.g., Kerlix) soaked in 5 mL sterile saline and 5000 units of thrombin. Administer intravenous broad spectrum antibiotics if the uterus is packed with gauze to prevent a subsequent toxic shock syndrome. Carefully monitor hematocrit, urine output, and uterine size. Blood may collect behind in the uterus with all forms of tamponade.

RETAINED PLACENTA

Postpartum hemorrhage, whether primary or secondary, may be caused by retained placental tissue within the uterine cavity. The retained placental tissue may be completely attached, partially separated, or completely separated from the uterine wall. Placental fragments completely attached to the uterine wall may not be removable manually and may require a curettage or laparotomy. Completely or partially separated placental fragments may remain due to a closed cervix entrapping them or inadequate uterine contractions. Manual extraction will remove the retained placental fragments. **Administer adequate anesthesia. A uterine relaxant may be utilized to relax the lower uterine segment in the absence of uterine atony. This must be performed using strict aseptic technique.**

Insert a sterile gloved hand through the open cervix and into the uterine cavity (**Figure 135-2**). Place the other hand on the abdominal wall and over the fundus of the uterus. Gently and carefully sweep the fingers around the circumference of the uterus to determine if any fragments of placenta remain. Identify the edge of the fragment if it has not separated from the uterine wall. Gently place the fingertips under the edge of the fragment. Gently remove any placental fragments from the uterus by alternating abducting, adducting, and advancing the fingers in a scissors-like motion until the entire fragment is separated from the uterus.[8] Grasp and gently remove the placental fragments when separated from the uterine wall. **Ensure that the entire placenta is removed. Reinsert a hand into the uterine cavity and palpate for any remaining placental fragments. Examine the placenta carefully to make sure that no cotyledons are missing.**

Determine if any placental membranes are retained. Reinsert the gloved hand covered with a gauze sponge (**Figure 135-3**). Wipe the uterine walls with the sponge to collect any retained membranes. Remove the gauze sponge with any adherent membranes.

Identify the edge of the placenta if it has not separated from the uterine wall. Gently place the fingertips under the edge of the placenta, forming a line of cleavage between the uterine wall and the placenta. Alternately abduct, adduct, and advance the fingers in a scissors-like motion until the entire placenta is separated from the fundus (**Figure 135-2**).[8] Gently remove the placenta from the uterine cavity. **Make sure that the entire placenta is removed. Reinsert a hand into the uterine cavity and palpate for any remaining placental fragments. Examine the placenta carefully to make sure that no cotyledons are missing.** Initiate intravenous oxytocin following removal of the placenta.

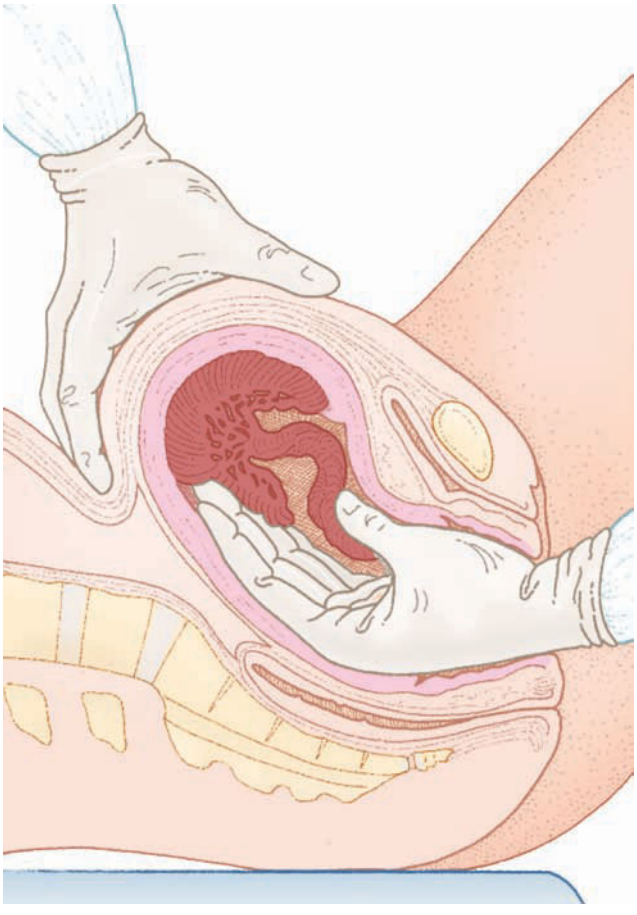


FIGURE 135-2. Manual removal of the placenta. The fingers are abducted, adducted, and advanced continually (in a scissor-like motion) in this sequence of movements until the placenta is completely detached.

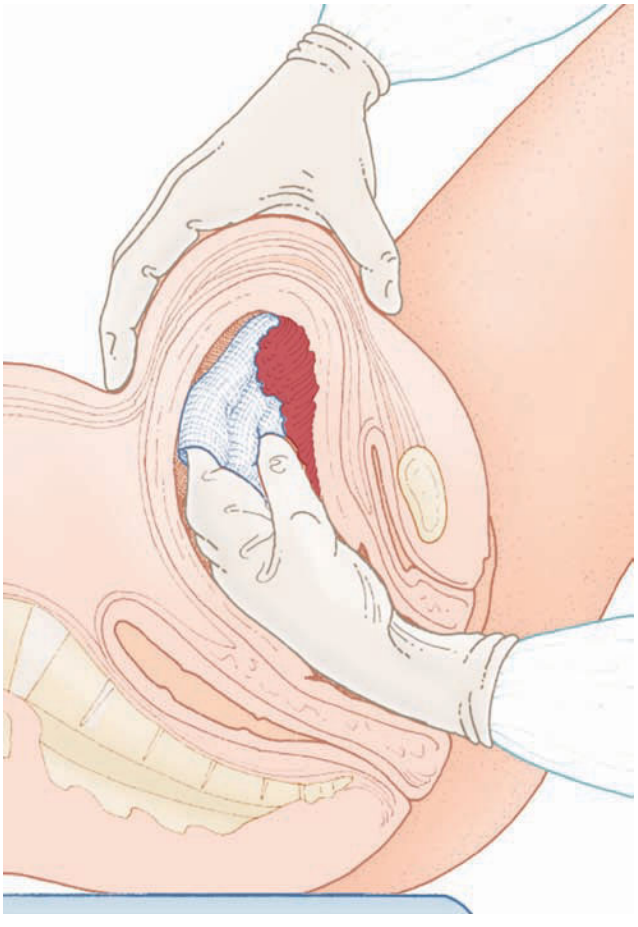


FIGURE 135-3. Manual removal of retained placental membranes.

The placenta is likely embedded into the wall of the uterus if it does not manually separate. This is known as placenta accreta, percreta, or increta depending on the degree of myometrial penetration. Consult an Obstetrician as a laparotomy, hysterotomy, and possibly a hysterectomy will be required.

GENITAL TRACT ABNORMALITIES

Bleeding from the lower uterine segment, cervix, or upper vagina is difficult to diagnose and manage. The anatomic locations are awkward and difficult to visualize. Excessive bleeding makes visualization even more problematic. It may be almost impossible to see a small laceration or an individual bleeding vessel. **Do not attempt to repair a laceration that cannot be completely visualized as this could result in damage to other structures.** The uterotonic medications, such as oxytocin and the prostaglandins, are less effective due to the relative paucity of contractile muscle in these tissues. Consider packing the uterus with gauze or a vaginal pack if available. Management of excessive bleeding from this area may require a laparotomy with uterine artery embolization or a hysterectomy. Discussion of these techniques is beyond the scope of this chapter.

LACERATION REPAIR

All lacerations must be repaired. Always make sure there is adequate exposure and visualization of the laceration. Insert a Foley catheter if the laceration is in proximity to the urethra. This ensures urethral patency and helps preclude inclusion when placing sutures. Scrub the perineum with povidone iodine or chlorhexidine solution. Apply sterile drapes beneath the patient's buttocks, on the legs, and on the abdomen to prevent contamination from nonsterile areas. Provide anesthesia with the injection of local anesthetic solution directly into the laceration or with a nerve block. Refer to Chapter 132 for details regarding perineal nerve blocks.

Thorough knowledge of the anatomy and awareness of where sutures are being placed is necessary to avoid perforation of any proximate viscera. Always use absorbable suture. Refer to Chapter 132 for complete details regarding the repair of an episiotomy. A brief description of the repair procedure is provided below.

FIRST-DEGREE LACERATIONS

First-degree lacerations involve the fourchette, the perineal skin, and/or the vaginal mucous membrane. They spare the underlying fascia and muscle. If the lacerations are small and hemostatic, they do not need to be repaired. Use continuous (running) 2-0 or 3-0 polyglactin (Vicryl) suture to close the vaginal mucosa and submucosa. Chromic gut suture is an alternative but causes more postprocedural pain until it is absorbed. Interrupted sutures may better approximate the laceration if it is very irregular. Approximate the cut margins of the hymenal ring with a stitch. Repair skin lacerations with subcuticular 3-0 sutures as they cause less perineal pain.[5] An alternative is to place interrupted 3-0 sutures.[5]

SECOND-DEGREE LACERATIONS

Second-degree lacerations involve the perineal skin, vaginal mucous membrane, subcutaneous tissue, fascia, and muscles of the perineum but not the anal sphincter muscle. Repair is essentially the same as for an episiotomy but complicated by the irregularity of the laceration. Begin as in a first-degree laceration by repairing the vaginal mucosa and submucosa. Do not place the sutures too deep as to avoid injuring the ureters above the vaginal fornices. Approximate the hymenal ring. Place interrupted 2-0 or 3-0 Vicryl or chromic gut sutures to close the fascia and muscles of the lacerated perineum. Carry a continuous (running) suture downward to unite the superficial fascia and then upward to close the subcutaneous tissue. Close the skin with a running subcuticular stitch. Alternatively, the subcutaneous tissue and skin may be closed together with interrupted 3-0 chromic sutures to minimize the amount of buried suture in the superficial perineal layers.[5]

THIRD-DEGREE LACERATIONS

Third-degree lacerations involve a second-degree laceration that extends into the anal sphincter but not the rectal mucosa. Isolate, approximate, and suture together the cut ends of the anal sphincter muscle with interrupted 2-0 Vicryl sutures. The remainder of the repair is the same as that for second-degree lacerations.[5]

FOURTH-DEGREE LACERATIONS

Fourth-degree lacerations extend through the rectal mucosa to expose the rectal lumen. Approximate the torn rectal mucosa with running or interrupted 3-0 or 4-0 chromic gut sutures placed approximately 0.5 cm apart. Cover this muscular layer with a layer of fascia. Proceed as with the repair of third-degree lacerations.[5]

CERVICAL LACERATIONS

Gently grasp each side of the cervical laceration with ringed forceps. Start at the apex of the laceration using 2-0 chromic gut suture and close the laceration in a running pattern. **Do not suture closed the endocervical canal.** If the apex cannot be visualized, start at the highest point that can be visualized and place the first stitch as a single interrupted stitch. Use the suture to apply gentle traction to identify the upper part of the laceration. Place interrupted 2-0 chromic gut sutures to close the apex. Use a running stitch to close the lower part of the laceration.

ASSESSMENT

Thoroughly examine the patient to ensure the cessation of bleeding. **Any additional bleeding sites must be found and repaired.** Carefully monitor the patient's vital signs and urinary output. Manage any hypotension with fluid boluses and packed red blood cells as indicated. Follow serial complete blood counts if the patient has lost a significant amount of blood. Persistent hypotension, tachycardia, or a hematocrit less than 21% may require a transfusion. Hemodynamically stable patients may be expectantly managed.

AFTERCARE

The aftercare for postpartum hemorrhage is targeted toward the etiology of the bleeding episode. Warm sitz baths alternated with ice packs applied to the perineum three to four times a day will decrease inflammation and the risk of infection in patients with lacerations or episiotomies. Stool softeners will decrease the pain of defecation and the risk of wound dehiscence, especially with third- or fourth-degree lacerations. A high-fiber, low-residue diet may be helpful. Prescribe oral analgesics for pain relief. Nonsteroidal anti-inflammatory drugs or acetaminophen provide adequate analgesia for most patients. Narcotic analgesics such as hydrocodone or acetaminophen with codeine may be necessary initially. Avoid formulations that increase constipation in patients with third- or fourth-degree lacerations.

Follow complete blood count values until the patient is asymptomatic and stable. Consider a transfusion if the patient's hematocrit is less than 25, the patient is symptomatic from anemia, or is hemodynamically unstable. Prescribe 325 mg of iron sulfate orally twice daily.

Follow-up therapy for uterine atony often includes the use of oxytocin (20 to 40 U/L of intravenous fluid) for 12 to 24 hours. An alternative is oral Methergine. Initiate therapy after consultation with an Obstetrician.

COMPLICATIONS

Maternal complications resulting from postpartum hemorrhage include shock, acute renal failure, acute respiratory distress syndrome, the need for blood transfusion, a consumptive or dilutional coagulopathy, the need for surgical intervention (dilatation and curettage or laparotomy) and its associated complications, extreme fatigue, postpartum endometritis, and Sheehan's syndrome. Complications associated with pharmacologic therapy can be avoided by carefully selecting the appropriate patient for each agent (see "Contraindications," above).

SUMMARY

Postpartum hemorrhage is a serious and potentially lethal condition. Early identification of risk factors and a prompt response to the early signs and symptoms of postpartum bleeding will decrease the morbidity and mortality of this situation. Always consult an Obstetrician immediately if the patient experiences postpartum hemorrhage.

136 Perimortem Cesarean Section

Silvia Linares

INTRODUCTION

The term "perimortem cesarean section" was introduced in 1986 to describe a cesarean section done at time of cardiopulmonary resuscitation and within the first 4 minutes if resuscitative efforts were not successful.[1] The goal of this procedure is to improve survival for the fetus, and sometimes provide a better chance for the mother to be resuscitated.[2,3]

The incidence of cardiac arrest during pregnancy is estimated to be about 1 in 30,000 pregnancies.[4] According to a review of reported perimortem cesarean deliveries from 1985 to 2004, the most frequent causes are trauma, cardiogenic, emboli (e.g., amniotic fluid and air), magnesium overdose, sepsis, anesthesia, eclampsia, spontaneous uterine rupture, and intracranial hemorrhage.[2]

Trauma is the leading cause of death in women of reproductive age and accounts for 25% to 50% of maternal morbidity. Major maternal injury is associated with a 45% to 50% fetal loss rate. **The primary goal in the management of the severely injured pregnant patient is maternal assessment and stabilization. Prompt**

attention to the needs of the gravid patient can save the life of both the fetus and the mother. Nonetheless, there are occasions when emergent cesarean delivery of the fetus is necessary to save the fetus, and sometimes, the mother.

This procedure is best performed by a qualified Surgeon in the Operating Room. However, there are circumstances that may necessitate the performance of this procedure in the Emergency Department. These include the possibility of uterine rupture, placental abruption, fetal distress, and imminent maternal demise. The perimortem cesarean section is a key procedure that all Emergency Physicians need to be able to perform in the rare instance it is required.

There are several simple principles to keep in mind. Quickly establish that the mother is deceased or that no further intervention is possible. Quickly open the abdominal wall and uterus with vertical incisions. The use of strict aseptic technique is not required and only wastes valuable time. Deliver the fetus and begin resuscitation. Manually remove the placenta. Close the uterus and abdominal wall with running sutures.

ANATOMY AND PATHOPHYSIOLOGY

MATERNAL PHYSIOLOGY

Important maternal physiologic changes during pregnancy should be considered in the event of a cardiorespiratory arrest. Pregnancy changes almost all maternal body systems. Cardiac output, blood volume, and heart rate all increase. Pulmonary and systemic vascular resistance decreases. Uteroplacental blood flow increases, with the uterus receiving up to 30% of the cardiac output during pregnancy. Aortocaval compression during the second half of pregnancy can result in decreased venous return to the heart, decreased cardiac output, and systemic hypotension. These changes complicate the resuscitation efforts. The pregnant woman is predisposed to a more rapid decrease in arterial and venous oxygen tension during episodes of hypoxia. Gastrointestinal changes include decreased motility, relaxation of the esophageal sphincter, and thus a predisposition to aspiration of gastric contents.[3–6]

In general, the same algorithms used for the nonpregnant patient should be used for the pregnant patient during a cardiorespiratory arrest. There are some modifications to keep in mind.[5] The stroke volume of a term pregnant patient lying supine is only 30% of normal. Lateral displacement of the uterus will increase the stroke volume and cardiac output by at least 25%.[7] Pregnancy increases oxygen requirements and the risk of aspiration. Early intubation to protect airway is indicated. Be cautious in using of sodium bicarbonate to reverse metabolic acidosis. Rapid correction of maternal, but not fetal, acidosis could lead to reduced compensatory hyperventilation and normalization of fetal $PaCO_2$ with worsening of the fetal acidosis.[4]

The performance of adequate CPR in the gravid patient at or near term is extremely difficult. Adequate CPR produces a cardiac output equivalent to 30% of normal under ideal circumstances. The enlarged uterus lies anterior to the inferior vena cava and suppresses venous return in the gravid patient. **Place a wedge under the patient's right flank and hip to position them in 15° of left lateral tilt to adequately relieve the obstruction of the inferior vena cava by the uterus.** Give early consideration to performing a perimortem cesarean delivery.

Evacuation of the uterus by cesarean section may save the fetus and, by enabling adequate maternal resuscitation, save the mother as well. The pregnant patient has a decreased tolerance for anoxic brain injury. The fetus can tolerate anoxic injury slightly longer than the mother.

EVALUATION FOR PERIMORTEM CESAREAN SECTION

Quickly determine the gestational age using ultrasonography, the last known menstrual period, the history of term gestation by family members, or fundal height. A quick rule to remember is if you can place at least four fingers above the umbilicus to the top of the fundus, the gestational age is likely to be equal to or more than 24 weeks.[2] Twenty-four weeks is also the beginning of aortocaval compression by the uterus.[7] Nevertheless, this estimate can be distorted by overweight patients, abdominal distention, and a history of multiple pregnancies. Unfortunately, no other quick rule has been yet described.

Perform ultrasonography only if the unit is immediately available and if experienced in obstetric ultrasound. Note the time of the maternal arrest. Immediately consider performing a perimortem cesarean section in the resuscitation of a pregnant patient with an estimated gestational age of 24 weeks or greater and with a cardiorespiratory arrest that has not responded to aggressive resuscitation within 4 minutes from onset.

The single most important prognostic factor for neonatal outcome is the time from maternal arrest to delivery. Delivery of the fetus can also maximize maternal resuscitation efforts and minimize the risk of maternal brain injury. Delay the initiation of vasopressor agents until after adequate volume replacement. However, they should not be withheld if needed to resuscitate the patient.

INDICATIONS

The major indication for performing a perimortem cesarean section is to optimize maternal cardiopulmonary resuscitation. The rescue of a viable fetus greater than 24 weeks gestation is an important consideration, but such rescue is always secondary to the safety and life of the mother. Consider performing a postmortem cesarean section if CPR does not resuscitate the mother within 4 minutes of the arrest. Waiting for the Obstetrical and Pediatric teams is contraindicated.[2,7]

CONTRAINDICATIONS

There are few contraindications to performing a perimortem cesarean delivery. The best fetal outcomes are reported when cesarean delivery occurs within 5 minutes of maternal arrest. However, perimortem cesarean section should be considered if the time from the maternal arrest to delivery would be no greater than 25 minutes. It is contraindicated if the mother has a serious brain injury but is otherwise hemodynamically stable and the fetus shows no signs of distress. Other contraindications to a perimortem cesarean delivery are the inability to adequately resuscitate the infant after delivery or extreme fetal prematurity/immaturity.

Attempt to obtain consent for the procedure. However, there is no documentation of physician liability in these situations. **Do not delay treatment pending consent.** The unanimous consensus in the medical literature and of legal authorities is that a civil suit for performing a perimortem cesarean delivery, regardless of the outcome, would not result in a judgment against the Emergency Physician.

EQUIPMENT

- 10 towel clips
- 16 Kelly clamps
- 16 hemostats
- 10 Peon or Pennington clamps
- Eight Allis forceps
- Six Babcock forceps

- Six ring forceps
- Six straight Kocher clamps
- #10 surgical scalpel blade and handle
- #15 surgical scalpel blade and handle
- Straight Mayo scissors
- Curved Mayo scissors
- Metzenbaum scissors
- Bandage scissors
- Two suture scissors
- Two Adson forceps, or other forceps with teeth
- Two Russian forceps, 5 1/2 inches and 8 inches
- Dressing forceps
- Bladder retractor
- Two medium Richardson retractors
- Two small Richardson retractors
- Two malleable retractors
- Two Army–Navy retractors
- Needle drivers, 8 inches and 6 inches long
- Two suction tips
- Suction tubing set(s)
- Wall suction
- Electrocautery unit with disposable tips
- Povidone iodine or chlorhexidine solution
- Sterile drapes
- Sterile gloves
- Two skin staplers
- Three packs 0 chromic suture with CTX taper needle
- One pack 2-0 chromic suture with taper SH needle
- Two packs of 1-0 Vicryl suture with a CT taper needle
- Chromic, Polysorb, or Vicryl suture (2-0 or 1-0)
- Nylon suture, 3-0
- Bulb syringe
- Clean towels or blanket for baby
- Umbilical cord clamp
- Sterile scissors to trim umbilical cord
- Infant warmer
- Neonatal resuscitation equipment

Ideally, all of the equipment should be prepackaged in a sterile cesarean section instrument tray prepared by the hospital. A prepackaged sterile instrument tray is commercially produced but may not be available as this procedure is rarely performed in the Emergency Department. A standard thoracotomy tray or tube thoracostomy tray will contain all the required equipment except for the bulb syringe and umbilical cord clamp.

PATIENT PREPARATION

Time is of the essence. Establishing IV access and endotracheal intubation takes several minutes. Thus, it is very important to activate a protocol for an emergency cesarean section as soon as a cardiorespiratory arrest occurs in a pregnant woman.[6,7] Every attempt should be made to contact an Obstetrician and Neonatologist if a perimortem cesarean section is anticipated. Consult a General Surgeon if an Obstetrician is not available. Notify the neonatal resuscitation team and Anesthesia (Physician or Nurse Anesthetist) of the impending procedure. The procedure should not be delayed in an attempt to obtain consent.[1,6,8] The medicolegal risks are few since the Emergency Physician is acting under the principle of beneficence.

Administer adequate anesthesia if the patient is awake and aware of their surroundings. General or epidural/spinal anesthesia is preferred as provided by a qualified Anesthesiologist or Nurse Anesthetist. However, local infiltration of anesthetic solution may be performed in conjunction with procedural sedation. The deceased patient requires no anesthesia.

Surgical preparation in an emergency is minimal.[1,8,9] Perform a minimal shave of the lower abdomen and pubic region if time permits. Prepare the abdomen with povidone iodine or chlorhexidine solution. Place a Foley catheter to continuously drain the bladder and to decrease the risk of inadvertent entry into the bladder during the procedure. Perform an appropriate surgical scrub if time allows. Apply relevant surgical clothing and covers (i.e., a hat, mask, booties, sterile gloves, and a sterile gown). Apply sterile surgical drapes over the patient to isolate a surgical field.

The patient will be clinically deceased in most cases if this procedure is performed in the Emergency Department. Patient preparation is not necessary and wastes valuable time when trying to salvage the fetus. The Emergency Physician should follow body fluid precautions (hat, mask, sterile gloves, boots, and sterile gown). Administer broad-spectrum intravenous antibiotics if the mother survives the procedure. Continue cardiopulmonary resuscitation throughout the preparation and procedure until the fetus is delivered.

TECHNIQUE

The "classical" technique of cesarean delivery is the most appropriate and is described in this section. It provides better exposure, easy access, and a larger opening for the delivery. Identify the patient's umbilicus and pubic symphysis. Make a vertical midline skin incision with a #10 scalpel blade beginning 1 cm below the umbilicus and extending caudally to 2 to 3 cm above the pubic symphysis (**Figure 136-1A**). This incision is long enough to deliver a full-term infant.[7,8,10] Ignore any subcutaneous bleeding unless it is arterial. Clamp the bleeding artery or use an electrocautery unit, if available, to coagulate the vessel.

Extend the incision through the subcutaneous fat to the rectus sheath (**Figure 136-1B**). **Do not be overzealous and cut through the rectus sheath, peritoneum, uterus, abdominal organs, or bladder.** Grasp and elevate the rectus sheath using a toothed forceps (**Figure 136-1C**). Make an incision in the rectus sheath with a Mayo scissors. Extend the rectus sheath incision superiorly and inferiorly with the Mayo scissors (**Figure 136-1C**). **Be cautious not to cut any abdominal or pelvic organs.**

Expose the uterus (**Figure 136-2**). The underlying peritoneal membrane (peritoneum) should be visible (**Figure 136-2A**). It may occasionally be attached to the rectus sheath and opened simultaneously. Insert retractors to fully expose the peritoneal membrane (**Figure 136-2A**). Grasp and elevate the peritoneal membrane with a toothed forceps. Incise the peritoneal membrane with a Mayo or Metzenbaum scissors in a manner similar to that used to open the rectus sheath (**Figure 136-2A**).[10]

Make reasonable attempts to protect the bowel and bladder from injury. Elevate the bowel off the field and cover it with a saline-soaked towel. Place a bladder retractor over the pubic symphysis to retract the rectus sheath and bladder (**Figure 136-3A**).[10] This will allow visualization of the uterus and prevent injury to the bladder. Alternatively, grasp and elevate the bladder from the pelvis with a saline-soaked gauze or towel (**Figure 136-2B**).

Identify the position of the fetal head by palpating the uterus. Make a 2 to 4 cm midline vertical incision in the uterus

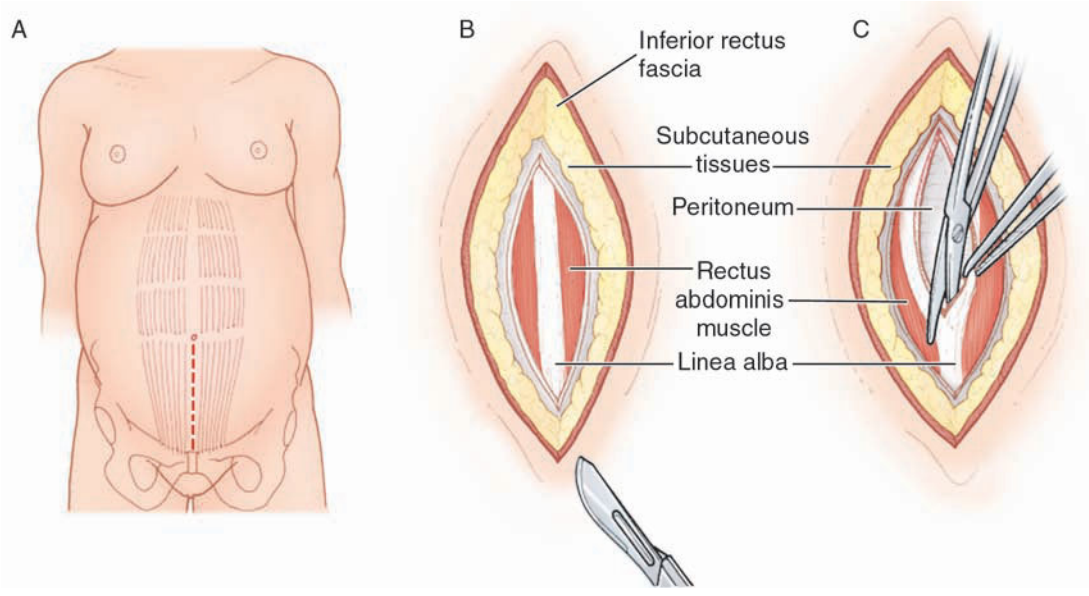


FIGURE 136-1. Accessing the peritoneal cavity. **A.** Make a midline skin incision from just below the umbilicus to just above the pubic symphysis. **B.** Extend the incision through the subcutaneous tissues and down to the linea alba. **C.** Grasp and elevate the rectus abdominis muscle while opening the linea alba with a Mayo scissors.

(**Figure 136-3A**). The amniotic sac will bulge through the incision if the membranes are intact. **Place a finger into the uterine incision and aimed vertically (Figure 136-3B). Insert one blade of a bandage or Mayo scissors between the finger and the uterine wall (Figure 136-3B).** The finger will protect the fetus from the scissors. The other blade of the scissors should be outside the uterus. Extend the vertical uterine incision fundally, superior and away from the bladder (**Figure 136-3B**). The finger inside the uterus will protect the fetus from injury when opening the uterine wall. Repeat this procedure to open the uterine wall inferiorly (**Figure 136-3C**).

Rupture the amniotic membranes with a clamp or other blunt instrument. The placenta will often be embedded in the anterior wall of the uterus. It is imperative to expedite the delivery of the fetus by cutting through the placenta. Carefully transect the placenta if it is anterior to the fetus. There is an urgency to deliver the fetus and clamp the umbilical cord to prevent significant fetal hemorrhage. Insert a hand between the pubic symphysis and the fetal occiput if the fetus is in a cephalic presentation (**Figure 136-4A**). Advance the hand to the base of the occiput. Gently flex the fetal head with your fingers and palm (**Figure 136-4A**). Apply gentle anteriorly and superiorly directed traction to elevate and deliver the head (**Figure 136-4B**). Deliver the entire fetal head (**Figure 136-4C**). Suction the mouth and nose with a bulb syringe (**Figure 136-4D**).[10] Deliver the shoulders in a manner similar to that of a vaginal delivery (**Figure 136-4E**). Apply gentle upward traction on the head while an assistant applies pressure on the uterine fundus. First deliver the anterior shoulder. Deliver the other shoulder followed by the torso and lower extremities. Once the shoulders are delivered, the remainder of the fetus readily follows.

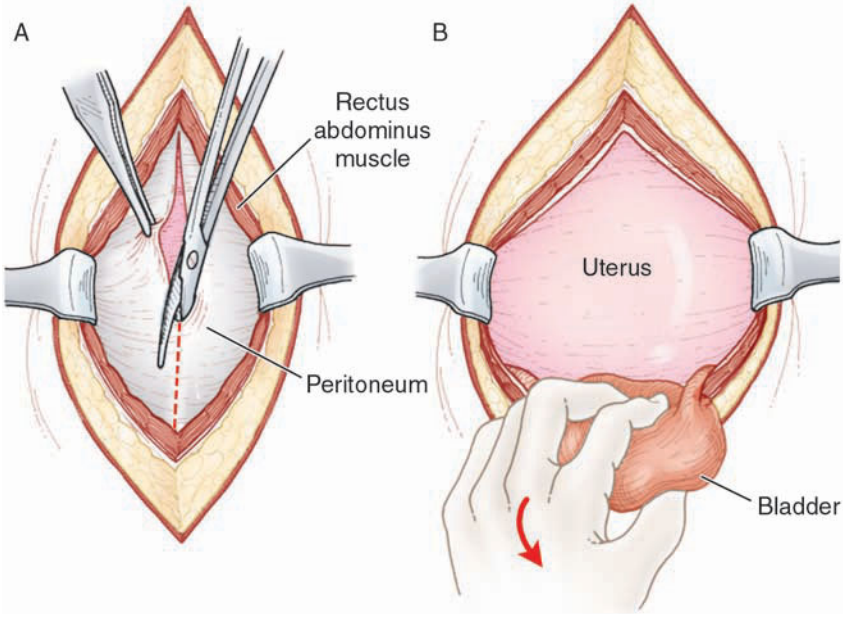


FIGURE 136-2. Exposure of the uterus. **A.** Apply retractors to hold the abdominal wall open. Grasp, elevate, and incise the peritoneal membrane in the midline. **B.** Grasp and elevate the bladder out of the pelvis.

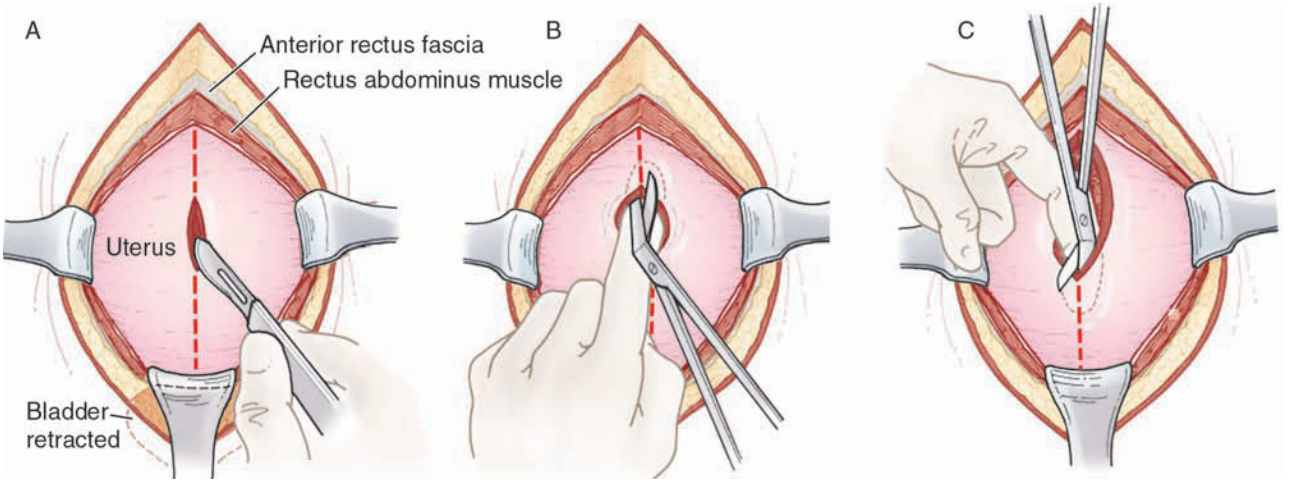


FIGURE 136-3. The vertical uterine incision. **A.** Make a 2 to 4 cm midline vertical incision with a scalpel blade. **B.** Place a finger into the incision to protect the fetus. Extend the uterine wall incision superiorly. **C.** Extension of the uterine wall incision inferiorly.

If the fetus is in a breech presentation or transverse lie, the feet first delivery is easiest. During the delivery, grasp the fetus by the pelvic bones and not by the abdomen to protect the delicate viscera.[8,10]

Clamp the umbilical cord with a hemostat or umbilical cord clamp approximately 10 to 15 cm from the fetus. Attach a second hemostat or clamp 2 to 3 cm distal to the first. Cut the umbilical cord between the clamps with a Mayo scissors. Hand the neonate

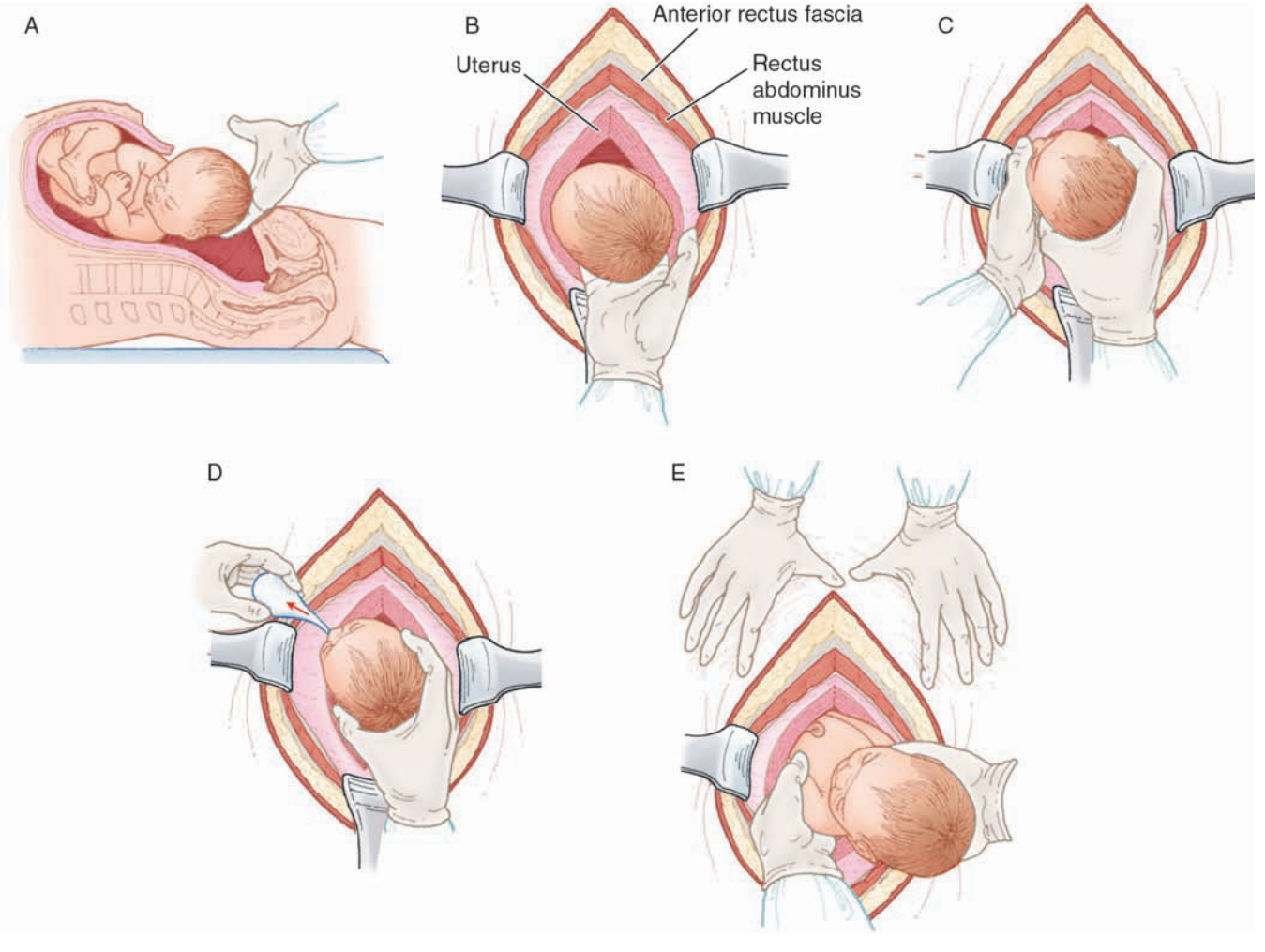


FIGURE 136-4. Delivery of the infant. **A.** Midsagittal section through the abdomen and pelvis. A hand is inserted between the pubic symphysis and the fetal head. **B.** Flex the fetal head while applying anterior and superior traction. **C.** Delivery of the entire fetal head. **D.** Suction the mouth and nose. **E.** Deliver the fetus while an assistant applies pressure to the uterine fundus.

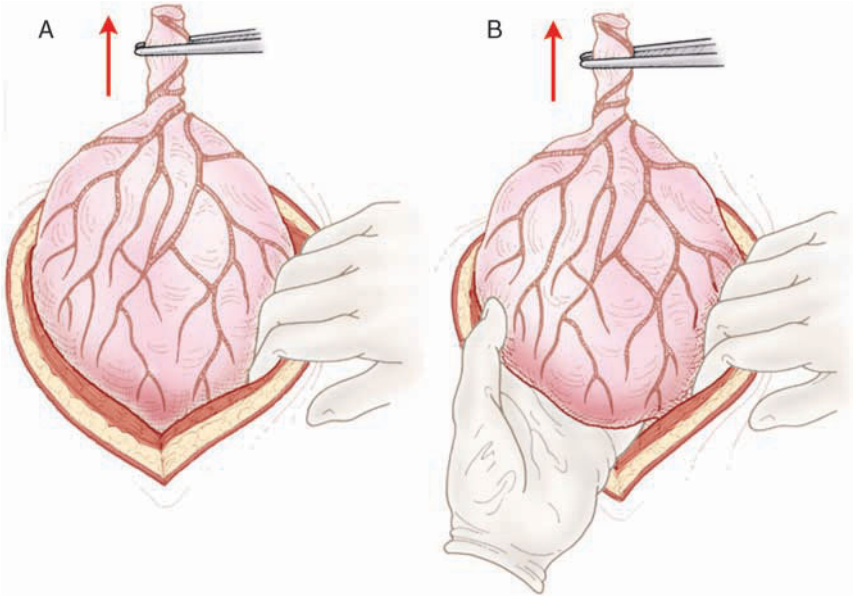


FIGURE 136-5. Delivery of the placenta. **A.** Apply gentle upward traction on the umbilical cord while holding the uterine wall open. **B.** Insert a hand between the placenta and the uterine wall to separate the placenta from the uterus.

to waiting personnel for resuscitation.[8,10] Resuscitate the neonate yourself if additional help is not available.

AFTERCARE

Palpate inside the uterus for another fetus to rule out an unknown twin pregnancy. Deliver the placenta if the patient is still alive or if they regain vital signs (**Figure 136-5**). Begin an oxytocin infusion of 20 units in 1 L of normal saline at a rate of 10 mL/min to help the uterus contract.[10] Apply gentle upward traction on the umbilical cord while holding the uterine wall open (**Figure 136-5A**). Insert the other hand between the placenta and uterine wall (**Figure 136-5B**). Apply gentle pressure to separate the placenta from the uterus.

Close the patient if they are still alive or if they regain vital signs (**Figure 136-6**). Apply ring forceps to the uterine incision. Close the uterus in two layers with 0 or 1-0 absorbable chromic gut, Polysorb, or Vicryl suture. Close the first layer in a running locked fashion (**Figure 136-6A**). This will provide hemostasis. A second running layer is necessary to ensure hemostasis and reapproximate the uterine wall. Closure of the serosa of the uterus (**Figure 136-6B**) and the peritoneal membrane (**Figure 136-6C**) is recommended but not required. Close the serosa and peritoneum with running 2-0 absorbable chromic gut, Polysorb, or Vicryl suture. Identify and grasp the cut ends of the rectus sheath with hemostats. Close the rectus sheath in a running pattern with 2-0 Vicryl suture (**Figure 136-6D**). Close the skin with running 3-0 nylon (**Figure 136-6E**) or staples for speed.[7,8,10]

The only closure required if the mother will not survive is a minimal closure of the skin. Use either a running baseball stitch or skin staples.

COMPLICATIONS

The major associated complications of the procedure include maternal sepsis, maternal visceral injury, maternal hemorrhage, and fetal injury secondary to delivery. The possible benefits of maternal and/or fetal survival far outweigh these considerations.[1]

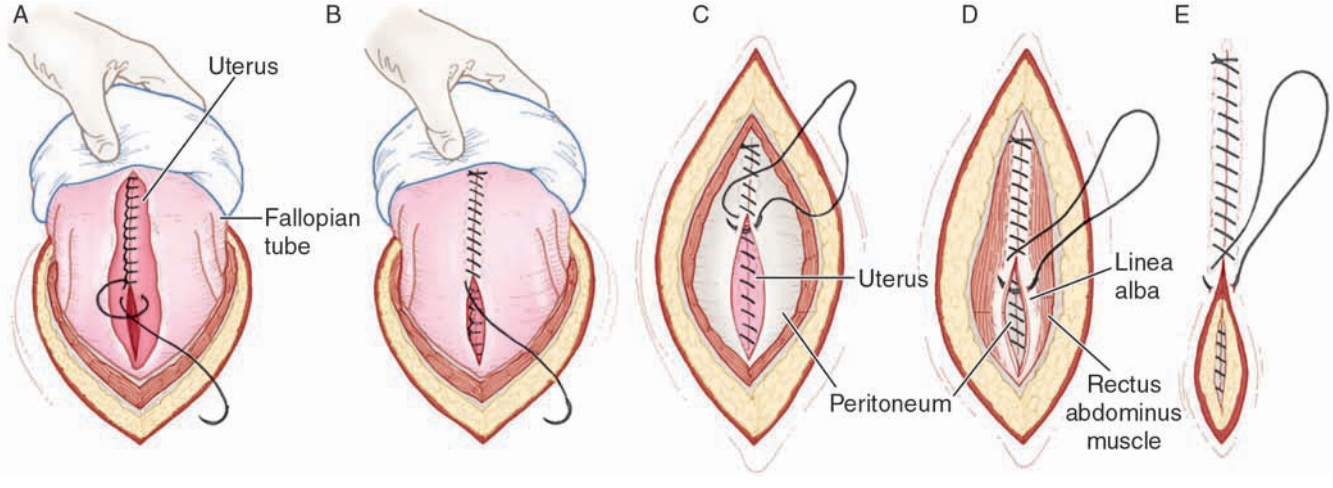


FIGURE 136-6. Closure of the incisions. **A.** Running locked closure of the uterine wall. **B.** Closure of the serosa of the uterus. **C.** Running closure of the peritoneal membrane. **D.** Running closure of the rectus sheath. **E.** Running closure of the skin.

SUMMARY

The perimortem cesarean section is a valuable procedure that should be considered in any maternal arrest with an estimated fetal gestational age of greater than 24 weeks. The procedure will bring a great deal of stress and fast decision making is required. It provides the fetus with a chance for survival in the face of maternal death. In addition to potentially saving the life of the infant, emergent delivery might also aid in the resuscitation of the mother. The medicolegal risks are few. It should ideally be performed within 5 minutes of maternal arrest, as this gives the greatest potential for successful fetal, and possibly maternal, resuscitation.

137 Symphysiotomy

Ikem Ajaelo

INTRODUCTION

Symphysiotomy is the artificial division and separation of the pubic symphysis in order to facilitate vaginal delivery. This is not to be confused with a pubiotomy, or the severance of the pubic bone a few centimeters lateral to the symphysis, for the same purpose. First performed in the seventeenth century, it is indicated in cases of cephalopelvic disproportion and may be a life-saving alternative to cesarean delivery.[1] The reported success rate of this procedure is approximately 80% when performed appropriately.[2]

The procedure itself is well described and can be accomplished under local anesthesia.[2] Early reports of urologic and orthopedic complications led to its decline and lack of acceptance in modern obstetrical practice despite initial successes.[3] Presently, a symphysiotomy is performed quite regularly and successfully in rural areas of the world where medical resources are not as abundant as in developed countries.[4]

Indications for a symphysiotomy include breech delivery, cephalopelvic disproportion, and for the relief of shoulder dystocia.[1,5,6] Each of these conditions poses significant potential risks to mother and child, even under optimal conditions. Emergency Physicians should be familiar with the indications and technique of symphysiotomy as expeditious delivery is vital in these scenarios.

ANATOMY AND PATHOPHYSIOLOGY

The pelvis is composed of four bones: the sacrum, the coccyx, and the two innominate bones. Each innominate bone is made up of the fused ischium, ilium, and pubis. The innominate bones are connected at the sacrum by the sacroiliac ligaments and at the pubic symphysis by the superior and arcuate pubic ligaments.[7] Together they determine the size and shape of the pelvis. The fetus assumes positions during labor that are primarily determined by the conformation of the mother's pelvis.[8]

The pelvis is divided into a true pelvis and a false pelvis. They are separated by the linea terminalis, an anatomic boundary formed by the pelvic brim (superior pelvic aperture). The true pelvis lies below the linea terminalis and is the more relevant portion in delivery.[9] Dense ligaments hold the walls of the true pelvis together. The posterior wall is the anterior surface of the sacrum and coccyx. The lateral boundaries are formed by the inner surface of the ischial bones as well as the sacrosciatic notches and ligaments. The ischial spines can be readily palpated during the vaginal or rectal examination. They serve as important landmarks in determining to which level the presenting part has descended into the true pelvis. The true pelvis is bounded anteriorly by the pubic bones, the ascending superior rami of the ischial bones, and the obturator foramina.

The ligaments of the pubic symphysis and the sacroiliac ligaments allow mobility and contribute to the increase in pelvic diameter during pregnancy.[8] The sacral nerves, the coccygeal nerves, and the pelvic portion of the autonomic nervous system innervate the pelvis. The important pudendal nerve arises from the sacral plexus and accompanies the internal pudendal artery. It enters the perineal region via the lesser sciatic foramen and around the sacrospinous ligament to supply the muscles of the perineum.[7] Anesthesia to the perineal region can be accomplished by performing a pudendal nerve block.

INDICATIONS

Symphysiotomy is indicated in any difficult delivery in the presence of fetal distress, when labor is obstructed, and when an Obstetrician is not immediately available. It has traditionally been reserved for complicated breech deliveries or cases of cephalopelvic disproportion in which the fetal head is presenting vertex and at least one-third of the fetal head has entered the pelvic brim and cervical dilatation is no more than 7 cm.[1] Symphysiotomy has been advocated more recently for the relief of intractable shoulder dystocia.[5,6]

CONTRAINDICATIONS

There are no absolute contraindications to performing a symphysiotomy. Some authors have recommended limiting symphysiotomy to mothers weighing between 50 to 80 kg and a fetus with an estimated mass of 2700 to 3700 g.[10,16] Other relative contraindications include the presence of maternal spinal deformities, hip deformities, pelvic deformities, and gross obesity.[10] Symphysiotomy has been performed after a prior cesarean section without added complications despite concerns regarding the safety of symphysiotomy in the presence of a previous cesarean scar.[10]

EQUIPMENT

- Local anesthetic solution
- Povidone iodine or chlorhexidine solution
- Sterile gloves and gown
- Face mask and cap
- Urethral catheter set
- Sterile drapes
- #10 scalpel blade on a handle
- Mayo scissors
- Finger guard
- Hemostats
- Sterile gloves
- Neonatal resuscitation equipment
- Infant warmer

PATIENT PREPARATION

Explain the risks, benefits, and potential complications to the patient and/or their representative. Obtain an informed consent to perform this procedure if time allows. Place the patient in the lithotomy position with the thighs separated no more than 90°. This position is necessary to prevent undue strain on the sacroiliac joints. Two assistants should be available to maintain proper maternal leg positioning. Insert a Foley catheter into the bladder (Chapter 142).

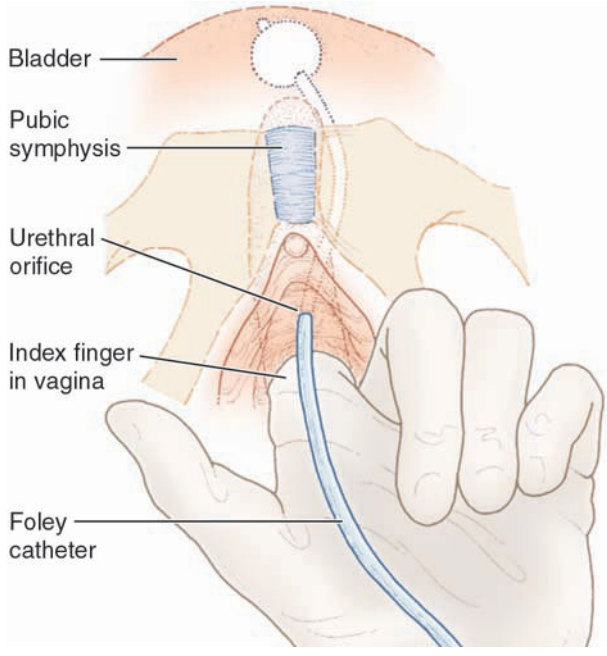


FIGURE 137-1. Frontal view demonstrating the operator's nondominant index finger inserted into the vagina and pushing anteriorly to palpate the pubic symphysis.

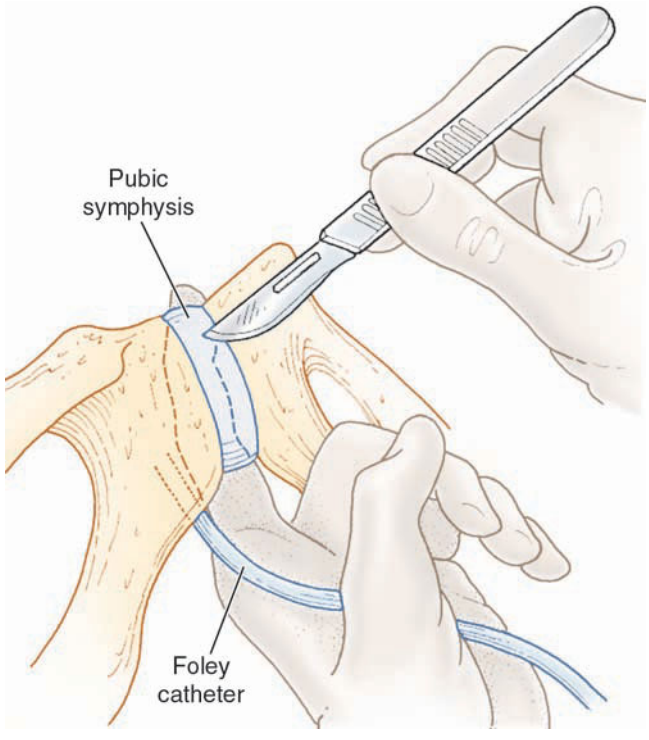


FIGURE 137-2. Skeletal outline demonstrating the position of the scalpel blade in relation to the pubic symphysis.

Prepare the surgical area. Shaving the mons pubis is optional. Apply povidone iodine or chlorhexidine solution onto the skin overlying the pubic symphysis and surrounding area and allow this to dry. The Emergency Physician must perform this procedure using aseptic technique. This includes wearing sterile gloves, a sterile gown, a cap, and a face mask. Apply sterile drapes to form a sterile field. Infiltrate the anterior and inferior aspects of the pubic symphysis and the surrounding skin with 5 to 10 mL of local anesthetic solution to anesthetize the pubic symphysis. Leaving the needle in place may be useful in identifying the pubic symphysis joint. Equipment for infant resuscitation should be readily available, as with all deliveries. Notify the neonatal resuscitation team and a Neonatologist of the impending procedure and delivery.

TECHNIQUE

Place the nondominant index finger into the vagina and against the posterior aspect of the pubic symphysis (**Figure 137-1**). Advance the finger approximately 2 to 3 cm beyond the superior aspect of the pubic symphysis to displace the bladder and urethra. **Do not move this finger until the procedure is complete.**

Grasp the scalpel in the dominant hand with the cutting edge of the blade facing you (**Figure 137-2**). **The scalpel blade must be kept in a strict midsagittal plane and perpendicular to the skin overlying the pubic symphysis.** Resting the hypothenar eminence of the dominant hand against the patient's pubic ramus will help maintain fine control of hand and finger movements.[2]

Make a midline stab incision 1 cm below the upper edge of the pubic symphysis (**Figure 137-3**). **Very little resistance should be met as the scalpel blade pierces the hyaline cartilage of the pubic symphysis if the scalpel is in the midline.** Carefully and slowly advance the scalpel blade until the tip is just felt through the anterior vaginal wall. Resistance is usually a result of lateral deviation of the scalpel blade against the pubic bones. Withdraw the scalpel blade 2 to 3 mm and re-advance it in the midline. **Use extreme caution so that the scalpel does not lacerate the vagina, the urethra, or the finger.**

Lower the handle of the scalpel blade cephalad, toward the abdomen, using the upper portion of the pubic symphysis as a fulcrum. Cut through the lower half of the pubic symphysis, dividing the cartilage and associated ligaments. Remove the scalpel blade and reinsert it with the cutting edge in the opposite direction and facing the cephalad. Repeat the same maneuver but with the scalpel handle lowered caudally to divide the upper portion of the pubic symphysis, thereby completing the separation.

Use the nondominant index finger to confirm complete separation of the pubic symphysis. **The symphysiotomy is complete when the index finger pressing through the vaginal wall can fit into the space between the pubic symphysis.** Reinsert the scalpel to complete the division if any ligaments or cartilage remains. The entire procedure should take 2 to 3 minutes. A variation of the above technique involves simply dividing the pubic symphysis in a single step by a repeated slow stabbing motion.

Once the symphysiotomy is completed, delivery of the infant should follow. Delivery of the infant usually requires more downward traction than is usually necessary.

AFTERCARE

Deliver the placenta and control any postpartum hemorrhage. Carefully return the mother to the supine position with the thighs in normal anatomic position. Close the skin and subcutaneous tissue with simple interrupted 4-0 nylon sutures. Some authors have recommended binding the knees for 12 to 48 hours to prevent inadvertent abduction or external rotation of the hips.[11] Admit the patient to the hospital for observation and monitoring of any potential complications. Leave the Foley catheter in place until any bleeding resolves or the patient begins to walk. Patients may begin ambulation with assistance between the second and fifth days. They should be warned against any unusual straining or heavy lifting.

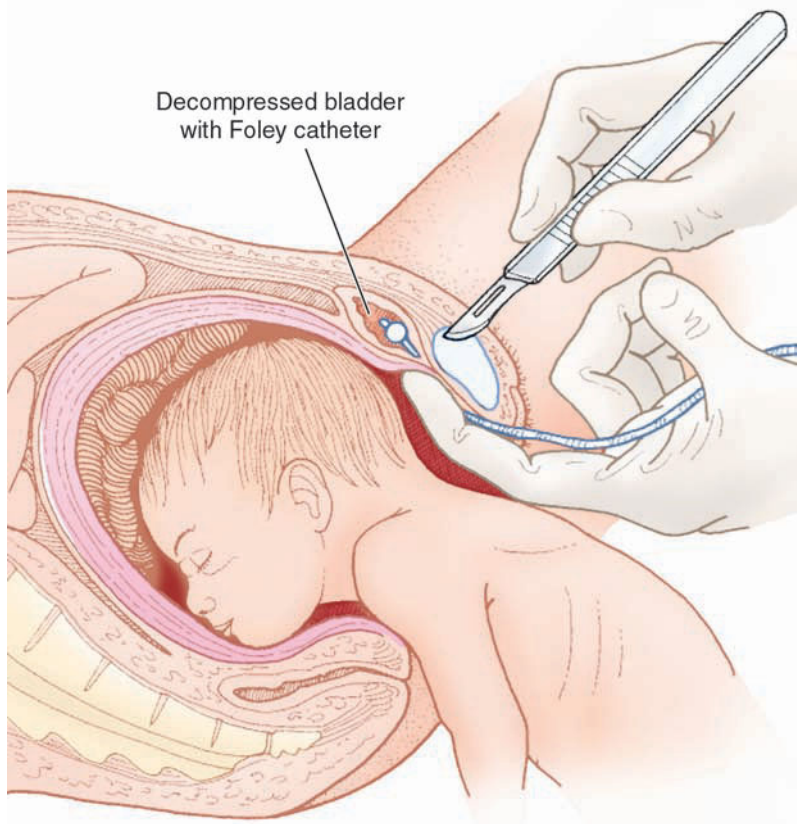


FIGURE 137-3. Sagittal view of a symphysiotomy using the scalpel blade to divide the pubic symphysis.

COMPLICATIONS

Experience and careful case selection appear to be the most important factors in determining outcome and morbidity associated with this procedure.[2] While symphysiotomies do not cause maternal death, immediate complications include bladder lacerations, urethral lacerations, subcutaneous bleeding, and urinary incontinence.[10,11] Some patients develop gait instability immediately after the operation that tends to be transient and does not appear to affect subsequent pelvic stability.[13]

Lacerations to the Emergency Physician's fingers are a significant concern.[12,15] Prevent lacerations by using the utmost of care and slowly transect the cartilage and ligaments of the pubic symphysis. The nondominant hand should be double-gloved at a minimum.[12] The use of a Kevlar glove that is resistant to scalpel injury may also be used.[15] A third option is to apply a malleable splint over the palmar aspect of the index finger before double gloving.[12]

Long-term complications include, but are not limited to, stress urinary incontinence, recurrent urinary tract infections, sepsis, and vesicovaginal fistulas.[14] Vaginal fistulas are frequently due to nonplacement of a Foley catheter during the procedure.[3] This important step should never be omitted. The effect of a symphysiotomy on subsequent pregnancies has not been studied in detail. However, the limited data available suggest that a symphysiotomy permanently enlarges the pelvis so that subsequent vaginal deliveries are in fact easier.[13]

SUMMARY

In developed countries, modern surgical techniques and obstetrical advances have diminished the practice of symphysiotomy. However, it still remains a simple and safe method to overcome the common and lethal problems of cephalopelvic disproportion, shoulder dystocia, and breech deliveries. Complications are uncommon when performed correctly. Emergency Physicians can master this procedure.[12] A symphysiotomy is a viable and potentially lifesaving option for those who may be working outside the confines of a well staffed and equipped hospital.

138 Bartholin Gland Abscess or Cyst Incision and Drainage

Charlie C. Kilpatrick

INTRODUCTION

Bartholin gland cysts and abscesses are common problems for women of reproductive age, with an incidence of 2% in this population.[1–3] A Bartholin gland and its duct may enlarge to form a Bartholin cyst or become infected and form a Bartholin abscess. A number of different techniques have been developed for the treatment of both cysts and abscesses.

ANATOMY AND PATHOPHYSIOLOGY

The Bartholin glands are named after Caspar Bartholin, a Danish anatomist.[1,4] They are located on each side of the vulvar vestibule beneath the fascia, posterolaterally to the vaginal orifice, and at the 4 and 8 o'clock positions.[5,6] The glands are approximately 1 cm in diameter, the size of a pea, and drain through a duct approximately 2.5 cm in length. The ducts of the glands open into the vulvar vestibule at the 5 and 7 o'clock positions, existing between the hymenal ring and the labia minora. The cells of the gland produce mucin which is secreted during sexual excitement and contributes

to vaginal lubrication.[4,7] The Bartholin glands are not normally palpable. The gland has an extensive blood supply from branches of the internal pudendal artery. The neural supply is provided from branches of the pudendal nerve.

A cyst of the Bartholin gland may develop most often secondary to obstruction of the duct. This leads to ductal dilation and cyst formation. Noninfectious etiologies of cyst formation include inspissated gland secretions, trauma, tumor of the vulva, or scarring of the duct from repeated bouts of cyst formation.[3] Cysts may grow as large as 1 to 3 cm. Bartholin cysts present as painless unilateral swellings in the labial area. A patient will become symptomatic if they become large enough or infected. Infected cysts contain purulent material and are known as a Bartholin's abscess; although it is more akin to a pseudoabscess unless the surrounding tissue appears erythematous, tender, and inflamed.[3] A Bartholin cyst may present with pain, dyspareunia, pressure, difficulty with walking, or may be completely asymptomatic.[4,7–11] The diagnosis is made on visual inspection of the vulva. Common signs are a mass near the inferior labia minora, drainage, and erythema.

Primary carcinoma of the Bartholin gland is a rare occurrence, but should be considered in the differential diagnosis. Most cancers occurring in the Bartholin gland are metastatic primary vulvar cancers. They can present as a Bartholin gland cyst when the vulvar cancer obstructs the ductal outflow of the gland. Adenocarcinoma (40%), squamous cell carcinoma (40%), adenoid cystic carcinoma (15%), and transitional cell carcinoma (5%) of the Bartholin gland have all been documented.[6,12–15] Carcinoma can easily mimic a Bartholin gland cyst or abscess.

The majority of Bartholin gland cysts appear to be sterile or contain bacteria common to the vaginal flora.[16] Studies of Bartholin gland abscesses have shown no bacterial growth in 7%, 10%, and 30% of specimens cultured.[16–18] The causative organisms are multiple in the cultures that do grow bacteria. The most prevalent organisms isolated are anaerobes, with *Bacteroides* and *Peptostreptococcus* being the most common species.[17] The remainder of the cultures demonstrated either aerobic/facultative isolates with *Escherichia coli* being the most common species or a mixture of both aerobic and anaerobic organisms. *Neisseria gonorrhea* and *Chlamydia trachomatis* have also been implicated as causative agents and have been isolated in 8% to 16% of cultures.[16,19]

INDICATIONS

Small and asymptomatic cysts in women less than 40 years of age can be managed expectantly. All others should be treated. Any cyst that becomes large and symptomatic (i.e., painful, interfering with physical or sexual activity) should be treated. Any cyst that appears tender, red, hot, or cellulitic represents a Bartholin abscess and requires treatment.

CONTRAINDICATIONS

There is some controversy about the treatment of Bartholin cysts and abscesses in women over the age of 40. Previously, the recommendation was to excise the gland in women over the age of 40, for concern of the possibility of carcinoma. Carcinoma of the Bartholin gland is rare, comprising less than 1% of female genital tract neoplasms.[11] It is felt that women over the age of 40 are at an increased risk for having carcinoma of the Bartholin gland, Bartholin duct, or adjacent structures; and thus all of these should be properly biopsied or completely excised and sent for pathologic evaluation.[1,6,7,12–14] Another study reported an incidence of Bartholin gland cancer in postmenopausal women of 0.114 per 100,000 women and suggests that selective biopsy be performed to reduce the number of total excisions.[15] Given the rarity of malignancies in this area, this view has been challenged in the recent literature. Currently, drainage and selective biopsy seems to be a reasonable alternative.[7] In general, these women should be referred to a Gynecologist for diagnosis and further treatment.

Patients who have had multiple recurrences and previous treatments are best served with a referral to their Gynecologist for more definitive measures.

Consider draining Bartholin abscesses that are large or extremely tender in the Operating Room. Other indications for drainage in the Operating Room include patients with a contraindication to procedural sedation, those that cannot be adequately anesthetized using procedural sedation and local anesthetics, and those who cannot be safely sedated in the Emergency Department.

EQUIPMENT

Simple Incision and Drainage

- Povidone iodine or chlorhexidine solution
- Gloves and gown
- Face mask with an eye shield or goggles
- Drapes
- Lidocaine, 1% to 2%
- 3 mL syringe
- 18 gauge needle
- 25 gauge needle
- 2 × 2 gauze squares
- 4 × 4 gauze squares
- #11 scalpel blade and scalpel handle
- Culture medium for routine bacteria, gonorrhea, and chlamydia
- Hemostat
- Small wick, 2 inches long

Incision and Insertion of a Word Catheter

- Equipment for simple incision and drainage
- Word catheter
- 5 mL sterile saline or water

Marsupialization

- Equipment for simple incision and drainage
- Two small retractors
- Specimen container for excised tissue
- Silver nitrate sticks or electrocautery
- Vicryl, 3-0 or 4-0 on cutting needle
- Scissors
- Small toothed forceps

Window Operation

- Same as equipment for marsupialization

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The postprocedural care should also be discussed. Obtain a signed consent for the procedure. Some Emergency Physicians may omit the signed consent and place in the procedure note a statement saying: "the risks, benefits, and complications were described and discussed with the patient. They understood this and gave verbal consent for the procedure."

Place the patient in the lithotomy position. Apply povidone iodine or chlorhexidine solution to the labia and allow it to dry. The surface of the vagina must be anesthetized as the procedure is extremely painful. The use of ice packs, topical refrigerant spray (Chapter 124), parenteral sedation, parenteral analgesics, or procedural sedation (Chapter 129) should be considered for patient comfort prior to infiltrating local anesthetic solution. Infiltrate 0.25 to 1.0 mL of local anesthetic solution subcutaneously under the mucosal surface of the labia minora for simple incision and drainage, with or without the use of a Word catheter. When injecting local anesthetics, ensure that you do not inject purulent material after aspiration as this can cause extensive inflammation. Infiltrate 2 to 3 mL of local anesthetic solution if a marsupialization will be performed.

The Emergency Physician should be wearing a gown, gloves, and a face mask with an eye shield or goggles. The cyst contents are usually under pressure and can spray out. A face mask and eye protection will prevent a mucous membrane exposure if the contents spray out of the incision. The gown will protect clothing from contamination.

TECHNIQUES

A number of different treatments and procedures have been developed to manage a Bartholin cyst or abscess. These are largely influenced by its size, patient symptoms, the age of the patient, the suspected etiology, and any previous treatment in the same patient. The techniques include simple incision and drainage, incision and insertion of a Word catheter, marsupialization, a window operation, and complete excision.

SIMPLE INCISION AND DRAINAGE

The standard treatment for most abscesses is simple incision and drainage.[7,9,10,20,21] Simple incision and drainage of a Bartholin cyst or abscess provides immediate pain relief but is often complicated by chronic recurrences. This technique is not recommended but described for the sake of completeness.

Spread open the labia to visualize the area (**Figure 138-1**). Make a 1 cm vertical incision on the mucosal surface of the labia minora in the vaginal vestibule. It should be parallel to the border of the hymenal ring, between the hymen and labia minora (**Figure 138-1**). **The incision should ideally be external to the hymenal ring, if possible, and in the area where the duct normally exits.** Extend the incision into the abscess/cyst cavity. **Do not make incisions along the skin surface of the labia minora.** Skin incisions can lead to the formation of a fistula tract, more postprocedural pain, and are fraught with complications. Culture the contents of the sac. Manually express the contents of the sac. Insert a hemostat and break any adhesions. Place a small wick within the cavity and exiting the incision to allow for complete drainage and prevent premature closure of the skin incision.

INCISION AND INSERTION OF A WORD CATHETER

Dr. B. Word first described this procedure in 1964.[4] It is a relatively simple procedure that can be accomplished in the Emergency Department.[4,7,9,10,22] The catheter is approximately 5 cm long and made of soft pliable latex with a 10 French tip. The tip contains a balloon that inflates up to a volume of 5 mL (**Figure 138-2**). These catheters cost approximately $15 each (Berkeley Medevices Inc., Berkeley, California).

Verify that the patient is not allergic to latex.[8] Fill a 5 mL syringe armed with a 21 gauge needle with saline or water. Insert the needle into the self-sealing port on the distal end of the Word catheter. Inject 3 to 4 mL of the fluid to inflate the balloon. Observe the balloon for any leaks. If no leaks are visible, aspirate the fluid back into the syringe to deflate the balloon. Remove the needle from the self-sealing port.

Spread open the labia to completely visualize the area (**Figure 138-3A**). Make a 0.5 cm long puncture on the mucosal surface of the labia minora with a #11 scalpel blade into the cyst or abscess cavity (**Figure 138-3A**). **This puncture should ideally be located just outside the hymenal ring and where the duct normally drains into the vaginal vestibule, between the hymen and labia majora at the 5 or 7 o'clock position.** The incision should be just large enough to allow the passage of the Word catheter. Culture the contents of the sac. Manually express the contents of the sac. Insert a small hemostat and break any adhesions.

Insert the tip of the Word catheter deep within the cavity (**Figure 138-3B**). Inject 2 to 4 mL of sterile saline into the free end of the catheter to inflate the balloon (**Figure 138-3C**). **Pain upon inflation of the balloon or persistent pain after the procedure indicates overinflation of the balloon. Do not use air to inflate the balloon.** The catheter will stay in place because the inflated balloon is larger than the puncture incision. Tuck the free

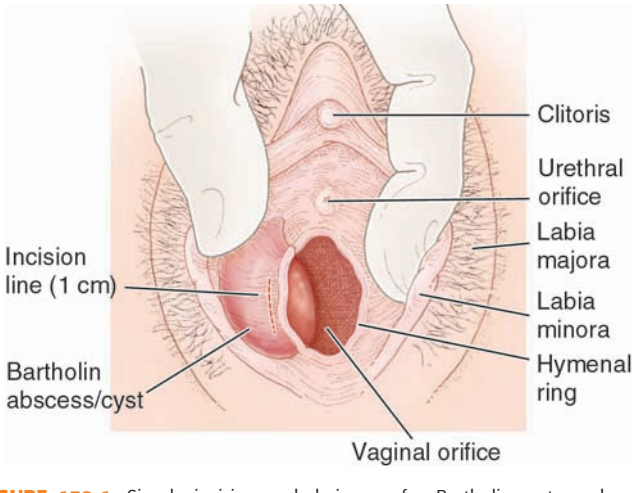


FIGURE 138-1. Simple incision and drainage of a Bartholin cyst or abscess. Spread open the labia to expose the area. The dotted line represents the incision line over the cyst or abscess.



FIGURE 138-2. The Word catheter. The plastic catheter has a port at its proximal end to insert a needle. The distal end contains a balloon that can be inflated.

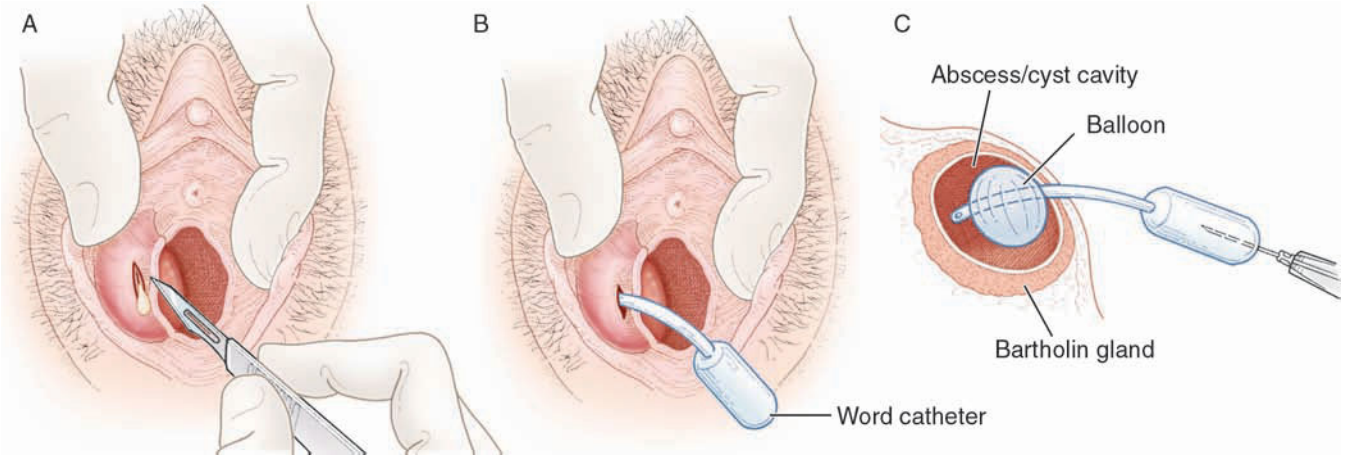


FIGURE 138-3. Incision and insertion of the Word catheter. **A.** Make a 0.5 cm long stab incision on the mucosal surface of the labia minora. **B.** The cavity has been evacuated and the Word catheter inserted. **C.** The balloon is inflated with saline.

end of the catheter within the vaginal canal. The Word catheter should ideally stay in place for up to 4 weeks. This allows the tract to become epithelialized and prevent a recurrence. The patient should abstain from sexual activity while the catheter is in place.

MARSUPIALIZATION

Marsupialization is an alternative treatment choice, initially described in 1950.[1,7,9,10,21,23–25] It is performed once and is curative in some case series greater than 90% of patients.[24,26] Advantages are that it can be done as an outpatient, is associated with little postoperative pain, has minimal postoperative scarring, and preserves the gland function.[8] Marsupialization can be easily and safely performed in the Emergency Department using local anesthesia. **Do not attempt to marsupialize a Bartholin abscess with an accompanying cellulitis.** Some Obstetricians prefer to perform this procedure in the Operating Room under general anesthesia.

Make an oval-shaped or elliptical incision approximately 1.5 cm long and 1 cm wide through the vestibular mucosa over the cyst/abscess and just outside the hymenal ring (**Figure 138-4A**). Remove this piece of mucosa to visualize the anterior wall of the cyst/abscess cavity. Insert a retractor to pull the skin edges open and better visualize the sac (**Figure 138-4B**). Make a similar incision through the anterior wall of the cyst/abscess cavity (**Figure 138-4B**). Most times the initial incision will pierce both the vaginal mucosa and cyst wall. Remove this piece of tissue leaving the cavity exposed. Culture the contents of the sac. Express the contents of the sac. Insert a small hemostat and break any adhesions.

Control any bleeding with electrocautery, silver nitrate application, or manual pressure. Closing the cavity with interrupted sutures, as a final option, will control the bleeding. Suture closure is only temporary for hemostasis as this pocket will become reinfected and require another procedure. Remove any sutures placed in 20 to 30 minutes. Identify the former bleeding site and treat it with electrocautery or silver nitrate to prevent rebleeding after the patient leaves the Emergency Department.

Evert the cyst/abscess wall. Approximate the wall of the cyst/abscess to the vestibular mucosa. Sew the wall of the cavity to the

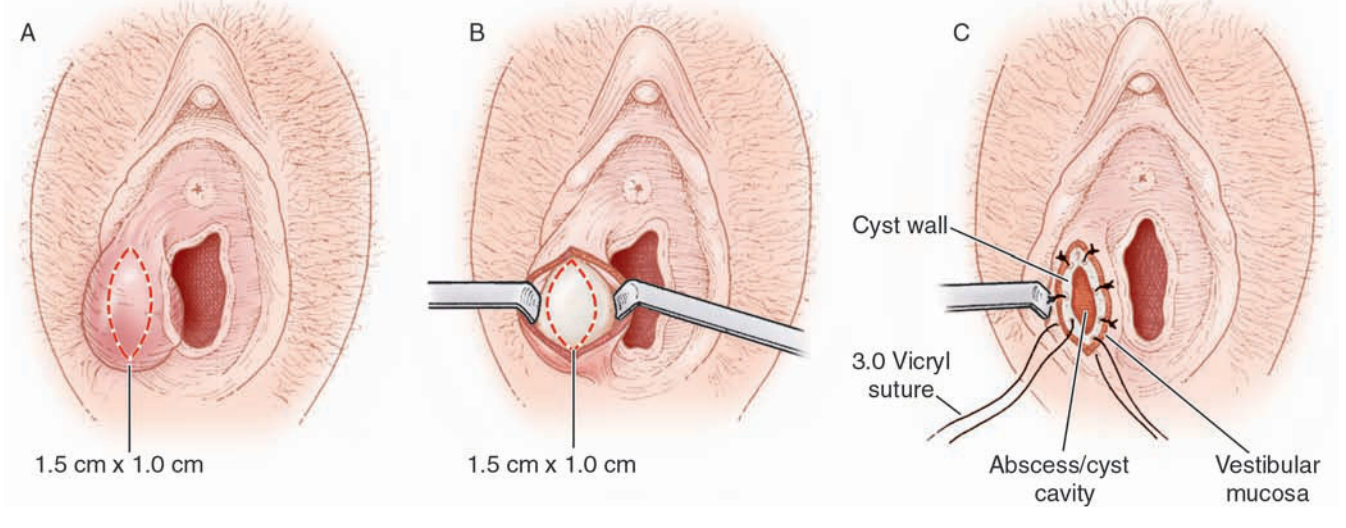


FIGURE 138-4. The marsupialization of a Bartholin cyst or abscess. **A.** An elliptical incision, 1.5 cm in length and 1.0 cm in width, is made through the vulvar mucosa and just outside the hymenal ring. The ellipse of mucosal tissue is then removed. **B.** An elliptical incision (*dotted line*) is then made through the anterior wall of the cyst or abscess. **C.** Approximation of the cyst or abscess wall to the vestibular mucosa with 3-0 or 4-0 interrupted Vicryl suture.

mucosa of the vaginal vestibule with interrupted 3-0 or 4-0 Vicryl sutures (**Figure 138-4C**). The orifice will reduce in size, epithelialize, and form a new duct in time. **Send all excised tissue to the Pathology Department to confirm the diagnosis and to rule out neoplasm.**

WINDOW OPERATION

This technique is almost identical to marsupialization.[27] It differs only in the size of the incision. One study claimed that this procedure had no long-term complications or recurrences, thus making it a more desirable technique.[27] However, the total patient population was small and the study has not been duplicated and republished. In essence, one follows the exact procedure for marsupialization with the exception of making a larger incision (2 to 3 cm long and 1.5 cm wide). At the completion of the procedure a wide opening is observed. The opening will be approximately one-half its original size at the 1 year follow-up. This much larger and radical incision is not recommended for the Emergency Physician.

COMPLETE EXCISION

This technique is reserved for the treatment of recurrent cysts and abscesses unresponsive to less invasive techniques.[7,9–12,15,21,27] It is also indicated in patients for whom carcinoma is suspected. Even though the function of the gland is to provide lubrication for sexual activity, in a well-estrogenized woman removal of the gland poses little clinical problem. In the past, excision of the Bartholin gland in all women over the age of 40 for fear of carcinoma was championed. This has been challenged given the low incidence of carcinoma of the Bartholin gland in favor of drainage and selective biopsy.[7] Significant bleeding may complicate dissection into this

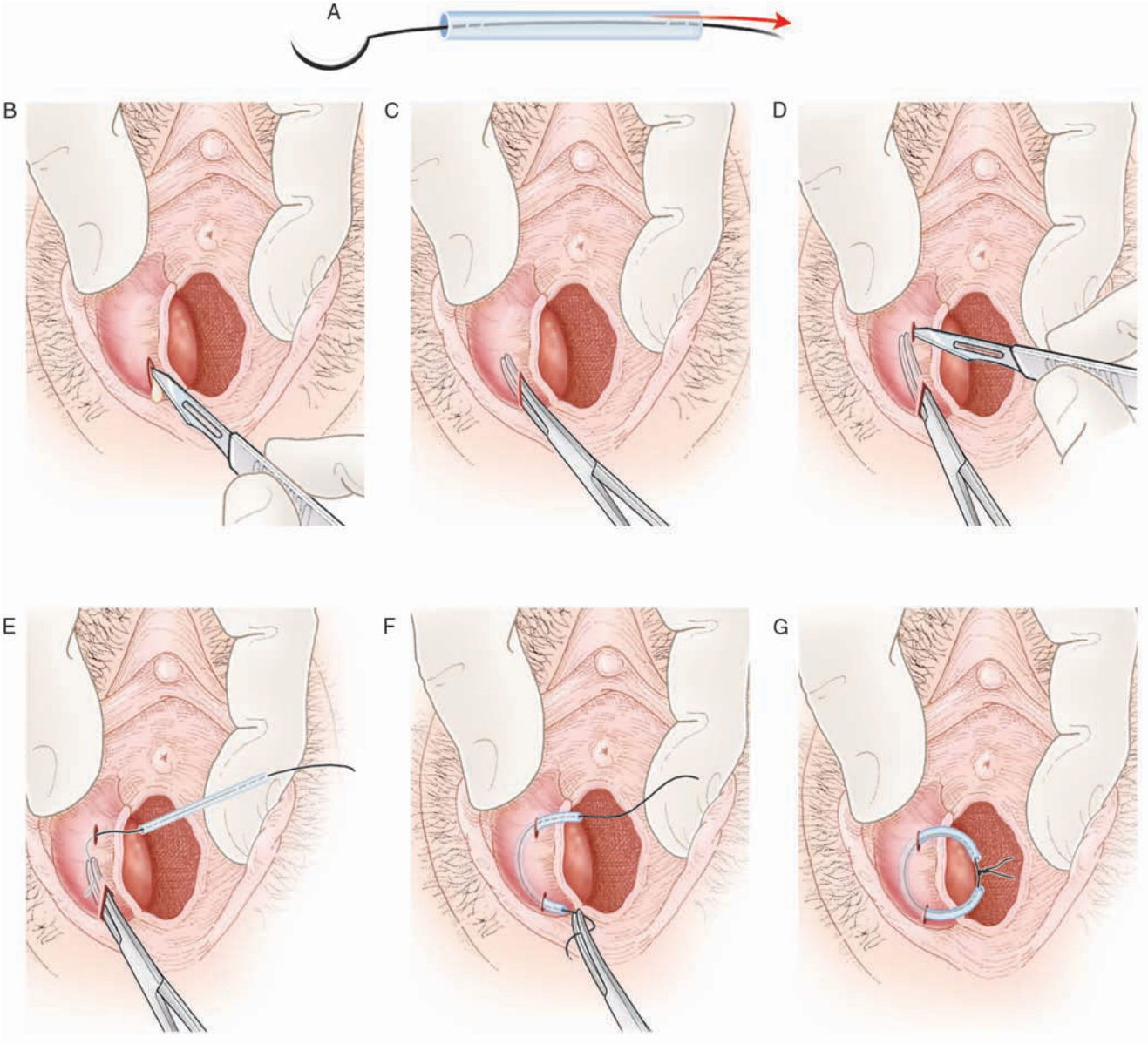


FIGURE 138-5. An alternative technique to incise and drain a Bartholin's cyst or abscess. **A.** A silk suture has been inserted through the tubing. **B.** A stab incision is made in the lower half of the abscess and outside the hymenal ring. **C.** A hemostat is inserted to break any loculations. **D.** The hemostat provides support as a second stab incision is made in the upper half of the abscess. **E.** One end of the silk suture is grasped with the hemostat. **F.** The suture and tubing are pulled out through the lower incision. **G.** The suture ends are tied to form a ring with the tubing.

area due to the underlying anastomosing venous plexus. If hemostasis is not achieved, a vulvar hematoma will result. Excision of the gland is often referred to as the "bloodiest little operation in gynecology." This procedure should only be performed by a Gynecologist in the controlled setting of an Operating Room under general anesthesia.

ALTERNATIVE TECHNIQUE

An alternative to the Word catheter has been described in the literature.[32,33] The advantages of this technique are that the materials are available in every Emergency Department, the device does not prematurely fall out as often happens with the Word catheter, and it is easily placed. Unfortunately, these reports had few patients. Larger studies comparing this technique to the Word catheter are required.

Prepare the equipment. Obtain a 5 to 7 cm long piece of tubing. Suggestions include cutting a piece from an 8 French T tube or a butterfly IV catheter.[32,33] Insert a strand of 2-0 silk suture, without a needle or the needle cut off, through the tubing (**Figure 138-5A**).

The procedure is quite similar to that previously described. Make a stab incision in the lower half of the abscess and outside the hymenal ring with a #11 scalpel blade (**Figure 138-5B**). Insert a hemostat and break any loculations (**Figure 138-5C**). With the hemostat in the abscess cavity for support, make a second stab incision in the upper half of the abscess (**Figure 138-5D**). Insert one end of the silk suture into the incision and grasp it with the hemostat (**Figure 138-5E**). Pull the suture and tubing out through the lower incision (**Figure 138-5F**). Tie the ends of the suture to form a ring with the tubing (**Figure 138-5G**). Place four to five knots in the suture. Cut off the excess suture.

AFTERCARE

All abscess and cyst contents should be cultured. The initiation of antibiotics can be delayed pending the culture results, at the discretion of the physician. Administer antibiotics if the abscess is accompanied by cellulitis. Keep in mind the prevalence of MRSA in soft tissue infections and specifically in labial abscesses when choosing antibiotics.[28,29]

All patients should begin sitz baths in 2 days. Prescribe appropriate oral analgesics. Nonsteroidal anti-inflammatory drugs will provide most patients with adequate analgesia. Some patients may require a brief course (1 to 3 days) of narcotic analgesics. Give written discharge instructions to each patient explaining the aftercare, the complications, and the actions to take if a complication does arise. All patients should abstain from sexual activity until the inflammation and pain resolves or until the Word catheter is removed.

COMPLICATIONS

The most common complication with the incision and drainage technique is frequent recurrence. The most common complication of Word catheter insertion is premature loss of the catheter resulting in early incision closure and recurrence. It can also be associated with significant discomfort if the catheter is inserted improperly. Marsupialization has few complications and a low recurrence rate. With any of these procedures, one can miss a carcinoma of the Bartholin duct or Bartholin gland if a biopsy or excision is not performed. Bleeding and progressive infection, including sepsis and toxic shock syndrome, are rare but possible complications.[30,31]

The immunocompromised patient (e.g., diabetic, steroid dependent, or HIV positive) needs particular attention paid to cleanliness during and after the procedure. If the abscess is accompanied by cellulitis and/or involves the labia majora, consider inpatient management and gynecologic consultation. Initial IV antibiotics should cover MRSA. A large Bartholin/labial abscess in a diabetic patient requires close surveillance and a high suspicion for necrotizing fasciitis. Daily follow-up visits are recommended for these patients during the initial postprocedural period. Early hospitalization and administration of intravenous antibiotics are warranted if there is any sign of progressive infection.

SUMMARY

Bartholin cysts and abscesses will be encountered by the Emergency Physician and can easily be treated. They present as a painful unilateral swelling of the inferior aspect of the labia. There are many treatments option. Culture all cyst or abscess contents. Send any tissue removed to the Pathology Department to rule out carcinoma. Refer patients with previously treated cysts or abscesses, those suspicious for carcinoma, and those over the age of 40 to a Gynecologist for definitive care. Give all patients written discharge instructions at the end of the procedure. All immunocompromised patients require very careful follow-up.

139 Sexual Assault Examination

Ann I. Schutt-Ainé and Audra E. Timmins

INTRODUCTION

The exact legal definition of sexual assault varies from state to state. Sexual assault is defined as forced sexual contact without consent. Nonconsensual sexual contact involves a continuum ranging from unwanted touching and fondling of sex organs to forced penetration (oral, anal, or vaginal). Fingers or objects (such as broomsticks, bottles, or knives) could be used instead of, or in addition to, a penis as a weapon of choice. Drugs such as gamma-hydroxybutyric acid (GHB), Rohypnol (flunitrazepam), ketamine, and alcohol are commonly used as "date rape" or "club drugs." These agents are used to disable the victim prior to a sexual assault.

Large studies have shown that 13% to 39% of women and 3% of men have experienced an attempted or completed sexual assault in their lifetime.[1,2] FBI and crime statistics grossly underestimate the incidence since only 16% of sexual assaults are reported to police.[1,2] In addition, the vulnerable populations such as homeless, sheltered, or institutionalized persons are not included in most large studies.[3] Approximately 300,000 to 700,000 adult women are victims of sexual assault annually in the United States, with 40,000 victims treated in Emergency Departments.[1,4]

Sexual assault is not generally a crime committed by strangers. Most women (78% to 82%) are sexually assaulted by someone known to them.[1,4–6] The assailant may include a spouse, boyfriend, family member, coworker, or neighbor. More than 50% of rape victims over the age of 30 are sexually assaulted by an intimate partner.[7] An acquaintance such as a contractor or package delivery person may be the perpetrator.

There is not a typical profile of a victim. Adolescent girls and young women face particularly high rates of sexual assault.[8] However, victims have been reported in all age groups. Sexual assault occurs across all socioeconomic groups, all racial backgrounds, and all ethnic backgrounds. Up to 39% of women will be sexually assaulted more than once during their lifetime.[1]

Some victims will not identify themselves as victims of sexual assault. They may be ashamed or fearful to disclose what happened. They also may be experiencing the rape trauma syndrome, a special category of posttraumatic stress disorder. The use of screening questions, as used for domestic violence, and a high index of suspicion are necessary to identify these patients. There is a significant increase in the utilization of medical resources after a sexual assault.[9]

The Emergency Department visit of a sexual assault victim is vital in assuring proper medical care, evidence collection, and treatment. Proper follow-up plans, medical appointments, and referrals to local rape crisis centers and/or hotlines are crucial for the mental and physical recovery of victims. The likelihood that the patient will seek follow-up care and pursue the case through legal avenues is strongly influenced by his or her initial experience in the Emergency Department. It is critical to not re-victimize the patient or make them feel responsible for the sexual assault.

INDICATIONS

Perform a sexual assault examination, including evidence collection, on all patients who present within 1 week of a sexual assault. Evidence collection has the highest yield if collected within 72 hours after the sexual assault. Proceed with the examination if the victim is unsure of when the assault occurred or when the patient is unsure if a sexual assault occurred. A thorough history and physical examination with extra attention to the areas violated should be performed to evaluate for injuries, even when the patient presents more than 1 week after the sexual assault. Evidence collection requirements vary from state to state. In some states, samples collected prior to assignment of a case number cannot be admitted as evidence. The Emergency Physician should become familiar with local laws. **Perform a complete history, as outlined in the technique sections, regardless of when the assault took place. Patients must consent to evidence collections (Figure 139-1).** Evidence collection should proceed if a patient is unable to consent due to a medical condition, with local statutes and hospital policy determining the release of evidence. Minors do not require parental consent for the initial evaluation of any potential life-threatening injuries. Many states require parental permission for the release of evidence.

CONTRAINDICATIONS

Life-threatening injuries and unstable vital signs must be managed per usual recommendations prior to evidence collection. Five percent of sexual assault victims have major nongenital physical injuries.[10] Victims must be able to consent to the examination and evidence collection unless prohibited by a medical condition.

EQUIPMENT

- Separate **paper bags** for clothing and undergarments
- Clean white sheet and large paper sheet to place on floor when patient disrobes
- Four sterile cotton-tipped swabs for oropharynx evidence collection
- Pharyngeal culturettes for gonorrhea and chlamydia
- Four sterile cotton-tipped swabs for vaginal/cervical/penile evidence collection
- Culturettes for gonorrhea and chlamydia of the vagina/penis
- Slides for vaginal wet mount for trichomonas
- Four sterile cotton-tipped swabs for rectal evidence collection
- Culturettes for gonorrhea and chlamydia of the rectum
- Extra sterile cotton-tipped applicator swabs for miscellaneous stains and bite marks
- Comb and a piece of clean white paper for loose pubic hairs
- Comb and a piece of clean white paper for loose head hairs
- Two sticks for fingernail scrapings
- Filter paper for blood collection
- Urine or blood collection equipment to test for pregnancy
- Equipment for serum collection to test for hepatitis, syphilis, and HIV
- Instant camera or forensic photographer
- Colposcope, as applicable
- Sterile water to moisten speculum and cotton-tipped swabs
- Change of clothing for the patient
- Separate envelopes to place evidence within for each body site
- Tape to seal all evidence

Most states have prepackaged evidence collection kits with most of the necessary equipment included. These kits usually do not contain paper bags for the clothes, culturettes, blood drawing equipment (i.e., needles, Vacutainers), and blood collection tubes; all of which are readily available in any Emergency Department.

PATIENT PREPARATION

Address any life-threatening injuries and unstable vital signs before proceeding to the formal sexual assault examination. Up to 5% of rape victims have major nongenital physical injuries.[10] **To best preserve evidence, do not to rip or cut any clothes. Life-threatening interventions always supersede evidence collection, but note on the patient's medical record if any clothing is cut or torn by medical personnel.**

Conduct the examination in a quiet, private room. It should ideally have the facilities to perform a pelvic examination so that the patient does not have to be moved multiple times. Assign a designated nurse and physician who are trained in the sexual assault protocol and aware of the multiple emotional manifestations that the patient may experience. **Safety and privacy must be ensured.** Notify a community- or hospital-based advocate upon the patient's arrival to the Emergency Department. Advocates can best define their own role. Allow the patient to decide if the advocate should stay for the examination and evidence collection. The number of providers should be kept to a minimum. All providers can be subpoenaed to testify in the event of legal action. Contact police per local laws and patient request. Alert hospital security to the possibility that the assailant may come to the hospital.

The patient must give written consent prior to the examination (**Figure 139-1**). **It is important to let the victim guide the process as much as possible to help them restore control of their life.** Let the victim know that you are their advocate. Obtaining consent has important legal and psychological implications for the patient. **The sexual assault victim has the right to refuse the sexual assault examination, any medical treatment, and any interviews by advocates or social workers.** Note in the medical record any and all portions of the sexual assault examination and treatment that the patient refuses. **Encourage the patient to at least have the examination, without the use of the sexual assault kit, so that you can provide proper medical treatment. Encourage the patient to allow the collection of evidence with the sexual assault kit in the event that they later change their mind and decide to prosecute the assailant.**

Discourage the patient from eating, drinking, changing clothes, urinating, or defecating prior to the examination. This is to best preserve evidence, especially if the patient is seen in close time proximity to the sexual assault. Perform examinations specific to the affected area earlier to accommodate the patient if they need to drink or void.

EXAMINATION OF FEMALE PATIENTS

Exact details of the examination will vary depending upon state and local evidence collection requirements. Some states have provisions for special Sexual Assault Nurse Examiners (SANEs) who are specially trained to perform the complete sexual assault examination and testify if the case is prosecuted. Other regions have a sexual assault team (SART) with representatives from healthcare, forensics, rape crisis centers, law enforcement, and the prosecutor's office. SANE and SART programs increase compliance with recommended medical care, quality of evidence collection, and the likelihood that charges will be filed and successfully prosecuted.[3]

The order of the examination may vary depending upon the patient's needs. The Emergency Department is often the first official system to which the victim reports an assault. **Patients may be reluctant to share their story with personnel in the criminal justice system if they are met with judgmental attitudes or insensitive treatment by emergency medical staff.**[12]

Collect a urine sample early if there is any possibility of the use of a "date rape" or "club drug." The decision to process the urine can be determined later. The window to detect drugs such as gamma-hydroxybutyric acid (GHB) or Rohypnol (flunitrazepam) can be as little as 8 hours after ingestion. Most toxicology screens will detect prescription drugs and recreational drugs that the patient may have taken. For this reason, some patients may decide not to have their urine tested.

HISTORY

Proceed with the history and physical examination once the patient is in a private room, has consented to the examination, and an advocate is made available. Obtain a complete history to guide the medical examination and help with possible legal matters (**Figure 139-2**). **Avoid judgmental questions that may feed into the victim's feeling of self-blame.** Aspects of the history should include the time and place of the assault, the race, gender, and number of assailants. Obtain and document a brief description of the assault including whether there was oral penetration, vaginal penetration, rectal penetration, and/or ejaculation. Elicit any use of force, restraints, foreign bodies, or lubricants. Ask the patient what they have done since the assault. Simple things such as changing clothes, douching, bathing, urinating, defecating, or using a tampon may change the ability to collect forensic evidence.

The past medical history should emphasize the gynecological history and include last menstrual period, type of birth control used if any, last consensual intercourse, previous sexually transmitted diseases, previous pregnancies, and previous gynecological surgeries. The time of the last voluntary intercourse is important, as mobile sperm may be found up to 72 hours in the cervix. Determine the tetanus immune status and provide immunoglobulin and boosters if needed. Determine if date rape drugs might have been given, especially if there seems to be a lapse of time between the assault and presentation to the ED.

PHYSICAL EXAMINATION

The physical examination serves to detect injuries and document them for future legal prosecution. A complete physical examination must be performed, even if the patient does not want to pursue legal matters. Although up to 70% of rape victims reported no physical injuries, 4% to 5% sustained serious physical injury, and 24% sustained minor physical injuries.[1,13] **It is important to help patients guide the examination and allow them to stop at points if they are not ready to proceed. Many patients will need encouragement through the examination.**

Note the patient's general appearance, affect, and emotional status. Instruct the patient to disrobe over a clean paper sheet if they are wearing the same clothes they wore prior to the assault. Place all clothes in paper bags, with the underwear in a separate paper bag. Fold the paper sheet, containing any debris, and place it in a collection envelope. Examine the entire body for abrasions, lacerations, bites, scratches, foreign bodies, and areas of ecchymoses. **Closely examine every laceration to ensure it is not a stab wound.** It is helpful to use a body diagram to document injuries (**Figure 139-3**).

Genital trauma after consensual sex is uncommon. However, genital injuries commonly occur after sexual assault at the posterior fourchette, labia minora, fossa navicularis (anterior to the fourchette), and hymen.[11] Commonly injured nongenital areas include the mouth, throat, wrist, breasts, and thighs.[12] Oral cavity injuries are common and include a torn frenulum and broken teeth. Bite marks on the genitalia and breast are common.[14] Use a Wood's lamp to examine the skin for fluorescent stains that may represent semen. Use an instant camera or a hospital photographer to document any bites, lacerations, scratches, abrasions, or any other injuries. **Photographs are much more informative than body diagrams.**

Collection of forensic evidence usually precedes the gynecological examination unless the patient is bleeding, has severe lower abdominal pain, or has pelvic pain. Most states have set evidence collection kits and the elements required will vary. Evidence is usually helpful up to 5 days after an assault. It is recommended to collect evidence up to a week after an assault as patients may not recall the dates exactly. Most sexual assault kits require fingernail scraping, head hair combing, saliva specimens, and blood type screening. Swab any stain on the patient's body that fluoresces under the Wood's light. Swab all orifices (oral, vaginal, and anal), even if not penetrated, as recollection of events may change and a negative examination in a nonpenetrated area helps to validate the patient's story. **Use only sterile water or sterile normal saline to moisten a swab.** Obtain samples of the patient's saliva by having them bite on a piece of filter paper in the kit. Obtain a sample of the patient's blood. Place five or six drops of blood on a piece of filter paper. Use a wooden stick to scrape under all the patient's fingernails over a piece of white paper to collect the scrapings. **Allow all specimens to air-dry before placing them in envelopes.**

Collect hair samples from the victim. Pluck two or three hairs from the scalp hair and place it in a labeled envelope. Comb the patient's pubic hair over a white piece of paper. Place the comb, paper, and any hair or debris in a labeled envelope. Pluck two or three hairs from the pubic region and place them in a labeled envelope. The process of plucking hairs is painful and somewhat insensitive to the patient. Consider asking the patient to pluck the hairs for the evidence collection. This allows them to actively participate in the process. These hair samples can also be obtained later if the case is prosecuted, as the patient's hair samples will not change. **Cutting off pieces of hair is of no value as the roots of the hairs are required for the forensic evidence process.**

Inspect the mouth and perioral structures for any signs of trauma. Carefully inspect the frenulum of the lower lip and tongue for bruising or tears. Examine the tonsils, the tonsillar pillars, and the oropharynx for bruising or lacerations. Swab the oral cavity thoroughly and allow the swabs to air-dry. These will later be tested for sperm

acid phosphate and the victim's blood group antigens. Obtain additional swabs for gonorrhea and chlamydia testing in the hospital laboratory. Prepare a wet mount to look for motile spermatozoa.

Thoroughly examine the anorectal area for signs of trauma. This includes abrasions, ecchymoses, and lacerations. Swab the rectum and anal canal. Send one swab to the hospital laboratory for gonorrhea and chlamydia testing. Place the remainder of the air-dried slides in envelopes for later sperm and acid phosphatase testing.

The gynecological examination is usually the most traumatic aspect of the examination for the patient. It may remind them of the assault. **Explain all procedures in simple terms prior to beginning. Allow the patient to help guide the examination.** Do all forensic evidence collection, including combing for pubic hairs and vaginal swabs, at the same time as the gynecological examination. Close attention to the external genitalia is important, as many patients are asymptomatic (**Figure 139-4**). Eight percent of patients have vulvar trauma.[15] **Only use sterile water to lubricate the speculum. Lubricants interfere with forensic evidence collection.** Examination of the hymen is important, as it is one of the most common areas of injury. A person's previous sexual history helps predict the location of lacerations of the vaginal wall. Lacerations are seen near the introitus in less sexually experienced patients and higher in more sexually experienced patients.

Collect baseline gonorrhea and chlamydia swabs at the time of the pelvic examination from pooled vaginal secretions and the endocervical canal. Obtain additional swabs to test for sperm acid phosphatase and blood group antigens. Colposcopy is used to detect and document more subtle injuries of the cervix and vagina. One study showed that colposcopy increased detection of genital trauma from 6% to 53% of victims.[16]

Toluidine blue can be used to identify small lacerations and abrasions that result from traumatic intercourse. It can increase the chances for detection of lacerations in sexual assault victims. Apply the dye with a cotton-tipped applicator to the external genitalia and wipe off the excess. Document and photograph any areas of uptake to toluidine blue. Toluidine blue should be used prior to the speculum examination, as the speculum can result in small lacerations that uptake the dye. Unfortunately, the dye is spermicidal and can interfere with wet mount examinations.

EXAMINATION OF MALE PATIENTS

Males should have a complete urogenital examination looking for abrasions, lesions, and bites (**Figure 139-4**). The same disrobing, specimens, and precautions should be observed in male sexual assault victims. Obtain oral, rectal, and urethral swabs for gonorrhea and chlamydia testing as well as for sperm acid phosphatase.

EXAMINATION OF CHILDREN

The procedure for a child is similar to that of an adult. Children are often referred to pediatric hospitals or specially trained physicians to perform the sexual assault examination. **Defer the sexual assault examination of a child to a specialist if you do not have experience in this area. The anatomy and examination of a child is different from that of an adult.** Restraining an uncooperative or combative child can result in significant psychological trauma. These children may require an examination under procedural sedation or general anesthesia.

LABORATORY INVESTIGATIONS

Decisions regarding STD testing should be individualized given the potential for STD diagnoses to be accessed later despite limitations in all 50 states on the evidentiary use of prior sexual history. Serum testing should be performed for HIV, hepatitis B, and syphilis.[17] These are baseline tests and will be repeated in later follow-up testing. Process the gonorrhea and chlamydia probes at the hospital laboratory. Nucleic acid amplification tests are the preferred tests for *C. trachomatis* and *N. gonorrhoeae* regardless of the site. A wet mount or other point of care testing should be performed for *T. vaginalis*. Toxicology screens should only be performed at the hospital laboratory if there is a medically necessary reason for the test, such as altered mental status. Individual states have protocols for urine testing, which is done at a crime lab to detect date rape drugs.

CHAIN OF EVIDENCE

The work does not stop after the evidence is collected. As each state has different rules for evidence collection, please verify the proper procedure in your current setting. No one should leave or enter the examination room until all evidence is properly tagged and secured. Seal all paper bags and envelopes with evidence tape. Place your signature across the sealed ends of each bag or envelope and the evidence tape. This will make it easier to determine if they have been opened and tampered with. Clearly label each bag or envelope with the patient's name and hospital identification number, the date of collection, the time of collection, the source of the sample, and the printed and signed name of the nurse or assistant. Secure all the evidence in a locked room or cabinet until it can be turned over to a law enforcement officer. Have the officer sign a form stating the officer's name and badge number, the date and time the evidence was transferred, and the name of the physician or nurse releasing the evidence to the officer (Figure 139-1). Both individuals must sign this form.

AFTERCARE

Referral to a Social Worker or Psychiatrist may be necessary, especially if a patient advocate is not available. Treat any injuries in the standard manner. Update the tetanus immune status as necessary. Make a written summary of the physical examination findings for the medical record (**Figure 139-5**). Place any photographs taken in the medical record.

Provide all follow-up instructions in writing (**Figure 139-6**). Arrange medical follow-up with a primary care physician in 1 to 2 weeks and again in 2 to 4 months. The follow-up appointment should include an examination for sexually transmitted diseases, HIV testing, and hepatitis immunizations.

Give all patients a 24 hour crisis phone number as well as a follow-up in 1 to 2 days with the local rape crisis center, if the community has one. The Rape, Abuse, and Incest National Network (RAINN) offers a 24-hour hotline (1-800-656-HOPE) as well as a website (www.rainn.org) with helpful information for the patient.

Arrange, with the help of the advocate or Social Worker, a safe place for the patient to stay. This is especially important if the offender is not in custody. Encourage the patient not to stay by themselves. A patient may need to be hospitalized in rare instances for psychiatric issues from the assault or for the patient's safety.

PREGNANCY PROPHYLAXIS

The risk of pregnancy after a sexual assault is estimated to be approximately 5% if the patient is of reproductive age.[4] Both the American College of Emergency Physicians (ACEP) and the American Congress of Obstetricians and Gynecologists (ACOG) support the provision of emergency contraception to victims of sexual assault.[18,19] There are two categories of emergency contraceptives: emergency contraceptive pills and the Copper-T380A intrauterine device (IUD). The only contraindication to emergency

PLEASE SEE INSIDE BOX COVER

STEP 1

Illinois State Police
Division of Forensic Services

Please print, type or use a patient information stamp.

(patient stamp)

PATIENT CONSENT/AUTHORIZATION TO RELEASE EVIDENCE TO LAW ENFORCEMENT AGENCY

Patient _____

DOB_____ Hospital Patient No. _____

CONSENT

I understand that in addition to consent for medical evaluation and treatment given to the hospital and physician, I also give consent to a medical examination for evidence of sexual assault. I understand that the evidence collected in the State Police Evidence Collection Kit will be sent to the Illinois State Police Forensic Sciences Command for the sole purpose of analysis to determine sexual activity relating to the investigation of sexual assault. I understand that this exam may include reference samples. I also understand that I may withdraw consent at any time for any portion of the exam.

_____
Patient, Parent, Guardian (please circle)

I understand that collection of evidence may include photographing injuries and that these photographs may include the genital area. Knowing this I consent to having photographs taken.

_____
Patient, Parent, Guardian (please circle)

RELEASE

I hereby authorize _____ to release to _____
(Name of hospital) (City) (Law enforcement agency name)

the following information covering treatment given to me on _____.
(Month) (Day) (Year)

	AUTHORIZED FOR RELEASE (check those which apply)	NOT AUTHORIZED FOR RELEASE
1. Copies of Forensic Laboratory Report Form	☐	☐
2. State Police Evidence Collection Kit	☐	☐
3. Photographs	☐	☐
4. X-rays or copies of x-rays taken in connection with exam	☐	☐
5. Clothing	☐	☐

Authorized for release (list clothing or miscellaneous items)

Article	Description
_____	_____
_____	_____
_____	_____

Signature of person authorizing release of information _____
Patient, Parent, Guardian (please circle)

STEP 13

RECEIPT OF INFORMATION

I certify that I have received the following items (check those which apply):

☐ One sealed evidence collection kit ☐ X-rays ☐ Photographs ☐ Swabs/specimens (if no evidence collection kit is used)

☐ Sealed paper clothing bag(s) (if more than one sealed clothing bag, please note) ☐ Other _____

Signature of person receiving information and/or articles_____ Date_____ Time _____

Officer ID# and rank_____ Representative of _____

Name of hospital representative who is releasing articles _____
(Printed name) (Signature)

ILSP501

(White copy to hospital; yellow copy to law enforcement agency)

FIGURE 139-1. Sample form for patient consent and release of information to a law enforcement agency. It includes the receipt of information form to be signed by the law enforcement officer when the evidence is transferred to their care. Courtesy of Illinois State Police.

STEP 2

FORENSIC LABORATORY REPORT
(4 PAGES)

Illinois State Police
Division of Forensic Services

Please print, type or use a patient information stamp.

(patient stamp)

Patient Name	DOB	Age	
Race	Sex	Arrival Date	Arrival Time
Address		City	
County	State	Zip	Phone
Hospital			ER#
For Children: Name of Guardian			Relationship
Person providing history		Relationship to patient	

For children: Avoid multiple interviews. Take time to establish rapport. Avoid leading or yes/no questions. Use direct quotes. Avoid surprise or negative emotions, while still showing concern and support.

1. Chief complaint of person providing history to include physical injuries and methods employed by perpetrator, i.e., weapons, restraint, biting, threats.

2. Chief complaint in child's words to include physical injuries and methods employed by perpetrator, i.e., weapons, restraint, biting, threats.

3. Date of Assault	Time of Assault	4. Location & geographical surroundings of assault

5. Name(s), number, & race of assailant(s) if known.

6. Sexual acts described by patient/historian

Acts Described	Yes	No	Attempted	Unsure
Penetration of vagina by:				
penis				
finger				
foreign object				
describe object				
Penetration of rectum by:				
penis				
finger				
foreign object				
describe object				
Oral copulation of genitals:				
of victim by assailant				
of assailant by victim				

Acts Described	Yes	No	Attempted	Unsure
Masturbation:				
of victim by assailant				
of assailant by victim				
Did ejaculation occur?				
inside body orifice				
outside body orifice				
If outside body orifice, describe location				
Other sexual acts?				
If yes, describe				
Did assailant use condom?				
Did you bite your assailant?				
Were you bitten by your assailant?				
Victim was licked/sucked?				
If yes, where_____				
Victim licked/sucked assailant?				
If yes, where_____				

7. Post-assault hygiene/activity	Yes	No
urinated	☐	☐
defecated	☐	☐
genital wipe/wash	☐	☐
bath/shower	☐	☐
douche	☐	☐
tampon, sponge, diaphragm removed/inserted (circle)	☐	☐
oral hygiene/intake/vomit	☐	☐
changed clothes	☐	☐

8. Pertinent medical history
   a. Date of LMP
   b. Sexual activity within 72 hrs. of assault?
      Yes No
   c. Contraceptive used at time of assault?
   d. Communicable diseases of risk to lab personnel
      (e.g., hepatitis, TB, HIV, lice, etc.)

ILSP502A

(White copy to hospital; yellow copy in kit)

FIGURE 139-2. Sample history form. Courtesy of Illinois State Police.

FORENSIC LABORATORY REPORT — PAGE 2

Please print, type or use a patient information stamp.

(patient stamp)

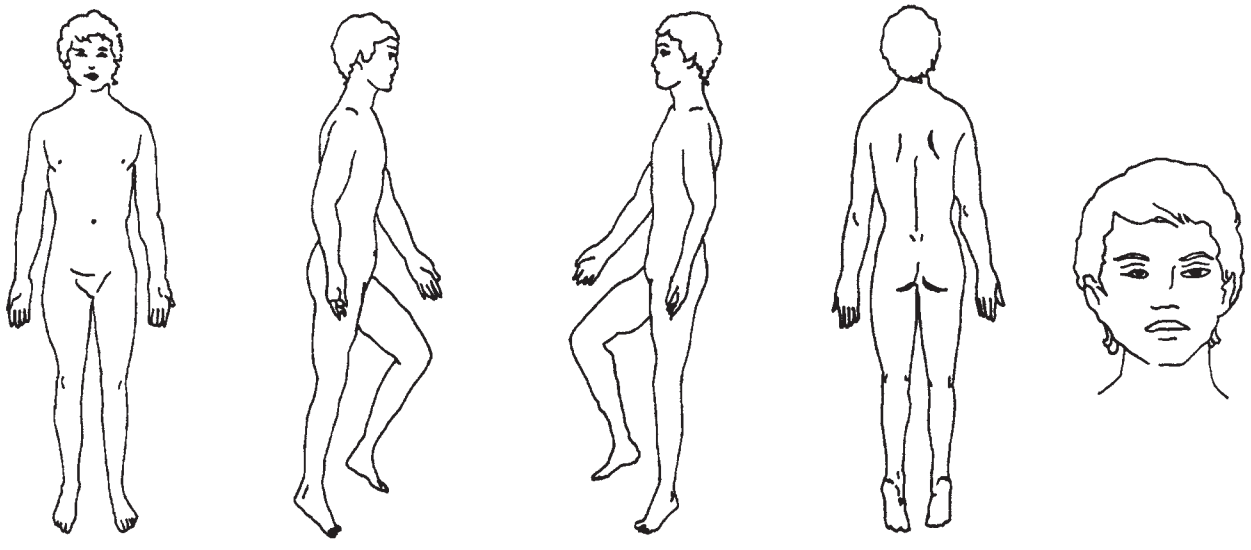
COMPLETE EVIDENCE COLLECTION STEPS 3, 4, AND 5

After STEP 5, obtain appropriate medical specimens from the mouth for clinical lab testing. Patient may rinse out his/her mouth after specimens are obtained. (DO NOT INCLUDE MEDICAL SPECIMENS IN KIT.)

GENERAL EXAM

Trauma should be recorded on the diagrams below which may be used in a criminal proceeding. These include: lacerations, scratches, bruises (detail size, shape, color), erythema, bites, patterned injury, burns, fractures and stains/foreign materials on body, swelling, tenderness. Be sure to note even the most minor signs of trauma. In children: include anogenital or behavioral symptoms. Note general appearance.

Note abnormalities in diagram and/or text.



TEXT

GENITAL EXAM

- For children: Take time to establish rapport and proceed slowly. Extent of examination, including physical as well as specimens, must be decided on a case-by-case basis by the attending physician. If the examination would be too physically or emotionally traumatic for the child, then specimens may need to be obtained by gently using a moist swab on the external vaginal and rectal areas, especially with small hymenal openings.
- Note all discharge, stains, and foreign materials. Note any bleeding.
- Draw shape of hymen and anus in diagrams.
- Use sterile, non-bacteriostatic water or saline for lubrication of speculum.
- Record all acute trauma (lacerations, scratches, bruises [detail size, shape and color], erythema, bites, patterned injury, burns, swelling, tenderness) and chronic trauma (scarring, notching, pigmentary changes) on below diagrams.

ILSP502B

(White copy to hospital; yellow copy in kit)

FIGURE 139-3. Sample general physical examination form with body diagrams. Courtesy of Illinois State Police.

FORENSIC LABORATORY REPORT — PAGE 3

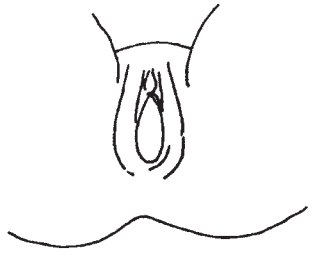
Please print, type or use a patient information stamp.

(patient stamp)

EXTERNAL GENITALIA

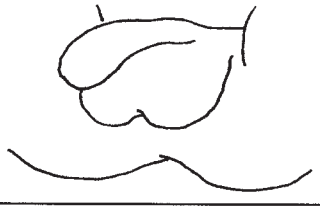
• Note abnormalities in diagrams and/or text.

Vulva/Hymen



• position during exam	lithotomy	knee chest	supine
• labia majora maneuver?	If yes, outward traction		lateral-down separation
• horizontal hymenal opening (with above position and maneuver)			mm
• description of hymen			
• draw picture of hymen on diagram			

Penis/Scrotum

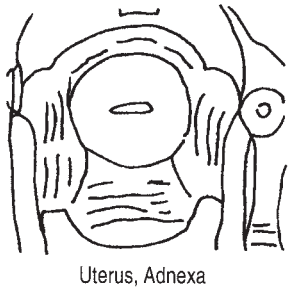


• circumcised? Yes ☐ No ☐

INTERNAL EXAM

• As noted above, most children require only vaginal introital specimens without speculum or bimanual exams. Please individualize.

Vagina and Cervix



Uterus, Adnexa

• Note abnormalities in diagram and/or text.

• Note abnormalities on bimanual exam, if indicated.

COMPLETE EVIDENCE COLLECTION STEP 6

After Step 6, obtain appropriate medical specimens from the vagina/cervix or male urethra for clinical lab testing. (DO NOT INCLUDE MEDICAL SPECIMENS IN KIT.)

RECTAL EXAM

• Digital or anoscopic exam at discretion of physician.

• Note abnormalities on above diagrams and/or text.

COMPLETE EVIDENCE COLLECTION STEPS 7 - 12

After Step 7, obtain appropriate medical specimens from the rectum for clinical lab testing. (DO NOT INCLUDE MEDICAL SPECIMENS IN KIT.) After Step 11, obtain appropriate blood specimens for clinical lab testing. (DO NOT INCLUDE MEDICAL SPECIMENS IN KIT.)

ILSP502C

(White copy to hospital; yellow copy in kit)

FIGURE 139-4. Sample physical examination form with diagrams for the genital examination. Courtesy of Illinois State Police.

FORENSIC LABORATORY REPORT — PAGE 4

Please print, type or use a patient information stamp.

(patient stamp)

Photographs — may be taken for evidentiary purposes with the written consent of the patient or the patient's guardian if the patient is a minor. If the patient is a minor and the parent/guardian is not immediately available, photographs may be taken but shall be released to law enforcement personnel and state's attorneys only with the written consent of the parent/guardian. If consent is refused, all photographs and negatives shall be given, without charge, to the parent/guardian.

SUMMARY OF FINDINGS

SIGNATURES

(Attending Physician Signature) (date)

(Attending Nurse/Assistant Signature) (date)

(Please print)

(Please print)

COMPLETE EVIDENCE COLLECTION STEP 13

FINAL INSTRUCTIONS

1. Make sure all information requested on all sample envelopes and bag labels have been filled out completely.
2. Separate all forms (Steps 1, 2, and 14) and follow distribution requirements on the bottom of each form.
3. With the exception of the large sealed and labeled clothing bags, return all other evidence envelopes/bags to the kit box.
4. Initial and affix red evidence tape on box top.
5. Fill out information required on kit box top.
6. Hand the sealed kit and sealed bags to investigating officer.

NOTE: If officer is not present at this time, place sealed kit and sealed bags in secure area, and hold for pickup by investigating officer.

COMPLETE EVIDENCE COLLECTION STEP 14

ILSP502D

(White copy to hospital; yellow copy in kit)

FIGURE 139-5. Sample form for summary of physical examination findings. Note that the form is signed by the attending physician and the nurse, or assistant, who was present during the examination. Courtesy of Illinois State Police.

Illinois State Police
Division of Forensic Services

STEP 14

Please print, type or use a patient information stamp.

(patient stamp)

PATIENT DISCHARGE MATERIALS

Patient name	DOB/Age
Hospital name/phone	
Date of examination	ER#
Examining physician	

With your consent, a number of specimens were collected from you to provide evidence in court should your attacker be caught and you decide to prosecute.

Additional tests were conducted as follows: ☐ A blood test for syphilis, ☐ A culture for gonorrhea, ☐ Tests for chlamydia, ☐ Other tests_____

_____, and ☐ A pregnancy test to determine pre-existing pregnancy only, not to determine a possible pregnancy as a result of the assault.

VENEREAL DISEASE TREATMENT

☐ You were given an antibiotic to prevent gonorrhea. However, you must return in six weeks following this treatment for another test to be sure you do not have syphilis. Return for this test and possible treatment the week of _____ name of drug _____ dosage _____

☐ You were *not* given treatment to prevent gonorrhea or any other venereal disease because _____

☐ If you wish to obtain follow-up testing or treatment for venereal disease, please visit your local health clinic or contact _____

_____ (name, address, and telephone)

☐ Patient declines

PREGNANCY PREVENTION

☐ You were given medication to prevent pregnancy as a result of the sexual assault. If you should become pregnant despite having been given treatment, you should return immediately to the hospital emergency room or go to your private physician because the drug you were given may cause damage to the fetus. Name of drug _____ Dosage_____

☐ You were *not* given medication to prevent pregnancy because _____

If you want counseling, referrals and/or follow-up pregnancy testing information, consult the social service department of this hospital or call one of the agencies listed below for assistance.

Agency _____ Agency _____

Address _____ Address _____

Telephone _____ Telephone _____

☐ Patient declines

FOLLOW-UP

☐ An appointment was made for you at this hospital for follow-up *medical* treatment on (date) _____

☐ No appointment was made for follow-up medical treatment because _____

☐ An appointment was made for you at this hospital for follow-up *counseling* on (date) _____

☐ No appointment was made for follow-up counseling because _____

PSYCHOLOGICAL SUPPORT referral to

Was written and verbal information given to patient? ☐ Yes ☐ No

DOCUMENTATION

If the patient is less than 18 years of age, was DCFS notified, if appropriate? ☐ Yes ☐ No

Were police notified? ☐ Yes ☐ No Was Patient Consent and Authorization Form completed? ☐ Yes ☐ No

INFORMATION

I have received the following written information:

☐ Illinois Department of Public Health brochure, "After Sexual Assault" ☐ Attorney General's Office flyer "Illinois Crime Victims Compensation Act"

☐ Patient Medication information sheets listing anticipated effects and side effects of medicines given to me.

☐ This patient information sheet _____

Patient Signature Date

☐ I do not wish to receive this sheet _____

Patient Signature Date

ILSP514

(White copy to patient; yellow copy to hospital)

FIGURE 139-6. Sample patient discharge instruction form. Courtesy of Illinois State Police.

contraception is pregnancy. Emergency contraceptive pills will not harm an existing pregnancy. IUD placement may disrupt a pregnancy or increase the risk of a serious infection and septic abortion. Early emergency contraceptive pills consisted of high doses of common oral contraceptive pills (Yuzpe method).[20] Emergency contraceptives which contain only the progestin component (levonorgestrel) are both better tolerated and more effective than the Yuzpe method.[21] Recent data have shown that a single, 1.5 mg dose of levonorgestrel to be equally effective up to 5 days after unprotected intercourse.[22]

In August 2010, the FDA approved ulipristal acetate (Ella®) for emergency contraception. Studies have shown pregnancy rates 42% lower than levonorgestrel when used up to 72 hours after unprotected intercourse, and 65% lower when used between 72 and 120 hours after.[23,24]

The Copper-T380A IUD (ParaGard®) is the most effective form of emergency contraception and can be inserted up to 8 days after unprotected intercourse.[25] There is no evidence to support the routine use of prophylactic antibiotics prior to placement of an IUD.[26] However, antimicrobial prophylaxis is recommended after sexual assault as described in the next section.

While ACOG believes that "emergency contraception should be available in hospitals and facilities where victims of sexual assault at risk of pregnancy are treated,"[19] there are hospitals that prohibit contraception and practitioners who morally object to it. In such cases, patients should be promptly referred to a center where they can receive the appropriate treatment.

ANTIMICROBIAL PROPHYLAXIS

Postexposure prophylaxis for sexually transmitted diseases is recommended since compliance with follow-up visits is poor. The risk of acquiring a sexually transmitted disease is relatively high and the side effects from the medications is relatively low. The most common infections diagnosed during sexual assault exams are trichomonas (12%), bacterial vaginosis (12%), gonorrhea (4% to 12%), and chlamydia (2% to 14%).[27,28] The current recommendation is to provide prophylaxis for gonorrhea and chlamydia. The current CDC guidelines recommend an empiric antibiotic regimen for chlamydia, gonorrhea, and trichomonas. The current CDC recommendation is intramuscular ceftriaxone (250 mg) or oral cefixime (400 mg) plus oral metronidazole (2 g) plus oral azithromycin (1000 mg) or doxycycline (100 mg) twice a day for 7 days.[17] The current guidelines do not recommend prophylaxis for syphilis. The treatment for bacterial vaginosis and trichomonas is a single 2000 mg dose of oral metronidazole. Trichomonas prophylaxis is controversial as ascending infections are rare. The side effects include significant nausea that may interfere or complicate pregnancy prophylaxis. As resistance emerges to various treatments, a yearly check of the current CDC guidelines is advisable.

Hepatitis B vaccination, without HBIG, is recommended if the patient has not been previously vaccinated.[17] This is especially important in high-risk exposures such as unprotected penetration, contact with the assailant's blood, or contact with the assailant's body fluid. Provide the first dose of the hepatitis B vaccine in the Emergency Department. Boosters are recommended at 1 to 2 months and 4 to 6 months.

There are no clear guidelines for postexposure prophylaxis for HIV. Clinical factors increasing the risk of HIV infection include the site of penetration (oral is lowest vs. vaginal vs. rectal being highest), trauma, and the presence of lesions from other STDs in the assailant or the victim. Possible benefits of postexposure prophylaxis should be discussed with the patient with case-specific risks and benefits of HIV prophylaxis. Have a specific discussion regarding the importance of adherence, close follow-up, and early initiation.[17] Consult the CDC website (www.cdc.gov) for the most current medication regimens for prophylaxis.

Treatment for the male sexual assault victim is the same except for trichomonas treatment and pregnancy prophylaxis. These are not necessary in the male patient.

If there are any questions, contact the National Clinician's Postexposure Prophylaxis Hotline (PEP Line) at 1-888-448-4911.

COMPLICATIONS

There are no physical complications to performing the sexual assault examination. **Be aware of potential psychological complications. Treat the patient with the utmost privacy and dignity to help them through this stressful situation and not victimize them. Do not add to the abuse that they have already suffered. Allow the patient to make decisions during the history and physical examination so that they have a voice in the process.**

SUMMARY

The Emergency Department plays a key role in providing quality treatment to the sexual assault victim. Providing compassionate care strongly influences the healing process from being a victim to becoming a survivor. It is important to perform a complete examination for trauma and not just focus on evidence collection. Careful collection and documentation of the elements of the evidence collection kit will impact successful prosecution. Proper follow-up care and a strong link to a local rape crisis center are important.

140 Culdocentesis

David L. Levine

INTRODUCTION

Culdocentesis is a procedure used to sample peritoneal fluid to help confirm a diagnosis or to obtain a culture. It has mainly been used for diagnosing a ruptured ectopic pregnancy or ruptured ovarian cyst.[1–9] Culdocentesis involves introducing a hollow needle through the posterior vaginal cuff and into the peritoneal space. This is a relatively simple and fast procedure. Ultrasound, with its improved resolution and availability, has virtually replaced culdocentesis as the test of choice.

ANATOMY AND PATHOPHYSIOLOGY

The key anatomy to be familiar with is the vagina and the pouch of Douglas, also known as the rectouterine pouch or the cul-de-sac. The rectouterine pouch is formed by reflections of the peritoneum between the posterior surface of the uterus and the anterior surface of the rectum. It is the most dependent intraperitoneal space in both the upright and supine positions. This allows blood, pus, and other free fluids to pool in this space. The rectouterine pouch separates the upper portion of the rectum from the uterus and the upper portion of the vagina. The small intestine and a small amount of peritoneal fluid often lie within the rectouterine pouch. The sensory innervation of the vagina is greatest near the introitus. There is minimal sensory innervation in the posterior vaginal fornix adjacent to the rectouterine pouch.

INDICATIONS

Culdocentesis has been used in the Emergency Department in the past to diagnose a ruptured viscus, particularly an ectopic pregnancy. The use of culdocentesis has decreased significantly with the emergence of improved serum and urine tests for pregnancy, increased accessibility to ultrasonography, and the increased resolution of ultrasound. Recent studies have clearly shown ultrasonography to be more sensitive and noninvasive in detecting a hemoperitoneum.[1] Despite this, there still remains three main indications to perform a culdocentesis.

The first indication is a hemodynamically unstable female patient of reproductive age with evidence of peritoneal irritation in the pelvic region. This patient most likely has a ruptured ectopic pregnancy and needs emergent surgery. A diagnostic test is usually not necessary to take the patient directly to the Operating Room if a rapid pregnancy test is positive. An unstable patient cannot be sent to the Radiology Department for an ultrasound. A culdocentesis may be performed if bedside ultrasonography is not available. Many Emergency Departments now have the availability of bedside ultrasound or have Radiology Technician available to perform bedside ultrasounds. Approximately 85% to 90% of patients with ruptured ectopic pregnancies have a positive culdocentesis.[2]

The second indication for a culdocentesis is a stable pregnant patient with ultrasonographic evidence of free fluid in the pelvis or pouch of Douglas. A culdocentesis can confirm if the fluid is blood. Approximately 65% to 70% of patients who have a stable presentation and unruptured ectopic pregnancy have a positive culdocentesis.

A culdocentesis is indicated if ultrasonography or laparoscopy is not readily available. A negative culdocentesis may be used to reassure the Emergency Physician that following serial quantitative beta-HCG levels can be performed before committing a stable patient to an operative procedure. A positive culdocentesis would indicate intraabdominal bleeding that requires immediate operative intervention.[3]

Other indications for a culdocentesis include the evaluation of ascites, blunt abdominal trauma, or in cases of pelvic inflammatory disease. It can be performed to obtain ascitic fluid to evaluate for infection, malignancy, or the type of fluid (i.e., exudate or transudate). Culdocentesis has been used in place of a diagnostic peritoneal lavage to detect a hemoperitoneum in blunt abdominal trauma since small amounts of blood tend to collect in the rectouterine pouch. Aspiration of clear peritoneal fluid excludes a hemoperitoneum. Ultrasonography and CT scanning have significantly reduced the usefulness of culdocentesis for this indication. Intraperitoneal fluid from patients with pelvic inflammatory disease can be cultured to guide treatment, especially in treatment-resistant cases.

CONTRAINDICATIONS

There are a few contraindications to performing a culdocentesis. Ultrasonography is the preferred diagnostic method to confirm intraperitoneal bleeding if it is available in a timely manner. A pelvic mass detected on bimanual pelvic examination is a contraindication. A pelvic mass may be a tubo-ovarian abscess, an appendiceal abscess, an ovarian mass, or a pelvic kidney. There is a concern of rupturing an abscess, if present, into the peritoneal cavity with the culdocentesis needle. Other contraindications include a nonmobile uterus and patients with a coagulopathy. The procedure is limited to patients beyond puberty on the basis of anatomy. It is difficult to perform the procedure through a small prepubertal vagina. **A patient with unstable vital signs and a positive bedside pregnancy test should be immediately taken to the Operating Room and does not require a culdocentesis; although they will require fluid and blood resuscitation until the Operating Room and Surgeon are available.**

Culdocentesis may be unsatisfactory in women with previous salpingitis and pelvic peritonitis because the rectouterine pouch may have been obliterated. **The failure to obtain blood does not exclude the diagnosis of a hemoperitoneum and, therefore, cannot exclude an ectopic pregnancy.**[4]

EQUIPMENT

- Exam table with stirrups
- Water-soluble lubricant
- Vaginal speculum
- Cervical tenaculum
- 19 gauge butterfly needle or 18 gauge spinal needle
- 25 and 27 gauge needles
- Ring forceps
- 20 mL aspirating syringe
- Povidone iodine or chlorhexidine solution
- Sterile water
- Cotton balls
- 4 × 4 gauze squares
- Local anesthetic solution with epinephrine
- 4% cocaine
- 20% benzocaine
- Red top test tube for laboratory analysis
- Purple top test tube for laboratory analysis
- Culture tubes
- Light source

PATIENT PREPARATION

Explain the risks, benefits, potential complications, and alternatives (such as ultrasound or immediate laparoscopy) to culdocentesis to the patient and/or their representative. Obtain a signed consent for the procedure. If verbal consent is obtained, a statement in the chart should state the following: "The risks, benefits, alternatives, and complications were described and discussed in detail. The patient has a clear understanding of these and any questions were answered." A witness should be noted in the record.

Perform a bimanual pelvic examination to rule out a fixed pelvic mass and to assess the position of the uterus prior to the culdocentesis. Place the patient in the lithotomy position with the head of the table slightly elevated (i.e., reverse Trendelenburg) so that the intraperitoneal fluid gravitates into the rectouterine pouch. Place the patient's feet in stirrups. Procedural sedation or premedication with intravenous narcotics or sedatives is recommended and may make the procedure more tolerable for the patient. Premedication is not required in an unstable patient.

Some Emergency Physicians obtain stat upright plain radiographs in stable patients prior to the procedure. These are performed to assess for a pneumoperitoneum. This will also help in determining if a pneumoperitoneum was secondary to the procedure upon obtaining postprocedural radiographs.

TECHNIQUES

Insert a lubricated speculum as deep into the vagina as possible without causing the patient discomfort. Open the speculum widely so the blades are above and below the cervix (**Figure 140-1C**). Grasp

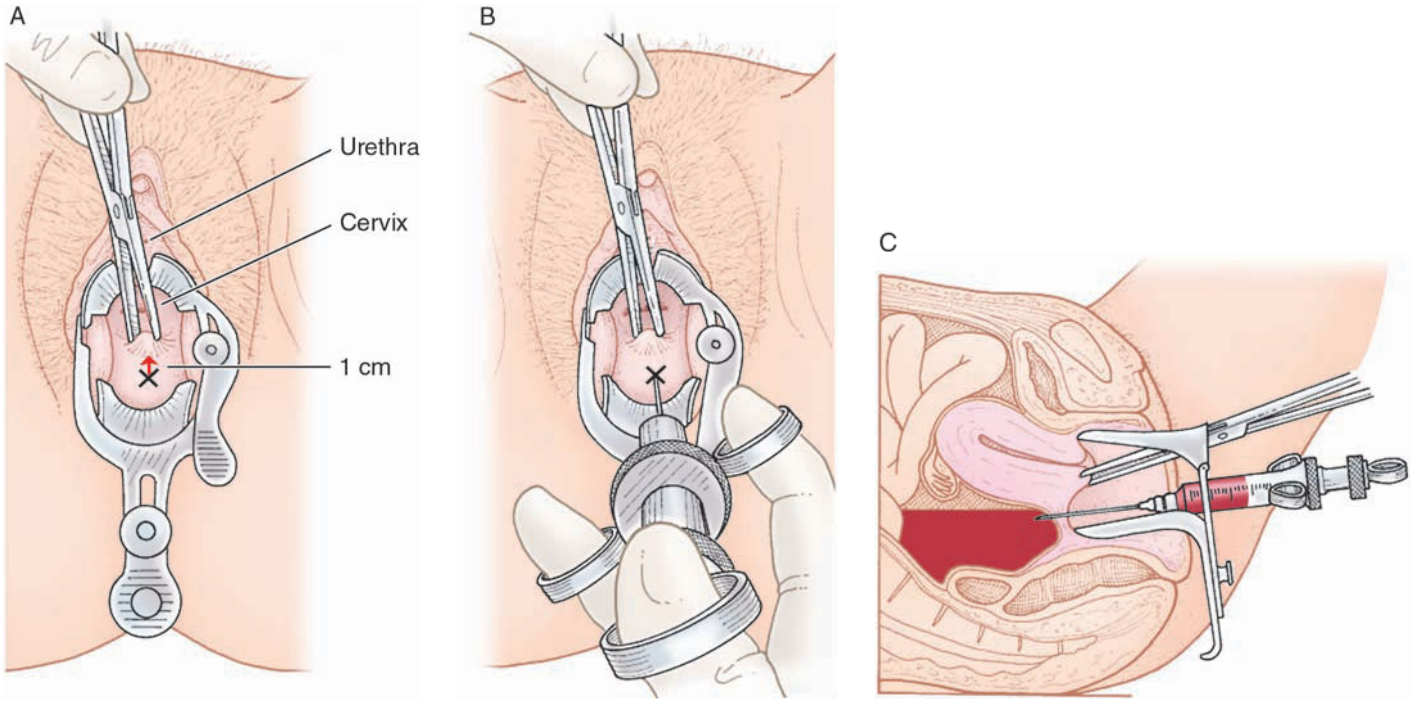


FIGURE 140-1. Culdocentesis. A speculum has been inserted in the vagina and opened. **A.** Grasp the posterior lip of the cervix with a toothed tenaculum and elevate it. The "X" marks a spot 1 cm from the junction of the cervix and posterior vaginal wall where the needle will be inserted. **B.** The needle used for anesthesia and culdocentesis are inserted 1 cm from the junction of the cervix and posterior vaginal wall. **C.** Midsagittal section of the female pelvis during a culdocentesis. The needle is inserted and aimed slightly posterior to access the fluid.

the posterior lip of the cervix with the toothed tenaculum or a ring forceps (**Figure 140-1A**). **Forewarn the patient that grasping of the cervix with a tenaculum may be painful.** Elevate the cervix to elevate a retroverted uterus from the pouch and to stabilize the posterior wall of the uterus during the needle puncture. This also results in a tightening of the vaginal wall adjacent to the rectouterine pouch to expose the puncture site and keep it from moving away from the needle as the vaginal wall is punctured.

Prepare the area. Swab any secretions out of the vagina. Swab the vaginal wall in the area of the rectouterine pouch with povidone iodine or chlorhexidine followed by sterile water. Some Emergency Physicians may optionally choose to topically anesthetize the area with a cotton ball soaked in 4% cocaine or 20% benzocaine prior to infiltrating with local anesthetic solution. Insert the cocaine or benzocaine soaked cotton ball into the posterior vaginal fornix area and allow it to remain for 3 minutes. The maximum dose of cocaine to apply to the cotton ball is 3 mg/kg. Arm a 5 mL syringe containing local anesthetic solution with epinephrine with a 25 gauge needle. Insert the needle in the midline and 1.0 cm posterior (inferior) to the point at which the posterior vaginal wall joins the cervix (**Figure 140-1B**). Inject 2 mL of local anesthetic solution containing epinephrine into the tissues of the vaginal wall.

Fill a 20 mL aspirating syringe with 2 to 3 mL of sterile saline. Local anesthetic solution can be used instead of saline, but note that it is bacteriostatic and any aspirated fluid cannot be cultured. Attach an 18 gauge spinal needle to the 20 mL syringe. Insert the spinal needle parallel to the lower blade of the speculum. Penetrate the vaginal wall in the midline and 1.0 cm posterior (inferior) to the point at which the vaginal wall joins the cervix (**Figure 140-1C**). Advance the needle 2.0 to 2.5 cm.[4,5] Slowly inject 0.5 to 1.0 mL of saline. It should flow freely and without resistance if the needle is within the rectouterine pouch (**Figure 140-1C**). It may otherwise be within the wall of the uterus or intestines. Withdraw and redirect the tip of the needle until the saline flows freely upon injection. Apply negative pressure to the syringe while slowly withdrawing the needle. **It is important to avoid aspirating any blood that has accumulated in the vagina from previous needle punctures or cervical bleeding.**

Fluid may not be aspirated. Withdraw the needle and reintroduce it slightly to the left or right of the midline. Avoid directing the needle too far laterally. This can result in the puncture of a mesenteric or pelvic vessel. Always repeat the procedure once if no fluid is obtained on the first attempt.

Place some of the peritoneal fluid into a red top and purple top test tube. Place some of the fluid into aerobic and anaerobic culture tubes. Observe the fluid for clotting. Transport the samples to the laboratory for Gram's stain, culture, cell count, and hematocrit.

ALTERNATE TECHNIQUES

Slight alterations in the described technique have been used successfully. Longitudinal traction on the cervix instead of grasping and elevating the posterior lip of the cervix is sometimes used to elevate the uterus. A 19 gauge butterfly needle held with ring forceps can be used instead of the spinal needle (**Figure 140-2**). This allows for good control of the needle during the puncture and also offers a built-in guide for needle depth. An assistant is required for this alternative to aspirate the tubing while the Emergency Physician positions and withdraws the butterfly needle.

ASSESSMENT

A normal culdocentesis when there is no pathology should yield 2 to 4 mL of clear-to-yellowish peritoneal fluid. There is no diagnostic value when there is no return of fluid of any type, also known

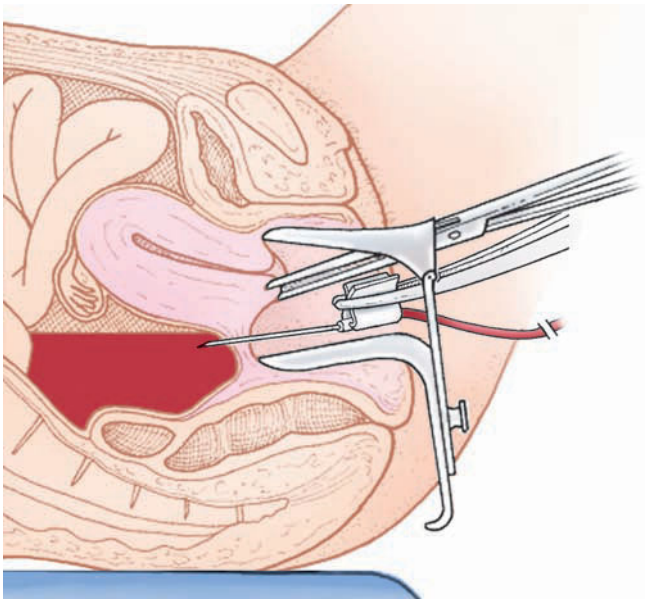


FIGURE 140-2. The alternate technique of using a butterfly needle and ring forceps to perform a culdocentesis.

as a dry tap. It is considered nondiagnostic if less than 2 mL of clotting blood is obtained. This may have come from a puncture site on the vaginal wall.

A hemoperitoneum is signified by the aspiration of more than 2 mL of nonclotting blood. It has been suggested that as little as 0.3 mL of nonclotting blood equates with a positive tap.[6] The finding of nonclotting blood with a hematocrit greater than 15% has been 70% to 97% predictive of a significant bleeding source, such as ectopic pregnancy.[3] Approximately 70% to 83% of ectopic pregnancies will have nonclotting blood on culdocentesis. In addition, 10% to 20% of ectopic pregnancies will have a negative or nondiagnostic culdocentesis. False positives will occur in 2% of cases.[7]

Culdocentesis is less sensitive with unruptured ectopic pregnancies, 70% versus 85% to 90% positive rate.[8] The quantity of blood greater than 2 mL has no further significance as it may be related to needle position or rate of bleeding. Blood remains nonclotted for days in the syringe due to defibrination activity of the peritoneum. A ruptured ectopic pregnancy, a hemorrhagic ovarian cyst, or a ruptured spleen can all result in a hemoperitoneum. Peritoneal bleeding usually has a hematocrit of greater than 10%. One study showed that 97% of cases with an ectopic pregnancy had a hematocrit of at least 15%.[9]

A positive culdocentesis with a positive pregnancy test is not always an ectopic pregnancy. A ruptured corpus luteum cyst is the most common cause of a false-positive result. The false-positive rate is estimated at 9%.

A culdocentesis is considered negative when the aspirated fluid is pus, cystic, or straw-colored if performed for the purpose of diagnosing an ectopic pregnancy. Greater than 10 mL of clear fluid most likely indicates a ruptured ovarian cyst, aspiration of an intact corpus luteal cyst, ascites, or possibly carcinoma. **Obtaining greater than 10 mL of clear fluid does not automatically rule out an ectopic pregnancy since it may coexist with other pathology.**[2]

Ultrasound was far superior in recent studies comparing ultrasound versus culdocentesis. The sensitivity and specificity of echogenic fluid for establishing a hemoperitoneum were 100% and 100%, respectively, compared with 66% and 80%, respectively, for culdocentesis.[1] The negative predictive value of a nondiagnostic culdocentesis was 25% compared to 100% for echogenic fluid in the ectopic pregnancy subgroup of patients.[1]

AFTERCARE

Aftercare is limited to local wound care of the puncture site. Proper postsedation monitoring and precautions are necessary. Bleeding from the tenaculum puncture sites on the cervix or the vaginal wall puncture site is usually self-limited. Apply manual pressure with a gauze square to provide hemostasis. Obtain upright plain radiographs to rule out an iatrogenic pneumoperitoneum from the procedure.

COMPLICATIONS

Complications associated with performing a culdocentesis are rare. The most common and serious complication reported includes the rupture of an unsuspected tubo-ovarian abscess.[4] Other complications include puncture of the gravid uterus, bowel perforation, perforation of a pelvic kidney, and bleeding from the puncture site in patients with bleeding disorders. Bowel and uterine wall punctures usually do not result in serious morbidity. Most complications are eliminated by a careful bimanual examination to detect a pelvic mass prior to the procedure.

SUMMARY

Culdocentesis can be very useful in evaluating for an ectopic pregnancy. It is easy to perform, rapid, and relatively safe. Its utility has decreased as the test of choice with the improved capability and availability of ultrasonography. It is indicated when ultrasound is not available or a patient is unstable and bedside ultrasonography is unavailable.

141 Prolapsed Uterus Reduction

Eric R. Snoey

INTRODUCTION

There is a progressive relaxation of pelvic support for the uterus and vagina with advancing age. This relaxation may in turn lead to symptomatically important uterine prolapse in susceptible women. The quality of life issues associated with uterine prolapse have become increasingly more relevant with women living a third of their lives in the susceptible period after menopause. Population-based studies note that up to 10% of women report symptoms of pelvic organ prolapse. The Women's Health Initiative study found evidence of uterine prolapse on physical examination in 14% of study participants. Manual reduction of the prolapsed uterus and placement of a pessary represents a safe and temporizing measure that may be performed in the Emergency Department. Surgical correction may ultimately be necessary. It is estimated that pelvic organ prolapse is responsible for more than 200,000 surgical repair procedures each year (22.7 per 10,000 women). This chapter will address the nonsurgical management of a prolapsed uterus.[1–4]

The structural support of the female pelvis is subject to a number of identifiable stresses that may predispose certain women

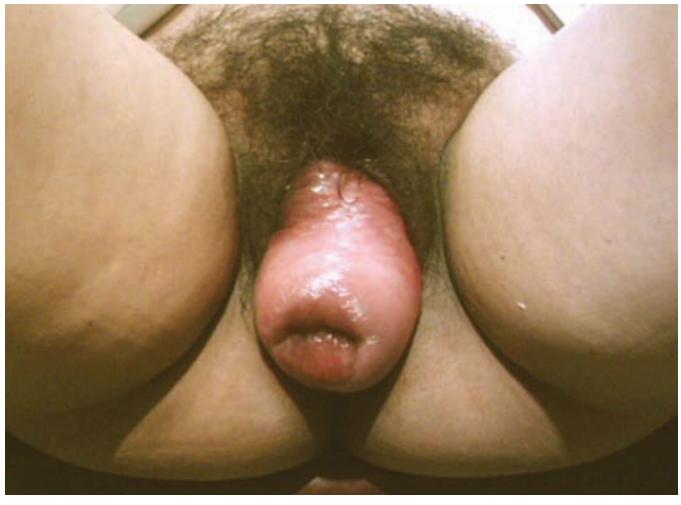


FIGURE 141-1. Uterine procidentia (Used with permission from: Cunningham GF, et al: *Williams Obstetrics*, 23rd ed, 2010).

to uterine prolapse later in life. Multiparity seems to be the most commonly shared trait, suggesting that birth trauma has a primary role to play. Alternative mechanisms include anything that may increase intraabdominal pressure, such as heavy lifting, ascites, obesity, large intraabdominal tumors, or pelvic tumors. Similarly, chronic respiratory disorders (e.g., asthma, bronchitis, or emphysema) may put undue tension on the pelvic floor musculature.[5] Two cases of acute uterine prolapse after restrained motor vehicle collisions were recently described.[6] It was hypothesized that the sudden increase in intraabdominal pressure from the lap belt was the cause of the prolapse. A congenital form of uterine prolapse may be seen in newborns due to vigorous crying.[7] The integrity of the pelvic connective tissues may have a role to play as suggested by the increased incidence of uterine prolapse in women with Marfan syndrome and other connective tissue disorders.[8]

Uterine prolapse is defined as the descent of the uterus and cervix down the vaginal canal toward the vaginal introitus. All forms of genital prolapse are described in reference to the hymen. The uterine displacement is typically graded on a scale of 0 to 4, with 0 referring to no prolapse, 1 halfway to the hymen, 2 at the hymen, 3 halfway out of the hymen, and 4 referring to total proplapse.[3] A first-degree or mild prolapse is defined with the cervix palpable as a firm mass in the lower third of the vagina. Patients with grades 0 or 1 prolapse are usually asymptomatic. Grade 3, or moderate prolapse, is characterized by the cervix being visible and projecting into or through the vaginal introitus. The patient may experience a falling-out sensation or may report the feeling of sitting on a ball. Additional symptoms include heaviness in the pelvis, low backache, lower abdominal discomfort, and inguinal discomfort. Grade 4, also known as severe prolapse or procidentia, involves the cervix and entire uterus projecting through the introitus, completely inverting the vaginal vault (**Figure 141-1**).[9] The uterine mass frequently has one or more areas of easily bleeding atrophic lesions secondary to exposure and local pressure effects. It may result in leukorrhea, abnormal uterine bleeding, or spontaneous abortions.[5]

ANATOMY AND PATHOPHYSIOLOGY

The pelvic diaphragm, the endopelvic fascia, and the vagina provide the primary support for the pelvic organs. The superficial muscles of the perineum lie below the pelvic diaphragm and indirectly support the pelvic organs by inserting centrally into the perineal body. The perineal body serves to fix the distal vagina and anus. The bony pelvis is the ultimate support for all the soft tissues of the pelvis.[8]

The pelvic diaphragm is made up of a bilaterally paired group of three striated muscles: the pubococcygeus (including the puborectalis), the iliococcygeus, and the coccygeus. The pelvic diaphragm is innervated by fibers originating from sacral segments four and five. The pelvic diaphragm is normally in a state of tonic contraction. It increases its tone reflexively in response to increases in intraabdominal pressure.[8]

The endopelvic fascia is the layer of fibrous connective tissue that envelops all pelvic organs. The endopelvic fascia develops supportive thickenings along lines of tension that are referred to as ligaments (e.g., uterosacral and cardinal ligament complex). These ligaments provide further support for the pelvic structures. The uterosacral and cardinal ligaments suspend the uterus and are in fact simple extensions of the endopelvic fascia.[8]

The vagina has supportive functions as well. The uterosacral and cardinal ligaments shift the upper one-third of the vagina posteriorly and laterally. This provides support for the cervix. The middle third of the vagina is attached bilaterally to the fascia overlying the pelvic sidewall musculature and supports the bladder. The lower third of the vagina is fused to the tissues about the vaginal outlet.

There are numerous causes that lead to the development of a prolapsed uterus. Prolonged labor can lead to significant pelvic floor damage, suggesting that women who delivered vaginally or who later required cesarean section because of failure to progress are more at risk.[8] As yet, no factor has been identified that allows the identification of apparently normal individuals in which pelvic floor dysfunction is destined to develop after vaginal delivery.[8] The quantity and quality of collagen appears to deteriorate in women after menopause, likely attributable to the resultant estrogen deficiency.[11,12] It is thought that defective connective tissue contributes significantly to uterine prolapse in the absence of other risk factors. One study of premenopausal women with uterine prolapse found a 25% reduction in the collagen content of tissues.[12] Conditions that affect spinal cord pathways and pelvic nerve roots (e.g., muscular dystrophy, trauma, myelodysplasia, meningomyelocele) can result in paralysis of the pelvic floor with the subsequent prolapse of pelvic structures. Spina bifida has been associated with the majority of cases of uterine prolapse in newborn girls and nulliparous women.[8]

Increased intraabdominal pressure is a major factor in the development of pelvic organ prolapse. Obesity contributes to pelvic prolapse by increasing intraabdominal pressure that is, in turn, transmitted to the pelvic organs. Chronic respiratory conditions that are associated with forceful coughing are also thought to predispose to uterine prolapse. Occupational and recreational activities, such as heavy lifting or repeated jumping, result in repeated and prolonged increases in intraabdominal pressure. A review of 1.6 million women found an increase risk of uterine prolapse in a group of nurses whose jobs required heavy lifting.[8] The deterioration in muscle function and connective tissue associated with aging together with gravity, childbirth, neurological deterioration, and hormonal status all combine to lead to a progressive decline in pelvic floor function in older women. This may be compounded by factors that increase intraabdominal pressure leading to the development of symptomatic pelvic floor prolapse.[11]

All aspects of the vaginal support should be carefully surveyed when examining a patient with a uterine prolapse. Look for the presence of a cystocele or rectocele. Examine the patient in the standing position, as well as in the standard dorsal lithotomy position, since the prolapse is almost invariably worse when the patient is upright.[11] It may be necessary to have the patient strain to assess

the full extent of the prolapse.[15] The examination may be facilitated by having the patient stand with one foot on a well-supported footstool. Some degree of a cystocele, urethrocele, enterocele, or rectocele may develop or may be associated with a uterine prolapse as the uterus progressively descends. Some authors recommend expanding the traditional speculum examination by using a single blade speculum (e.g., Sims speculum) to selectively visualize each portion of the vaginal vault for defects in pelvic support. Perform a rectovaginal examination with the patient in the standing position to detect an occult enterocele, suggested by the presence of small bowel easily palpable in the cul-de-sac using the thumb and forefinger.[13,14]

Asymptomatic uterine prolapse requires no treatment in the Emergency Department. The patient with only intermittent symptoms can prevent against prolapse by simply inserting a tampon or a diaphragm. This additional support may be used in anticipation of increased activity or prolonged periods of standing. The patient, however, should be informed that she is losing some aspects of pelvic support and should be referred to a Gynecologist for evaluation of future treatment options.[7] Lifestyle changes can prevent the progression or recurrence of prolapse, precluding the need for future surgical evaluation and complications. Most of these changes focus on decreasing unnecessary increases in intraabdominal pressure like losing weight, removing girdles, avoiding heavy lifting, stopping smoking, and treating allergies or pulmonary disease accordingly.[1] Kegel proposed a series of pelvic muscle exercises for the treatment of urinary incontinence, which can accompany uterine prolapse. These exercises strengthen the pelvic muscles and may be helpful early. They are of limited value in patients with significant prolapse since fascial attachments have already been disrupted.[7,16]

Symptomatic women can be treated conservatively or surgically. Pelvic organ prolapse is frequently not recognized until advanced disease is present because prolapse does not become symptomatic until the descending segment is at or through the introitus.[10] Therapeutic options are variable and relate to the age and health of the patient, the severity of the symptoms, and the degree of prolapse. The options for uterine prolapse include observation, reduction with or without supportive pessary therapy, vaginal hysterectomy with corrective therapy for pelvic relaxation (hysteropexy), and some form of colpocleisis (surgical obliteration of the vagina).[17]

INDICATIONS

Conservative management of symptomatic uterine prolapse in the Emergency Department involves reduction and subsequent fitting of the patient with a pessary. The pessary is largely used as an alternative to surgery or as a temporizing measure in patients awaiting surgery.[18] Preoperative use of a pessary in advanced degrees of prolapse may aid in decongesting the mucosa, improving circulation, and reestablishing vaginal tonicity. Patients desiring surgical management may be treated conservatively in the Emergency Department and referred to a Gynecologist. Symptomatic women who wish to complete childbearing before having a surgical repair may also be candidates for a vaginal pessary.[1] The gynecologic and obstetric indications for pessary support after reduction of the prolapsed uterus are listed in **Table 141-1**.[5]

CONTRAINDICATIONS

There are no absolute contraindications to the manual reduction of a prolapsed uterus. Pessaries are contraindicated in patients with acute genital tract infections and in those with adherent retroposition of the uterus.[5] Any vaginal inflammation, ulceration, infection, or atrophy should be treated before pessary fitting to decrease the likelihood of vaginal erosions and granulation tissue formation. These latter conditions can be mitigated by oral or topical estrogen supplementation. The use of large amounts of lubricants, such as K-Y Jelly, should be encouraged with the pessary in the event that estrogen is contraindicated.[18] Other contraindications include patients with impaired mental capacity, lack of patient dexterity, a history of noncompliance, or severe atrophic mucosal changes.

TABLE 141-1 The Indications for the Placement of a Pessary[5]

Gynecologic indications
Nonsurgical management of uterine prolapse
Aid in the healing of cervical stasis ulceration associated with uterine prolapse
Reduction of a cystocele, enterocele, or rectocele
To alleviate the complications of free uterine retroposition and adnexal prolapse
To determine if future hysteropexy will relieve backache associated with uterine malposition
To facilitate hysteropexy by holding the uterus in position for operation
To control stress urinary incontinence
To reduce infertility due to cervical retroposition
Obstetric indications
To avoid threatened abortion due to uterine retroposition and chronic passive congestion
To relieve urinary retention and/or pain that can accompany uterine retroposition in pregnancy
To prevent postpartum subinvolution or retroversion of uterus
To prevent and protect against abortion in cervical incompetence

EQUIPMENT

- Pessaries
- Standard pelvic bed
- Vaginal speculum
- Water-soluble lubricant
- Culture swabs
- Biopsy and Pap smear brush, optional
- Uterine forceps
- Sterile gloves
- Sedation, as needed

The vaginal pessary is of ancient lineage. They are now made of plastic, rubber, or silicone that functions to support the uterus, cervical stump, or hernias of the pelvic floor.[5] They are available in numerous sizes and shapes (**Figure 141-2**). Silicone pessaries have the advantage of being flexible and pliable while causing less vaginal discharge and odor than the rubber pessaries.[17] Pessaries elevate the vagina and maintain normal anatomic relations by supporting prolapsing structures against the perineal body and pubic bone. They thereby reduce vaginal relaxation and increase the tautness of the pelvic floor structures. Usually all that is needed is adequate support anteriorly and a reasonably good perineal body. Otherwise, the pessary may slip from behind the pubic symphysis and extrude from the vagina.[5] Unfortunately, the education of Emergency Physicians is somewhat compromised in the use of pessaries. Placement of a pessary is often a trial and error experience. Review the accompanying brochures to obtain the most satisfactory results from the pessary.[17]

PATIENT PREPARATION

Explain the procedure, its risks, and complications to the patient and/or their representative. Obtain an informed consent prior to performing the procedure. Place the patient in the lithotomy



FIGURE 141-2. Examples of different types of pessaries (Photo courtesy of CooperSurgical, Inc., Trumbull, CT).

position with both feet comfortably resting in standard stirrups. An assistant should be available to assist with positioning.

TECHNIQUES

The management of complete uterine prolapse in the Emergency Department depends upon successful replacement of the uterine fundus into the pelvis and subsequent fitting of the appropriate pessary. Refer the patient for surgical management upon discharge from the Emergency Department. An incarcerated uterus in the pregnant patient is an obstetrical emergency requiring immediate surgical elevation. Other indications include any pregnant patient who develops acute urinary retention or is at risk of aborting.[5]

UTERINE REDUCTION

Insert one gloved and lubricated hand into the vagina with the fingers extended to identify the margins of the cervix. Allow the uterine corpus to rest in the palm of the hand. Apply firm and gentle pressure to elevate the uterine fundus with the gloved hand by pressing against the cervix. Use the fingers on the edges of the uterus closest to the cervix to gently manipulate the uterus in the direction of the umbilicus. Gradually replace the uterus into the pelvis.

If this maneuver is not successful, insert a pessary into the posterior vaginal fornix while the patient is in the lithotomy position. Instruct the patient to sit up and assume the knee-chest position after insertion of the pessary. Instruct the patient to slip slowly into the prone position and then into the lithotomy position. The pessary will maintain the uterus in anteposition. It may be necessary to pack the vagina following manual reduction of a procidentia to maintain the uterine position as a preoperative management decision of an ulcerated or infected prolapse.[5,19] This should be performed in consultation with a Gynecologist.

FITTING OF THE PESSARY

Measure the distance from the introitus to the posterior vaginal vault using uterine forceps after reduction of the uterus. This measurement minus 1 cm is the approximate length of the pessary. To find the width (assuming an ovoid rather than a round pessary is required), place the forceps into the introitus to about the level of the cervix. Separate the handles until the blades touch the walls of the vagina. This represents the greatest diameter of the pessary.[5]

Liberally lubricate the pessary. Insert it with its widest dimension in the oblique diameter of the vagina to avoid painful distension of the introitus. Use the fingers of the nondominant hand to support the perineum. Slip the posterior bar behind the cervix using a finger on the dominant hand. The forefinger should pass easily between the sides of the frame and the vaginal wall at any point to ensure adequate fitting. If this is not possible, the pessary is too large.[5]

ASSESSMENT

Ask the patient initially to walk around the examination room to confirm comfort and exclude partial or complete expulsion of the pessary or recurrence of the prolapse. Replace the pessary with one of a different size or style to prevent any further prolapse.

AFTERCARE

Instruct the patient to remove the pessary each night and clean it with warm soapy water during the first few weeks of use. The soap should not contain any deodorants, detergents, or perfumes. These agents can irritate the vaginal mucosa and result in a chemical vaginitis. Weekly cleanings and overnight removal are adequate after the patient has become comfortable with its use. Apply vaginal cream once a week if the patient is not receiving systemic supplemental estrogen replacement. Warm, low-pressure acetic acid douches or acidic vaginal creams (such as ACI-JEL) may relieve irritation and prevent any discharge caused by the vaginal pessary.[5]

Refer the patient to a Gynecologist. Routine follow-up at 6 to 12 month intervals is recommended after several weeks of a well-managed and appropriately sized pessary. Additional care of these devices includes biannual pelvic examinations and replacement of pessaries every 12 to 18 months.[2] Patients should be counseled on the hazards of leaving the pessary in for prolonged periods of time and the importance of complying with recommended follow-up. It is not uncommon to have to change the pessary size and/or type. Patients are sometimes unable to manage the responsibilities of a pessary. A family member or a nurse trained in the insertion, removal, and care of the pessary is an appropriate alternative.

Advise all patients to return to the Emergency Department for difficulty urinating, defecating, signs of infection, or any problems with insertion and removal of the pessary.

COMPLICATIONS

Attempts at reducing the symptomatic uterine prolapse may be unsuccessful. Review the surgical and medical options with the patient and arrange the appropriate follow-up. Consult a Gynecologist before the patient is discharged from the Emergency Department.

A loose pessary is ineffective and usually will be expelled. The patient may experience pelvic pain, vaginal bleeding, vaginal ulcers, urinary retention, urinary fistulas, bowel fistulas, vaginal discharge, and/or dyspareunia if the pessary is too large or not removed and

cleaned periodically. **Therefore, proper fitting is important initially with appropriate follow-up to address these issues.**[17]

Minor complications include ulceration and abrasions of the vaginal mucosa secondary to local pressure effects. Pessaries act as foreign bodies and can become colonized by bacteria and lead to a vaginitis. Many patients experience a physiologic watery discharge with pessary use. This should not be confused with an infectious process that usually is accompanied by itching, burning, or odor. Severe vaginitis is more common in the elderly and debilitated patients because of the inability to remove and cleanse the pessary.[20,21] These conditions should be treated accordingly with discontinuation of the pessary until the infection has cleared and local care with estrogen or antibiotic creams.[18]

Serious complications are a result of prolonged, often decades long, uninterrupted use caused by neglect rather than the pessary itself.[18] Case reports described in the literature include vesicovaginal fistulas, rectovaginal fistulas, urosepsis, and malignancy.[22] Cervical and vaginal cancer associated with pessary use is a rare complication and is perhaps related to prolonged irritation or the chemical constituents of some of the older models of pessaries.[22] Pessary-related infections can occasionally develop local complications (e.g., abscess, sinus tract, pelvic cellulitis) or spread to other systems to cause systemic manifestations (e.g., pyelonephritis, peritonitis). Patient counseling and adequate follow-up is important.[18] **All of the complications are preventable and point to the need for periodic gynecologic examinations in pessary users.**[20]

SUMMARY

Reduction of the prolapsed uterus with subsequent pessary placement is a safe and acceptable mechanism for management of women who present to the Emergency Department with symptomatic prolapse. It is important that Emergency Physicians be familiar with this technique and recognize those women most at risk in order to avoid related complications.

SECTION 11

Genitourinary Procedures

142 Urethral Catheterization

Richard Dean Robinson and Eric F. Reichman

INTRODUCTION

Urethral catheterization is the most frequent manipulation of the urinary tract. It is routinely performed for diagnostic and therapeutic reasons in both urologic and nonurologic diseases.[1–11] Catheters may be inserted as an in-and-out procedure for immediate drainage, left in with a self-retaining device for short-term drainage, or left indwelling for long-term drainage.[6,7] Although this is one of the more routinely performed procedures in the Emergency Department, great care must be taken to avoid lower urinary tract injury, reduce the introduction of infection, and minimize patient discomfort. The basic principles underlying urethral catheterization are gender-neutral.[6,7] It is important to respect the patient's need for modesty and privacy as much as possible.

ANATOMY AND PATHOPHYSIOLOGY

The genitourinary system is frequently divided into upper and lower urinary tracts. The former refers to the kidneys and ureters or those structures above the bony pelvis. The lower urinary tract includes the bladder and urethra or those structures contained within or below the bony pelvis. Although the entire urinary tract may be catheterized, it is the lower tract, namely the urethra, which will be the focus of this chapter.

Averaging 4 cm in length, the female urethra is rarely a focus of difficulty. Most of the confusion related to urethral catheterization in the female results from poor anatomic knowledge of the external genitalia (**Figure 142-1**). The clitoris is often mistaken for the urethral meatus. This can result in catheter-related trauma, bleeding, patient discomfort, and frustration. After lateral retraction of the labia minora and exposure of the vaginal vault, the cephalad-most structure is the clitoris. Traveling in a caudal direction, the orifices encountered are the urethra, followed by the vagina, and the anus.

The male urethra is most often the site of catheter-associated difficulty.[3] In contrast to the female, the male urethra may extend upward of 20 cm in length and follows a tortuous course. The urethra is named based on the anatomic structure it traverses or travels with. The distal-most portion of the male urethra is the meatus, followed by the penile, bulbar, membranous, and prostatic portions (**Figure 142-2**). Resistance to the advancement of a catheter may occur at any point along the course of the urethra as a result of meatal stenosis, urethral strictures, urethral valves, false urethral passages, enlarged prostates, inflammatory processes, malignant processes, bladder neck contractures, urethral disruptions, and bladder neck disruptions. A careful clinical history and thorough physical examination will, in most

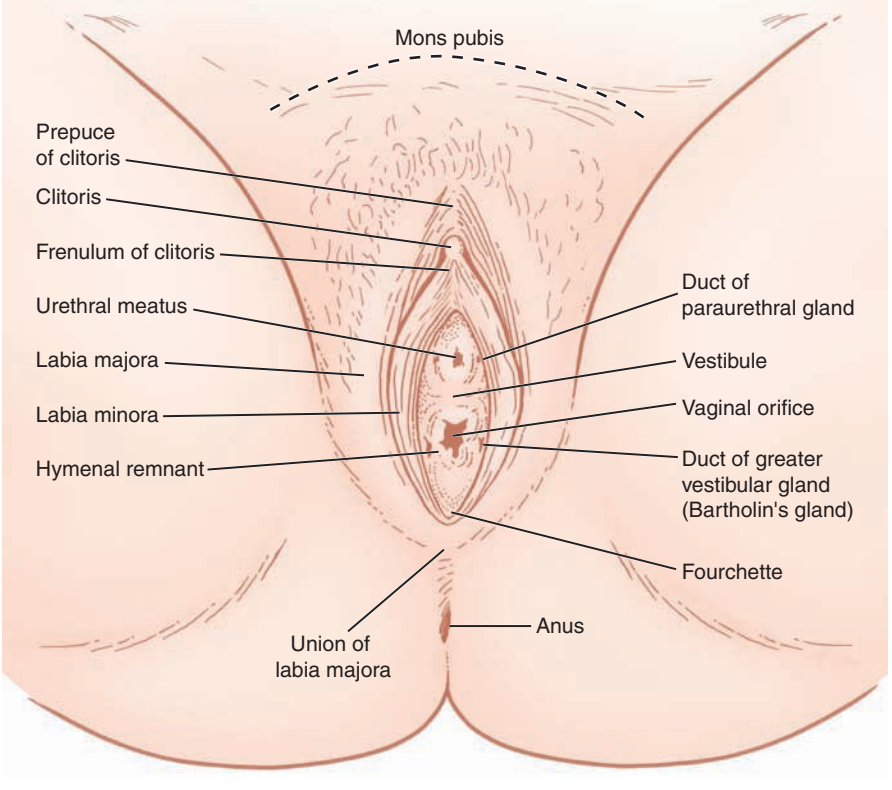


FIGURE 142-1. External anatomy of the female genitourinary tract.

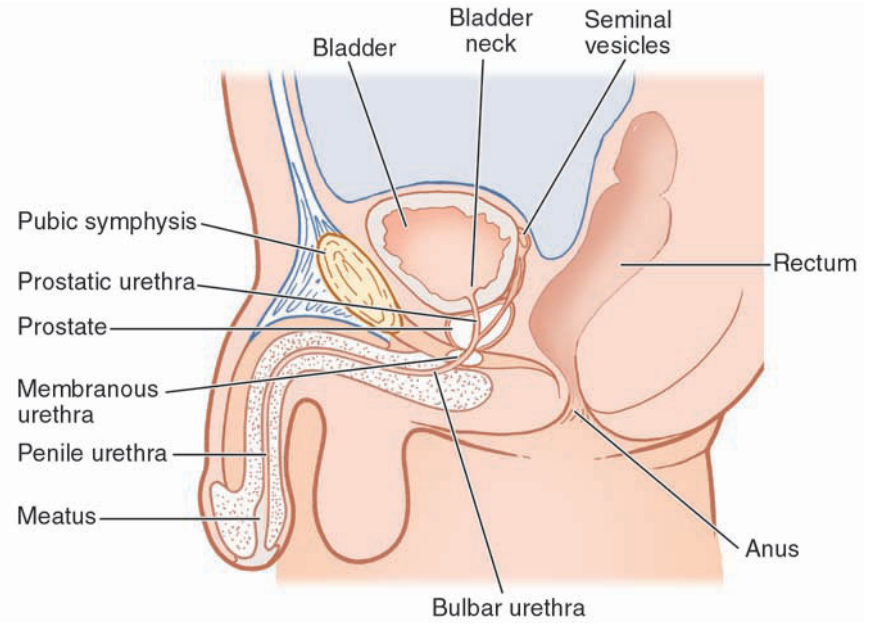


FIGURE 142-2. Anatomy of the male genitourinary tract.

cases, uncover these causes. The two most common sites that may be difficult for the catheter to pass are the junction between the bulbar and membranous urethra and the bladder neck.

INDICATIONS

Urinary catheterization can be performed for diagnostic and/or therapeutic reasons.[2,5] Urethral catheterization is often performed in females to collect urine for culture and avoid contamination from skin and vaginal flora. This is usually not necessary in males. Measurement of residual (i.e., postvoid) urine, urinary output monitoring, treatment of urinary incontinence, and to allow post-surgical healing are all indications for urethral catheterization. It can be performed to facilitate diagnostic studies, such as retrograde cystography and urodynamics. The main therapeutic indication for urethral catheterization is to relieve acute or chronic urinary retention. Patients with neurogenic bladders are often taught self-catheterization so they may perform this procedure at home. Other indications include bladder irrigation, instillation of medications into the bladder, surgery of the urinary tract or nearby structures, urodynamic testing, or in the intubated patient.

CONTRAINDICATIONS

The only absolute contraindication to urethral catheterization is in those patients with known or suspected traumatic injury to the lower urinary tract.[2,4,5] They should not undergo urethral catheterization until urethral continuity has been confirmed radiographically. Physical signs on examination that might suggest urethral trauma include blood at the urethral meatus, a perineal hematoma, or a high-riding prostate. Attempts at urethral catheterization may convert a partial urethral disruption into a complete disruption. Refer to Chapter 145 for the complete details regarding retrograde urethrography and cystography.

There are a few relative contraindications to urethral catheterization. Microscopic or gross hematuria in the absence of lower urinary tract trauma is not a contraindication to urethral catheterization. Patients with grossly bloody urine are at risk for urinary retention secondary to obstructing clots and require urethral catheterization for bladder irrigation. Although hypocoagulable states are not contraindications to urethral catheterization, great care must be exercised to avoid traumatic injuries and uncontrollable bleeding of the urethra. Prior placement of a penile prosthesis or an artificial urinary sphincter is not a contraindication to catheterization. However, vigorous attempts at inserting the catheter are discouraged. Urethral catheterization should not be performed in an uncooperative or combative patient unless they are sedated and/or restrained. A Urologist should be consulted prior to urethral catheterization in patients with known urethral strictures or recent surgery of the urethra or bladder neck.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves
- Commercially available kit containing the components listed below
- Water-soluble lubrication gel
- Lidocaine jelly in penile applicator (e.g., Uro-jet, Int'l Medication Systems Ltd, South El Monte, CA)
- Sterile drapes
- Urethral catheters (Foley, coudé, filiform, and followers)
- Christmas tree adapter
- Pediatric feeding tubes, sizes 5 to 8 French
- Sterile saline
- 10 mL syringe
- Urine meter, if catheter is to be retained
- Urine collection system
- Urethral catheter leg strap, if catheter is to be retained
- 1 inch tape
- Benzoin solution
- Ultrasound (optional)

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. **Urethral catheterization must be performed using strict sterile technique.** All equipment needed to perform the

procedure should be assembled at the bedside prior to beginning the procedure. The preparation for a male patient will be described below. The preparation for a female patient will be described in the techniques section.

Place the male patient in a bed or gurney. In uncircumcised patients, the foreskin must be retracted to expose the glans penis and the urethra. If a phimosis is encountered, it should be approached accordingly. In the pediatric population, male infants and children often have a physiologic phimosis. Attempts at aggressive foreskin retraction should be avoided. Clean any dirt and debris from the penis. Apply povidone iodine or chlorhexidine solution, with cotton balls or swabs, and allow it to dry. Place sterile drapes around the penis to isolate a sterile field.

Generous lubrication and anesthesia of the male urethra is one of the most important aspects of urethral catheterization.[9–10,13–15] A water-soluble lubricant (e.g., K-Y Jelly) or local anesthetic lubricant (e.g., 2% lidocaine jelly) can be applied to the tip of the urethral catheter before it is inserted. Unfortunately, this provides little-to-no anesthesia. Ideally, commercially packaged sterile blunt-tip syringes of lidocaine jelly (e.g., Uro-jet) should be used. Insert the blunt tip of the syringe into the urethral meatus. Firmly squeeze the glans penis to form a seal around the syringe tip. Inject the anesthetic jelly into the urethra. Maintain the syringe tip in the urethral meatus and manual pressure on the glans penis for 10 seconds to prevent egress of the anesthetic jelly.

Prophylactic antibiotic coverage is generally not indicated for urethral catheter placement. Patients with penile prostheses, artificial urinary sphincters, prosthetic heart valves, vascular graphs, and other indwelling foreign bodies may benefit from prophylactic antibiotics. An intravenous dose of a cephalosporin, quinolone, or other antibiotic that covers skin and perineal flora may be administered just prior to inserting the urethral catheter.

MALE CATHETERIZATION TECHNIQUES

FOLEY CATHETER INSERTION

Foley catheters are the most commonly placed urethral catheters. A Foley catheter is a dual lumen tube that contains an inflatable cuff near the distal end (**Figure 142-3**). The distal end has two holes for urine to enter the catheter. Urine traverses the large inner lumen of the catheter to exit the proximal port. The second lumen is extremely small and allows air or fluid to flow into the inflatable cuff. The proximal end contains two ports. One port allows the egress of urine from the catheter. The second port is an inflation port. An air-filled or saline-filled syringe attaches to this port and is used to inflate the cuff. When inflated, the cuff prevents the distal end of the catheter from slipping out of the bladder.

Foley catheters come in a variety of sizes and styles. A 14 or 16 French catheter is the size most commonly used in adolescent or adult patients. The two-way catheter is most commonly used. It is designed for urinary drainage and described in the preceding paragraph. It is a dual lumen tube with a small lumen to inflate the cuff and a large lumen to drain urine from the bladder. Three-way catheters are employed when bladder irrigation, in addition to urinary drainage, is required. These catheters have a small lumen to inflate the cuff, an intermediate-sized lumen to instill irrigation solution, and a large lumen to drain urine from the bladder. In the Emergency Department, they are placed in patients with gross hematuria and the passage of blood clots that may or have caused an acute urinary retention.

Clean and prep the penis, anesthetize the urethra, and set up a sterile field as mentioned previously. Select an appropriately sized Foley catheter. Inflate the cuff to check its integrity. Deflate the cuff. Grasp the penis with the nondominant hand. Pull the penis taut and upright to straighten out the penile urethra (**Figure 142-4A**). Retract the foreskin if the patient is uncircumcised. **Do not forget to reduce the foreskin after inserting the catheter to prevent the formation if a paraphimosis.** Grasp the Foley catheter with the dominant hand. Dip the tip of the catheter in, or an assistant can apply, water-soluble lubricant or anesthetic jelly (**Figure 142-4A**). Insert the catheter into the penile urethra via the meatus. Continue to gently but firmly advance the Foley catheter into the urethra until the proximal ports are at the urethral meatus (**Figure 142-4B**). This ensures that the distal tip of the catheter and the cuff will reside within the bladder (**Figure 142-4C**). **If the distal end of the catheter is not completely within the bladder, inflation of the cuff inside the urethra will result in severe pain, hematuria, and possible urethral rupture.**

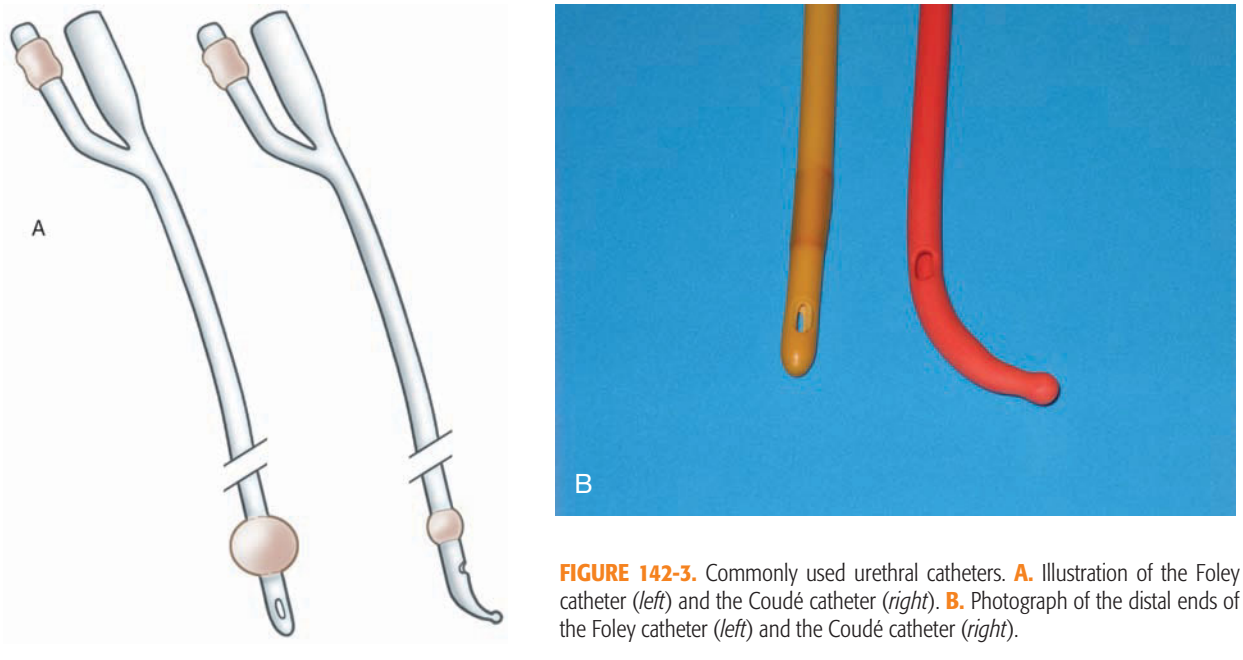


FIGURE 142-3. Commonly used urethral catheters. **A.** Illustration of the Foley catheter (*left*) and the Coudé catheter (*right*). **B.** Photograph of the distal ends of the Foley catheter (*left*) and the Coudé catheter (*right*).

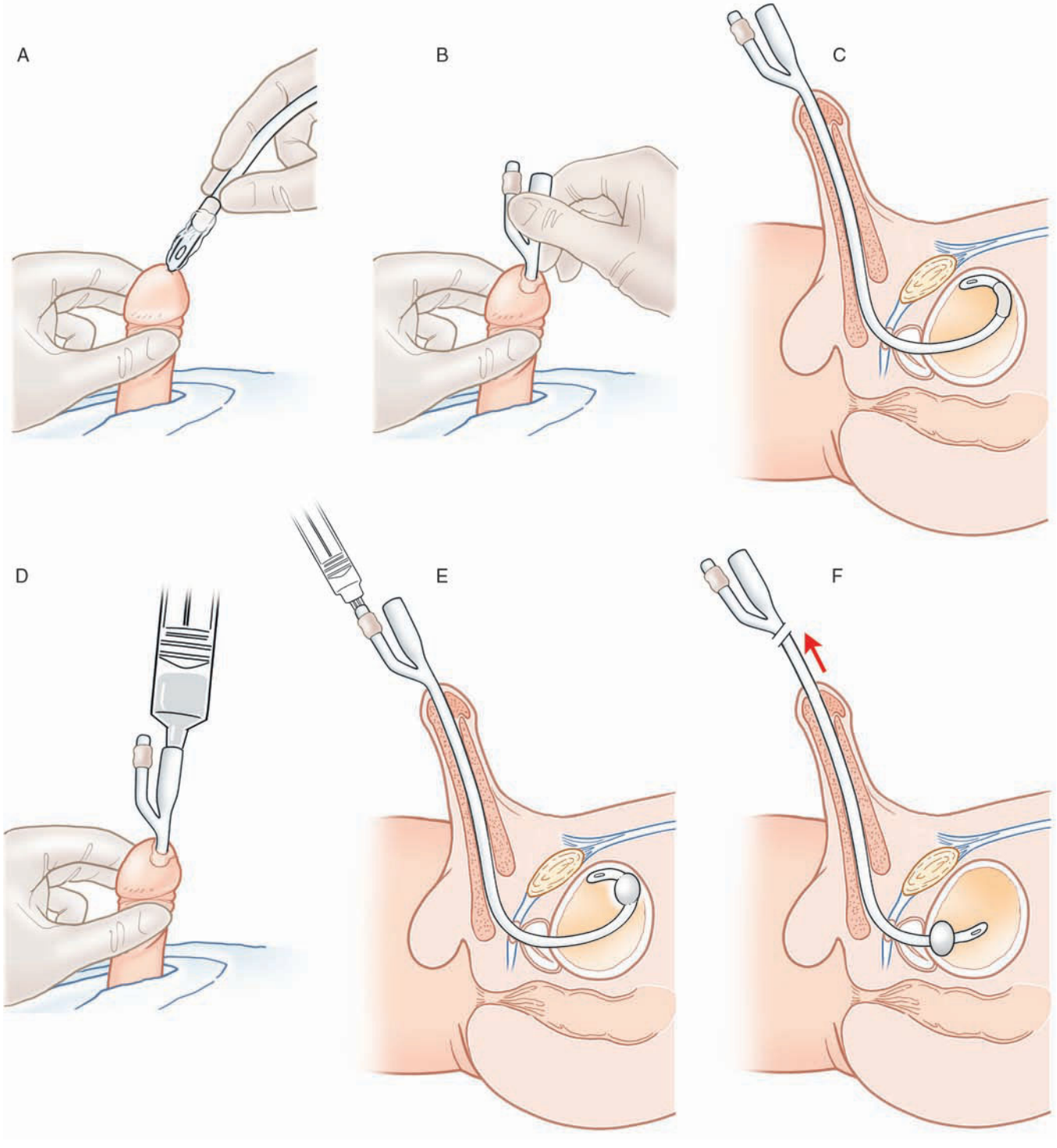


FIGURE 142-4. Foley catheter insertion. **A.** The lubricated catheter is inserted into the urethra. **B.** The catheter is advanced until the ports are at the meatus. **C.** Cross section of the male pelvis showing the distal catheter positioned within the bladder. **D.** Urine aspiration confirms proper placement of the catheter. **E.** The cuff at the tip of the catheter is inflated. **F.** The catheter is gently withdrawn to lodge the cuff against the bladder neck.

Urine should begin to spontaneously flow out of the large port. Insert the proximal end of the catheter into a sterile container to collect the urine. If urine does not spontaneously flow out of the large port, attach a 60 mL syringe to the port and aspirate urine to confirm proper placement of the catheter (**Figure 142-4D**). Consider using transabdominal ultrasonography to confirm proper catheter placement and the presence of urine within the bladder. If no urine is aspirated and/or ultrasound imaging does not confirm appropriate placement, remove the catheter from the urethra and reattempt the procedure.

Attach an air-filled or saline-filled syringe to the cuff inflation port (**Figure 142-4E**). Inject the air or saline to inflate the cuff (**Figure 142-4E**). Inject only the volume of air or sterile saline recommended by the catheter manufacturer. This can be found on the catheter package and is often printed on the cuff inflation port. Remove the syringe from the cuff inflation port. Gently withdraw

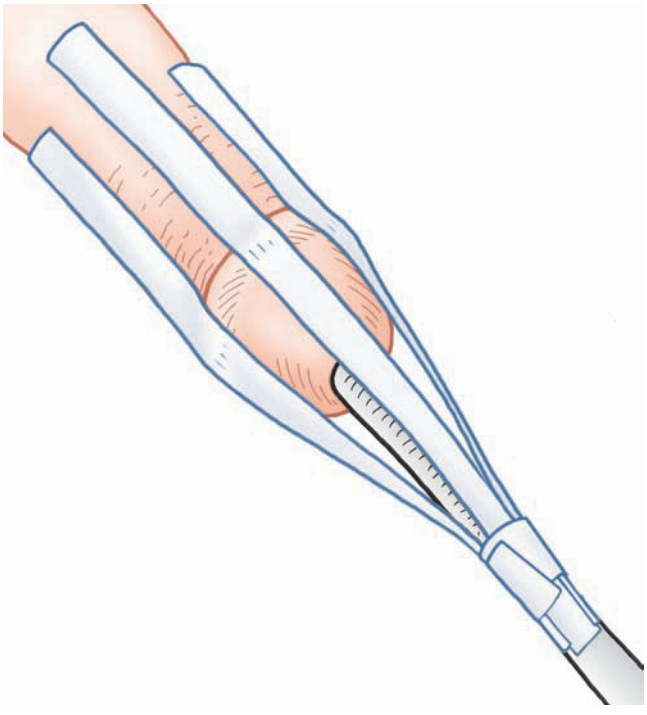


FIGURE 142-5. A method to secure the urethral catheter as it exits the penis.[5]

the Foley catheter until resistance is met. This signifies that the cuff is lodged against the bladder neck (**Figure 142-4F**). Attach an adapter and urine collection system to the urine port of the Foley catheter. Reduce the foreskin if present and it was retracted to insert the catheter.

Secure the catheter. Wrap tape around the urine port of the Foley catheter and continue it onto the adapter and first 3 to 5 cm of the collection tubing. This will prevent the system from disconnecting. Tape the collection tubing to the patient's thigh to prevent it from pulling out the adapter or the Foley catheter when the patient moves. Some authors also secure the Foley catheter as it exits the penile urethra (**Figure 142-5**).[5] This is especially important if a red rubber catheter or uncuffed coudé catheter is used as these cuffless catheters are not self-retaining. Place three thin strips of tape along the length of the penis and attached to the Foley catheter. Benzoin solution can be applied to the penis to aid in adhesion of the tape. Place a piece of tape circumferentially around the tape ends attached to the catheter. **Never apply tape circumferentially around the penis as it may cause ischemia.**

DIFFICULT URETHRAL CATHETERIZATION

Difficulty is commonly encountered when inserting a urethral catheter. Urethral pathology (e.g., valves, strictures, narrowing, or folds) or prostate enlargement can often be overcome by switching from a Foley to a coudé catheter and the application of digital assistance. If unsuccessful, the use of filiforms and followers can often be used to successfully insert the catheter. Foreskin edema from anasarca, pelvic lymphatic blockage, a paraphimosis, or penile trauma can often cover the glans penis and urethral meatus. Attempt to reduce the edema manually or with an elastic bandage (Chapter 148). Significant edema may require penile anesthesia and needle decompression (Chapter 148) or a dorsal slit of the foreskin (Chapter 150). A phimosis may be physiologic in children or acquired and the result of scarring in adults from repeated bouts of inflammation, infections, or sexually transmitted diseases. A phimosis may require a dorsal slit of the foreskin (Chapter 150) to allow for urethral catheterization or a dilation of the phimotic opening.

A relatively new device is the DirectVision™ microendoscope (PercuVision, Gahanna, OH). This consists of a rolling cart, fiberoptic endoscopic bundle, and tri-lumen silicone catheter. The cart houses a color monitor and the fiberoptic light source. A disposable fiberoptic bundle attaches to the light source and is inserted through the tri-lumen catheter. The fiberoptic bundle transmits light to the tip of the catheter and images back to the monitor. The system allows visually guided urethral catheterization in the male patient. It may decrease urinary tract trauma during catheterization, improve catheterization success rates, and simplify the catheterization process. At the time of this publication, this product cannot be recommended for routine urethral catheterization due to the initial expense of the system, the costs of the single-use disposable endoscopic bundles and catheters, and little clinical literature regarding its use in the Emergency Department. This device may be commonly used in the future as costs decrease and clinical information becomes more readily available.

COUDÉ CATHETER INSERTION

The coudé catheter is similar to a Foley catheter except that the distal end is curved and the tip has a small rounded ball (**Figure 142-3**). The catheter was designed to bypass the areas of the urethra that a straight catheter could not negotiate. A coudé catheter may be used if a Foley catheter cannot be passed into the bladder. It may also be used if the patient has a known urethral stricture, urethral valve, narrow urethra, or enlarged prostate.

The coudé catheter comes in various sizes and styles. Some models contain a cuff while others do not. The catheter is inserted into the urethra with the elbow on the tip of the catheter facing anteriorly. The procedure for placement of the catheter into the bladder is the same as that for a Foley catheter.

DIGITAL ASSISTANCE

Occasionally, the Foley or coudé catheter tip will become caught in a posterior fold of the urethra just distal to the urogenital diaphragm (**Figure 142-6A**). Place the fingers of the nondominant hand on the perineum between the scrotum and anus (**Figure 142-6B**). Apply upward pressure on the perineum to direct the catheter tip upward while simultaneously advancing the catheter with the dominant hand through the urogenital diaphragm and into the bladder. An assistant is often required to hold and stabilize the penis while the Emergency Physician uses their hands to manipulate the catheter and perineum.

If the patient has an enlarged prostate, the bladder neck is often elevated superiorly and anteriorly. Digital assistance on the skin of the perineum may be unsuccessful. A finger in the rectum may be used to move the catheter tip anteriorly so that it can be advanced into the bladder.

FILIFORM AND FOLLOWER CATHETERS

In patients with severe urethral strictures or urethral folds, it may be impossible to pass a Foley catheter or a coudé catheter. The next step in the progression to catheterize the bladder is to use filiform and follower catheters. Filiforms are very narrow, flexible, and solid catheters. Their sole function is to successfully negotiate a strictured urethral segment and enter the bladder. The distal end of the filiform catheter may be straight or pig-tailed and are available in a variety of sizes (**Figure 142-7A**). The proximal end of the filiform catheter is a standard size and contains a metal female connector (**Figure 142-7B**). The followers are flexible, hollow catheters that

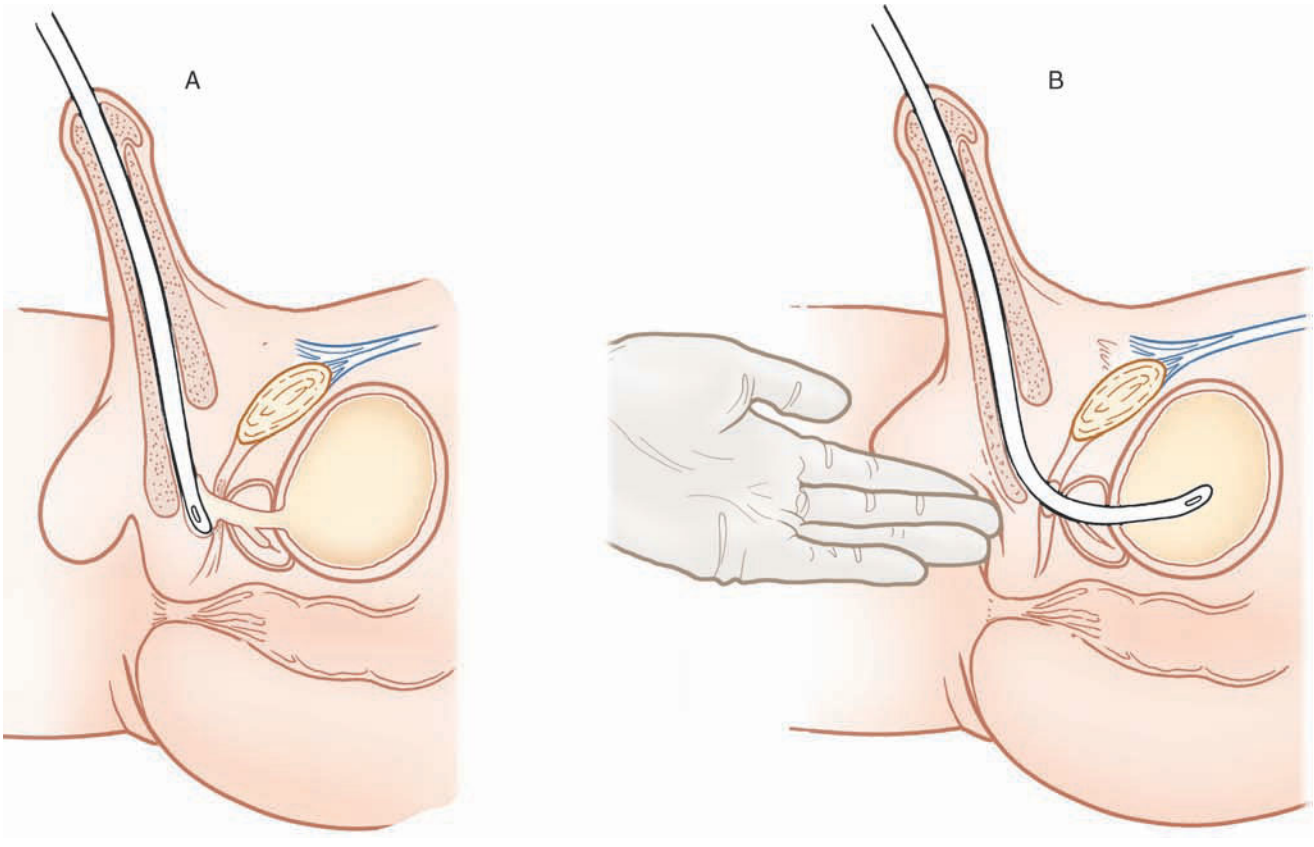


FIGURE 142-6. Digital assistance. **A.** The Foley catheter is caught in a posterior urethral fold. **B.** Digital upward pressure on the perineum will direct the catheter tip upward and through the urogenital diaphragm.

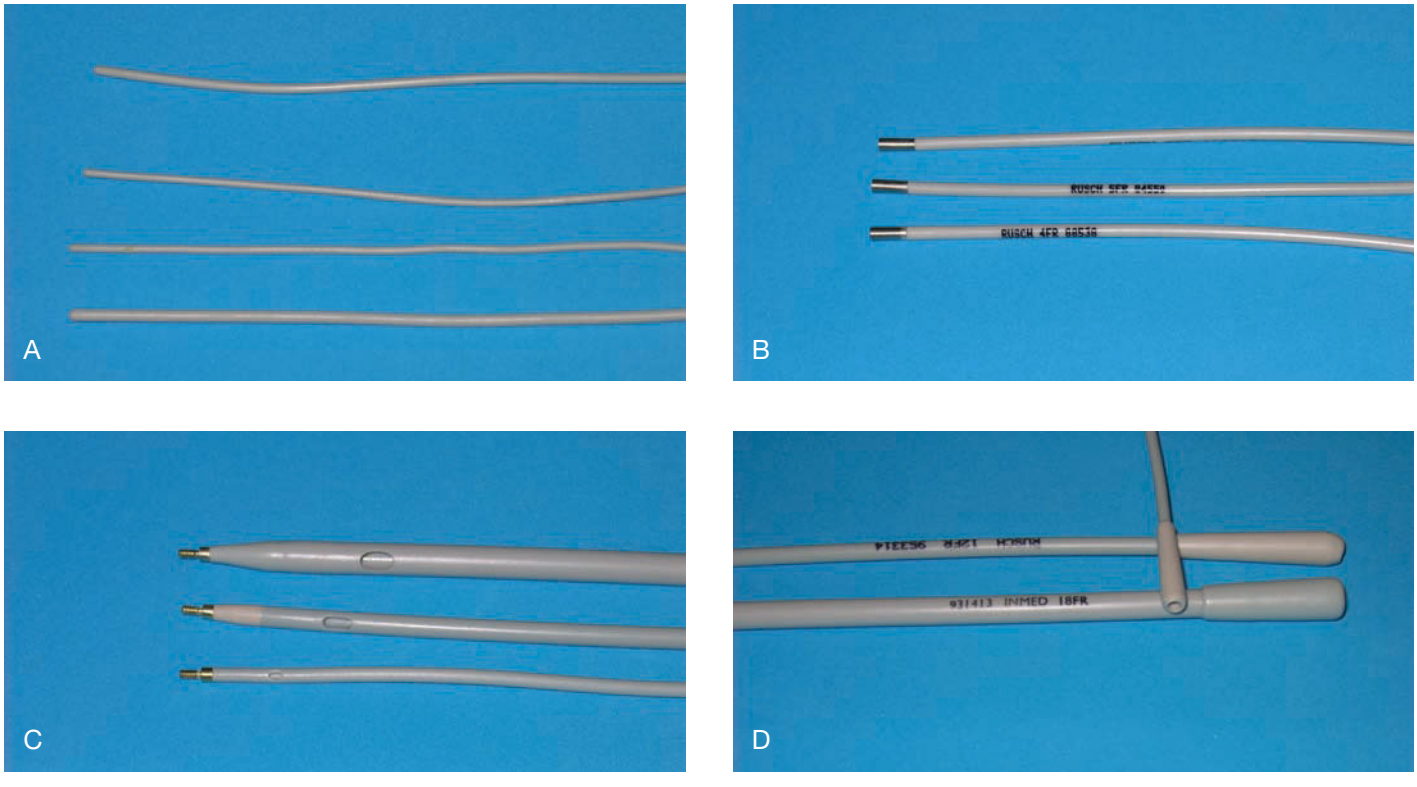


FIGURE 142-7. Photographs of the ends of the filiform and follower catheters. **A.** Distal ends of the filiform catheter. **B.** Proximal ends of the filiform catheter. **C.** Distal ends of the follower catheter. **D.** Proximal ends of the follower catheter.

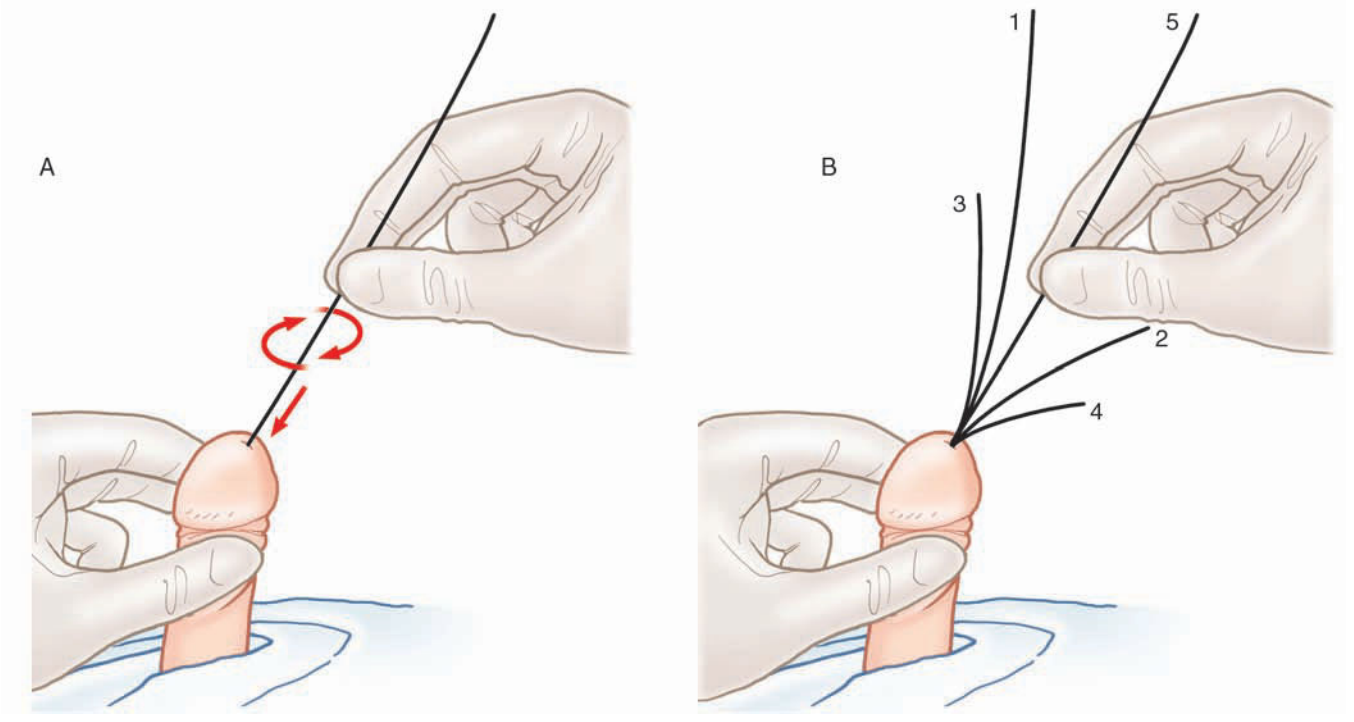


FIGURE 142-8. Insertion of the filiform catheters. **A.** The catheter is inserted and advanced into the urethra (*straight arrow*) with a twisting motion (*curved arrows*). **B.** Additional catheters are inserted until one advances into the bladder. The numbers represent the order of insertion of the filiform catheters.

attach to the filiform catheters. The distal end of the follower catheter contains a metal male connector, to attach to the proximal end of the filiform catheter, and a hole to allow urine to enter the catheter (**Figure 142-7C**). The follower catheters come in a variety of sizes and allow the physician to dilate the urethra and catheterize the bladder. The proximal end of the follower catheter is open and accepts a Christmas tree adaptor (**Figure 142-7D**).

A filiform and follower should be used only after unsuccessful catheterization attempts with a Foley catheter and a coudé catheter. The patient has already been prepped and draped for the prior catheterization attempts. Reinstill anesthetic jelly into the urethra to ensure adequate anesthesia. Numerous sizes and shapes of filiform and follower catheters should be available at the bedside. An assistant will be required to open each sterile packet and hand the filiforms and followers to the Emergency Physician as needed.

Grasp the cleaned, prepped, and anesthetized penis with the nondominant hand. Pull the penis taut and upright to straighten out the penile urethra (**Figure 142-8A**). Grasp a filiform catheter and dip the tip in water-soluble lubricant or anesthetic jelly. Gently insert and advance the filiform catheter into the urethra with a twisting motion (**Figure 142-8A**). Stop advancing the filiform catheter when resistance is met (**Figure 142-9A**). Insert a second well-lubricated filiform catheter into the urethra with a twisting motion until it meets resistance (**Figure 142-9B**). Gently attempt to advance the first filiform catheter. If it will not advance, insert

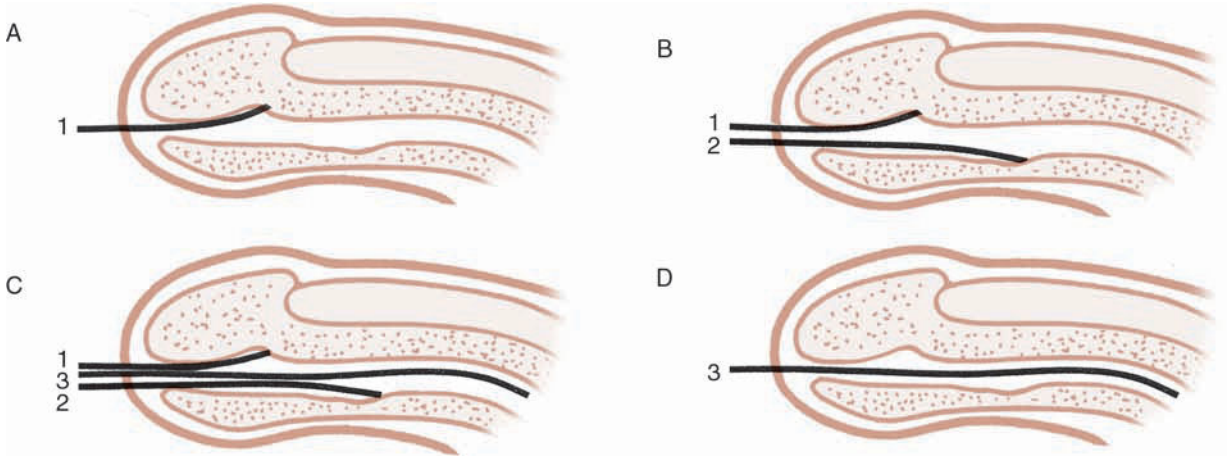


FIGURE 142-9. Midsagittal section of the penis demonstrating insertion of the filiform catheter. **A.** The filiform catheter is inserted until resistance is encountered. **B.** A second filiform catheter is inserted until it encounters resistance. **C.** A third filiform catheter is inserted and advances into the bladder. **D.** Filiform catheters #1 and #2 have been removed.

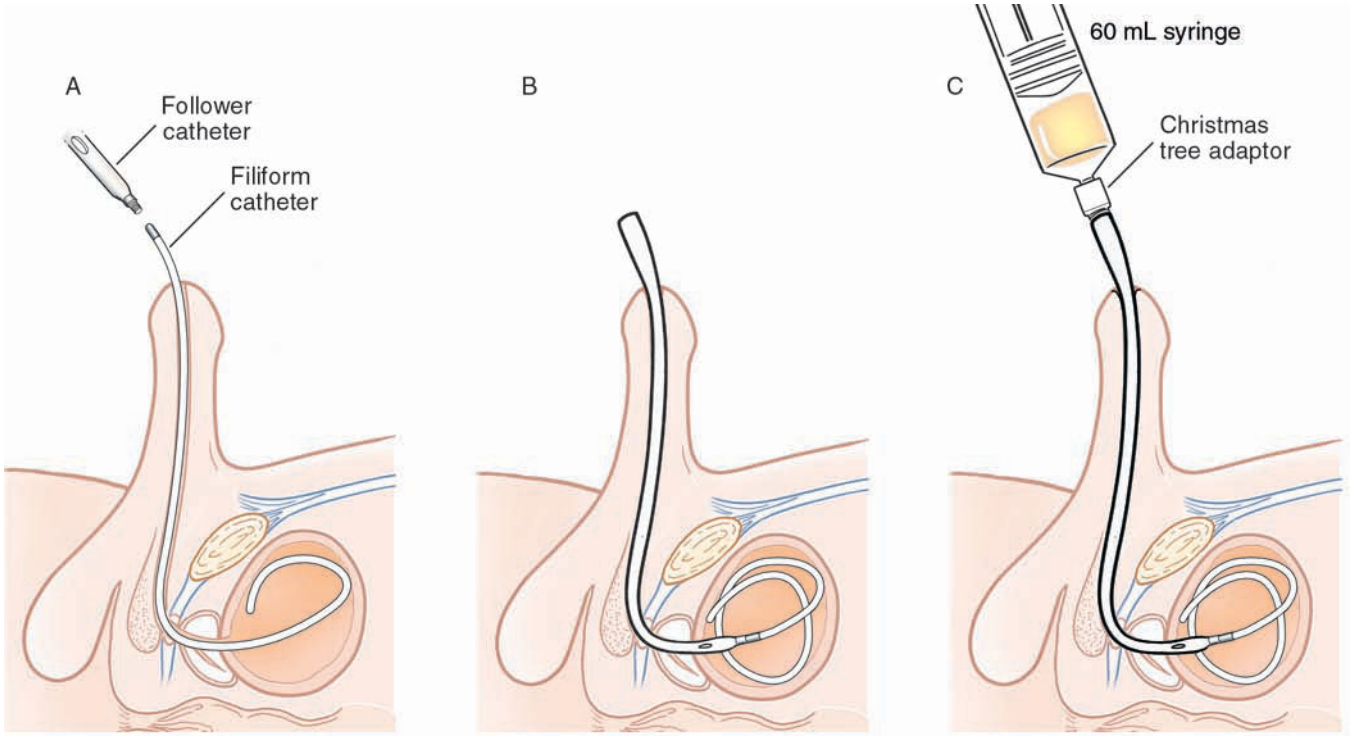


FIGURE 142-10. Insertion of the follower catheter. The filiform catheter has been previously inserted into the bladder. **A.** The follower catheter is screwed into the filiform catheter. **B.** The follower catheter is advanced into the bladder. **C.** Urine aspiration confirms proper placement.

a third filiform catheter (**Figure 142-9C**). Continue to insert filiform catheters and gently manipulate the previously inserted filiform catheters (**Figure 142-8B**). Continue this process until one filiform catheter advances into the bladder so that its proximal end is 2 cm from the tip of the penis (**Figure 142-9C**). Remove all the filiform catheters except the one that entered the bladder (**Figure 142-9D**).

Choose a follower catheter to insert into the bladder. Liberally lubricate the tip of the follower catheter and attach it to the filiform catheter (**Figure 142-10A**). Gently advance the follower catheter until its proximal end is 3 to 4 cm from the tip of the penis (**Figure 142-10B**). **If the follower catheter meets resistance during its advancement, do not force it into the urethra.** Instead, withdraw the follower catheter until the tip is 2 to 3 cm outside the penis. Remove the follower catheter from the filiform catheter. Attach a well-lubricated follower catheter onto the filiform catheter that is 1 or 2 French smaller and attempt to advance it into the bladder. Continue this process until a follower catheter can be completely advanced into the bladder. The filiform catheter will be completely curled up inside the bladder (**Figure 142-10B**).

Urine should spontaneously flow from the properly positioned follower catheter. If not, attach a 60 mL syringe and Christmas tree adaptor to the follower catheter (**Figure 142-10C**). Apply negative pressure to the syringe to aspirate urine and confirm the proper placement of the tip of the follower catheter. Attach a urinary collection system to the follower catheter and secure the catheter as described previously.

The patient with urinary obstruction cannot be discharged home with a filiform and follower inserted inside the bladder. If the follower catheter is a size 16 or 18 French, completely withdraw it and the filiform catheter and insert a 16 French Foley catheter. If the follower catheter is smaller than size 16 French, the urethra must be dilated. Withdraw the follower catheter until the distal tip is 2 to 3 cm outside the penis. Remove the follower catheter from the filiform catheter. Attach a well-lubricated follower catheter onto the filiform catheter that is 1 or 2 French larger than the previous one and gently advance it into the bladder. Continue this process until a follower catheter that is size 16 French easily passes into the bladder. Remove the filiform and follower catheters. Insert a size 16 French Foley catheter. Secure the catheter as described previously.

FEMALE CATHETERIZATION TECHNIQUES

Place the female patient supine in an examination bed. Place the patient in the frog-legged position. If an examination table equipped with stirrups is available, the patient can be placed in the lithotomy position. Separate the labia with the nondominant thumb and index finger to expose the vulva (**Figure 142-11A**). Identify the urethral meatus. Apply povidone iodine or chlorhexidine solution to the urethral meatus and surrounding vulva. Without moving the nondominant hand, apply sterile drapes to isolate the vulva. A lesser amount of anesthetic jelly is needed to lubricate the female urethra. Place anesthetic jelly on a sterile, cotton-tipped applicator. Insert the cotton-tipped applicator just into the tip of the urethral meatus for 8 to 10 seconds. Remove and discard the cotton-tipped applicator.

Grasp the Foley catheter with the dominant hand. Dip the tip of the catheter in, or an assistant can apply, water-soluble lubricant or anesthetic jelly. Insert the catheter into the urethral meatus (**Figures 142-11A & B**). Advance the catheter 6 to 8 cm to ensure the distal end and cuff are within the bladder. Urine should spontaneously begin to flow out of the large port. Insert the proximal end of the catheter into a sterile container to collect urine. If urine does not spontaneously flow out of the large port, attach a 60 mL syringe to the port and aspirate urine to confirm proper placement of the catheter. The remainder of the procedure is exactly the same as previously described for the male patient.

Some women may present with a cystocele, cystourethrocele, or urethrocele. These abnormalities result in the urethra running

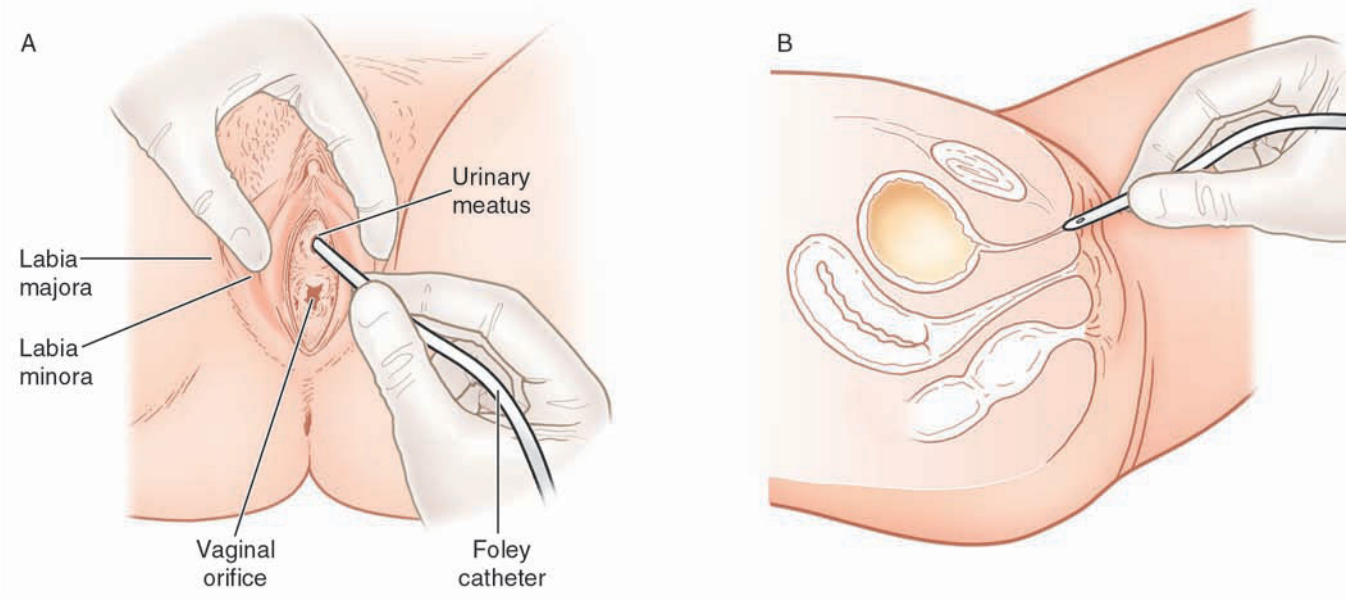


FIGURE 142-11. Female urethral catheterization. **A.** External view of the genitalia. The catheter is inserted into the urethral meatus and advanced. **B.** Midsagittal section of the female pelvis demonstrating catheter insertion.

posteriorly and downward, making urethral catheterization difficult. Insert your gloved and lubricated index and middle fingers into the vagina and gently push upward and anteriorly on the anterior vaginal wall. This maneuver will reposition the bladder and urethra to its normal position. While maintaining anteriorly directed pressure on the anterior vaginal wall, insert the urethral catheter in the usual manner.

INFANT AND CHILDREN CATHETERIZATION TECHNIQUES

The indications and contraindications for catheterization of infants and children are the same as for adults. The anatomy of the prepubertal child is similar to the adult, except for the difference in size and lack of secondary sexual characteristics. Identifying the urethral meatus can be difficult in uncircumcised boys. An assistant is often required to help position children during the procedure. Gently manipulate and retract the foreskin just enough to expose the meatus. It is worth noting that the urethral orifice may be difficult to identify in a young female due to abundant hymenal tissue covering the vaginal introitus. This can be circumvented by gentle lateral traction of the labia and downward pressure on the vaginal introital fold with a cotton-tipped applicator. The catheterization of newborns and infants is accomplished with an appropriately sized pediatric feeding tube, usually size 5 French in the neonate up to 8 French in newborns and infants. Small Foley catheters or feeding tubes (size 10 or 12 French) may be used in children aged 1 to 6 years. Children over 12 years of age can accommodate a 14 French catheter. The same techniques and cautions followed in the adult patient also apply to the pediatric patient.

ASSESSMENT

Urine drainage is the sign of appropriate catheter placement. Lubricating gel may plug the outflow port of the catheter. If no urine is seen, apply gentle pressure to the suprapubic area to force the flow of urine. Should this maneuver fail to initiate urine flow, irrigate the catheter with a small volume of sterile saline. The catheter will flush and withdraw fluid with ease if properly positioned in the urinary bladder. Use of an irrigation tray, which includes a 60 mL piston tipped syringe, is recommended. It may require greater than one fill (i.e., more than 60 mL of saline) to produce two-way flow. The inability to irrigate denotes obstruction or misplacement of catheter. Ensure that the catheter is inserted completely to the hub in males to prevent inadvertent inflation of the cuff in the membranous or prostatic urethra.

AFTERCARE

Always remember to reduce the foreskin after catheter placement to avoid the complication of a paraphimosis in uncircumcised males. Indwelling catheters should be secured to a closed gravity drainage system and attached to the anterior medial thigh. For long-term requirements in males, the catheter should be secured to the anterior abdominal wall to decrease the likelihood of stricture formation.

The patient may be discharged from the Emergency Department with a Foley catheter or coudé catheter. Instruct the patient on the proper care and emptying of the leg bag (**Table 142-1**). The patient

TABLE 142-1 Patient Instructions for the Proper Care of a Urinary Drainage Bag at Home

1. Always thoroughly wash your hands with soap and warm water before putting on gloves and emptying the drainage bag.
2. Never place the drainage bag on the floor to prevent contamination.
3. Always keep the drainage bag below the level of the genitals to prevent backflow of urine.
4. Clean the drainage port with an alcohol swab before emptying the bag.
5. Always empty the drainage bag into a clean container.
6. Do not touch the drainage port or allow it to touch the container.
7. Close the drainage port after emptying the bag and wipe it with an alcohol swab.
8. Discard the urine in the container and thoroughly wash the container with hot soapy water.
9. Discard the gloves and do not reuse them.
10. Always thoroughly wash your hands with soap and warm water after taking off your gloves.

should immediately return to the Emergency Department if they develop a fever, pain, hematuria, inability to void through the catheter, or abdominal pain. Consider prescribing a 3-day supply of broad spectrum antibiotics if the patient has valvular heart disease, mitral valve prolapse, cardiac valve replacements, a penile prosthesis, or an artificial joint.

COMPLICATIONS

GENERAL COMPLICATIONS

Creation of false passages, urethral perforations, bleeding, infection, and catheter misplacement are the complications associated with urethral catheterization. Urethritis is fairly common following catheterization, especially in patients with urethral strictures or prostatic enlargement. Epididymitis, cystitis, and pyelonephritis are uncommon complications and often seen with prolonged catheterization. Bacteremia can occur following the procedure. High-risk patients should receive antibiotic prophylaxis prior to catheterization. Iatrogenic trauma to the urethra can lead to strictures, hemorrhage, and hematuria. Creation of a false passage can occur by inserting the catheter alongside the urethra. Attempts at catheterization in a trauma patient with a urethral injury can convert a partial urethral tear to a complete tear. Failure to reduce the foreskin after catheter placement may result in a paraphimosis.

LEAKAGE AROUND THE CATHETER

Urine may occasionally leak out between the catheter and the walls of the urethra. Make sure that an appropriately size catheter has been inserted. Check the balloon to make sure it is properly inflated. Gently pull on the catheter to seat the balloon in the neck of the bladder. Too large of a catheter or balloon can irritate the urinary tract or bladder and result in bladder spasm and urine leakage. Check the catheter, tubing, and drainage bag for kinks. An occlusion distal to the catheter can result in retained urine, an overdistended bladder, and bladder spasm. Evaluate a urine sample for the presence of an infection. A urinary tract infection can result in bladder spasm.

DIFFICULTY REMOVING A CATHETER

A less common complication is difficulty removing an indwelling urethral catheter that has an inflated cuff. Ensure that the catheter is not clamped or kinked. This can compress the cuff inflation lumen. A vacuum may have formed in the inflation lumen causing it to collapse. Attach a syringe without the plunger to the inflation port and release the vacuum followed by aspiration to deflate the balloon. Gently turn the catheter clockwise and counterclockwise as the catheter may be compressed, kinked, or twisted. Gently advance the catheter further into the bladder and attempt to deflate the balloon. Gently inject 2 to 3 mL of sterile saline through the inflation port to open the inflation lumen or unclog it. Inspection of the valve sometimes reveals the problem. One may attempt to cut proximal to the valve in hopes of evacuating the cuff contents but this is not always successful.

In patients with a Foley catheter balloon that will not deflate, real-time ultrasound can facilitate percutaneous balloon puncture and removal of the catheter.[12] Prepare the skin, apply sterile single-use US gel to the patient's skin, and apply a sterile US probe cover. Stand to the side of the patient so that your dominant hand is cephalad (**Figure 143-7**). Position the US monitor on the opposite side of the patient so that it is easy to see (**Figure 143-7**). A longitudinal

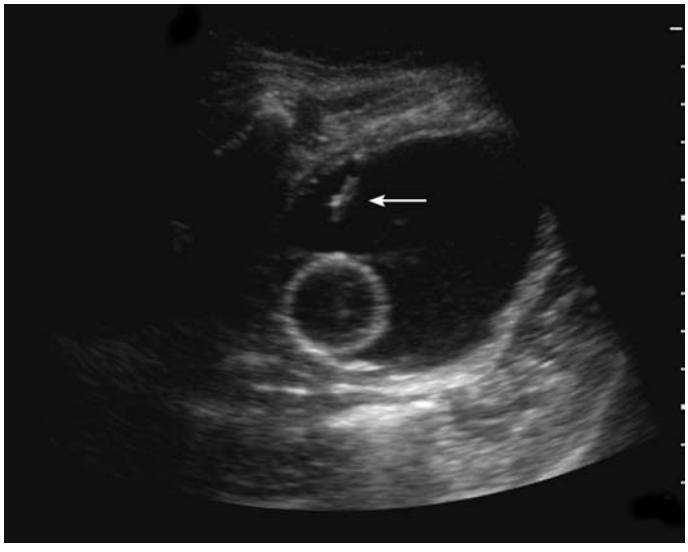


FIGURE 142-12. Longitudinal US view of the transabdominal spinal needle (*arrow*) approaching the Foley balloon.

US probe orientation is preferred for the dynamic approach since it allows visualization of the entire needle as it courses toward the bladder. Place the US probe marker to your left. This will ensure that the left–right orientation on the US screen matches the real-world orientation.

Place the longitudinally oriented US probe in the suprapubic area and move it from side to side to locate the largest bladder dimension. To deflate a Foley catheter balloon, make sure there is sufficient fluid in the bladder. If necessary, fill the bladder with enough sterile saline through the Foley catheter to make the bladder easily visible on ultrasound. Clamp the Foley catheter to retain the saline within the bladder. Instruct an assistant to apply gentle traction to the external portion of the Foley catheter to fix the balloon against the bladder neck.

Place a 5-inch, 22 or 24 gauge spinal needle on a 10 mL syringe. Position the spinal needle on the cephalad side of the US probe and angle it caudally (**Figure 143-8**). Insert and slowly advance the spinal needle. Look for the needle on the US screen as it is inserted and advanced. If the needle is a narrow gauge and the US probe is low frequency, the spinal needle will not necessarily be visible in the tissue. Rather, look for movements in the tissue as the spinal needle is advanced (**Figure 143-9**). Adjust the needle and the US probe side to side as needed to keep the needle in the same plane as the US beam. Continue to advance the spinal needle into the bladder (**Figure 142-12**). Continue to advance the spinal needle toward and into the inflated balloon. Puncture the balloon with the spinal needle. The balloon will deflate with a dramatic "pop." Remove the spinal needle. Remove the Foley catheter. Inspect the balloon to make sure there are no obvious missing fragments that are retained in the bladder.

Other options include transperineal cuff puncture, blind transabdominal cuff puncture, or injection of an organic agent (such as ether, acetone, mineral oil, or toluene) through the inflation port to dissolve the cuff. Occasionally, a narrow gauge guide wire may be placed through the cut balloon port to loosen any concretions that may have formed and allow the cuff to deflate. Obtain a plain radiograph of the pelvis to determine if the catheter is knotted within the bladder.[16] This will require cystoscopic manipulation to unknot the catheter. These techniques to reduce the cuff should be performed in consultation with a Urologist.

SUMMARY

Although urethral catheterization is one of the most routinely performed urologic procedures, it is not a benign process and should be attempted with mindfulness. A working knowledge of genital and perineal anatomy, along with a thorough clinical history and physical examination, is paramount to successful catheter placement and avoidance of complications. Liberal amounts of lubrication and topical local anesthetic should always be used when inserting the catheter. Those patients requiring chronic indwelling catheters should be versed in catheter care and have routine medical evaluations for catheter change and follow-up.

143 Suprapubic Bladder Aspiration

Richard Dean Robinson, Sam Hsu, and Eric F. Reichman

INTRODUCTION

Suprapubic bladder aspiration is the introduction of a needle through the anterior abdominal wall and into the bladder to obtain a urine specimen under strict sterile technique. It is performed primarily to diagnose urinary tract infections.[1–9] It is most commonly performed in children under the age of 2 years as part of the septic work-up.[7] The procedure is quick, simple to perform, safe, and has a low rate of complications. The main advantage of suprapubic bladder aspiration is that it bypasses the urethra and minimizes the risk of obtaining a contaminated urine specimen.

Urinary sampling remains the cornerstone for the diagnosis of many disease processes including metabolic derangements, infectious processes, catabolic states, and neoplastic conditions. In cases when the usual means of voided urine collection or bladder drainage is not possible or preferable, suprapubic bladder aspiration becomes a viable option both therapeutically and diagnostically. If properly performed, this technique can yield an uncontaminated urine sample without urethral or skin flora contamination.

ANATOMY AND PATHOPHYSIOLOGY

The urinary bladder of the neonate and infant begins as an abdominal organ (**Figure 143-1A**). As the child grows the pelvis enlarges and the bladder migrates down into the pelvis. The bladder eventually assumes its retropubic position that is maintained throughout life (**Figure 143-1B**).

The anatomic knowledge required to perform this procedure is minimal. The pubic symphysis is in the midline and forms the anterior border of the bony pelvis. The bladder resides posterior and superior to the pubic symphysis in the young child. The needle will pass through the skin and subcutaneous tissue of the lower abdominal wall, the rectus sheath, the peritoneum, and the bladder wall.

The adult urinary bladder resides behind the pubic symphysis and has both retroperitoneal and intraperitoneal attachments (**Figure 143-1B**). A working knowledge of this anatomy makes percutaneous bladder manipulation both safe and possible. The rectum lies just inferior and posterior to the urinary bladder. This relationship must be kept in mind when attempting percutaneous access. The bladder dome has peritoneal attachments and access in this area carries the potential for bowel injury and intraperitoneal bladder perforation.

Multiple major vascular structures, including the common iliac and hypogastric vessels, reside in the bony pelvis alongside the bladder. These structures are lateral to the bladder and eccentric percutaneous access may result in troublesome hemorrhage.

INDICATIONS

Suprapubic bladder aspiration is the preferred method of urinary sampling and drainage in instances where voided specimens are undesirable or unattainable, and when urethral catheterization is not technically possible or contraindicated.[1–10] It offers a means

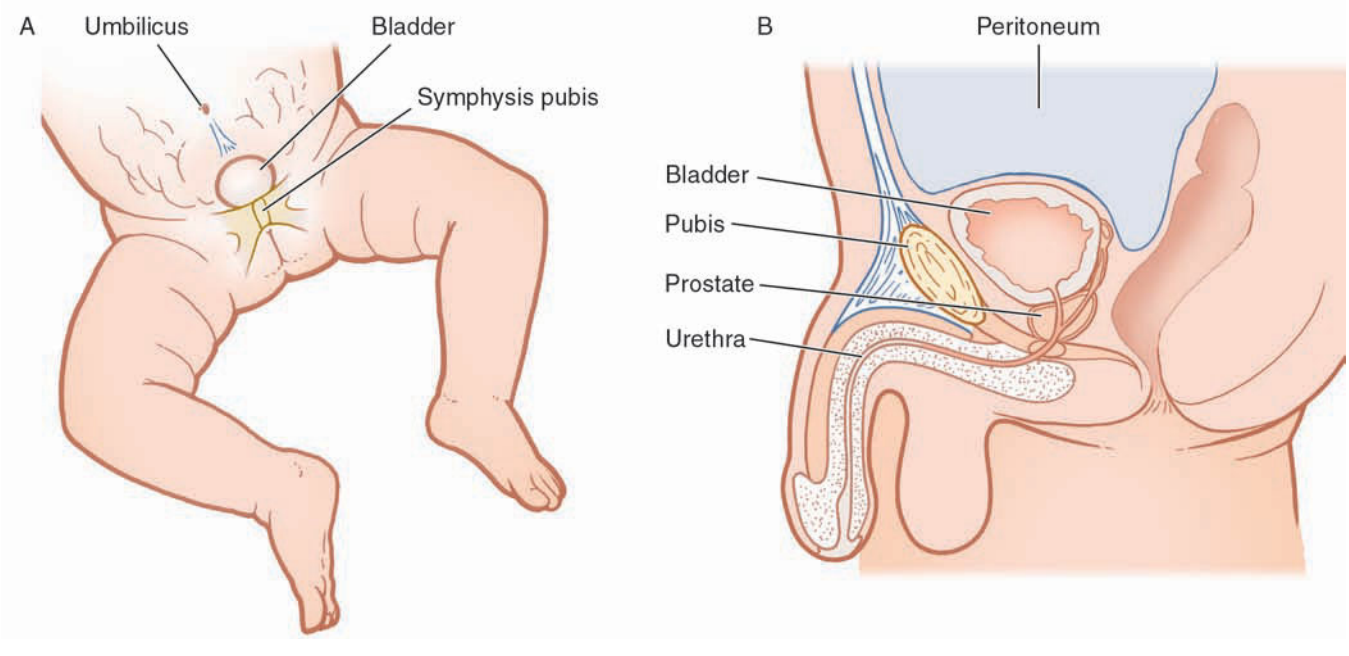


FIGURE 143-1. Position of the bladder. **A.** The bladder is an abdominal organ in the neonate and infant. **B.** The bladder is a pelvic organ in the older child, adolescent, and adult.

of obtaining an uncontaminated urine sample from the bladder. Obtaining a urine sample by urethral catheterization in the neonate or young child may be technically difficult, in which case suprapubic aspiration is a viable alternative. Although urethral catheterization may be an easier method of urine collection in the child or adult, suprapubic aspiration may be required to isolate infravesicular infections, to rule out contamination with asymptomatic bacteriuria, or in cases of urinary retention from a phimosis. The procedure may be performed to temporarily relieve acute urinary retention.

CONTRAINDICATIONS

The single most important aspect of suprapubic bladder manipulation is the presence of an identifiable (by palpation, percussion, transillumination, and/or ultrasonography) and distended urinary bladder. Under no circumstances should "blind" percutaneous access be attempted if the bladder is not palpable or visualized with the aid of ultrasonography.

Any physical alteration, spinal deformities, extremity contractures, truncal obesity, or other conditions that would preclude patients from lying supine and inhibiting bladder palpation are contraindications to this procedure. Skin infections overlying the puncture site are a contraindication to bladder aspiration. Abnormalities in genitourinary anatomy or enlargement of pelvic structures (e.g., ovarian cysts, uterine fibroids) increase the chance of complications with bladder aspiration. Known neoplastic processes of the lower genitourinary tract heighten the possibility of complications. Similarly, distention or enlargement of the abdominal viscera can increase complication rates. The return of ascitic fluid may lead to a false sense of security when the needle is actually intraperitoneal.

Patients with a coagulopathy are at an increased risk for troublesome hemorrhage from any percutaneous procedure, including suprapubic bladder access. Patients with a bleeding diathesis, anticoagulant therapy, or thrombocytopenia should be corrected prior to performing the procedure. In individuals with prior abdominal surgery, the peritoneal cavity has been violated and the bowel may be displaced more caudal and extend to the level of the urinary bladder. This heightens the risk of inadvertent bowel injury. The procedure should not be performed in patients with abdominal distention or the suspicion of an intestinal obstruction. An uncooperative patient should be sedated and/or restrained for the procedure.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves
- 22 to 24 gauge needle or spinal needle, 1½ to 3 inches long for neonates, infants, and young children
- 22 to 24 gauge needle or spinal needle, 3 inches long for older children, adolescents, and adults
- 10 mL syringe
- Injectable local anesthetic solution, most commonly 1% lidocaine
- 4 × 4 gauze squares
- 25 gauge needle and 3 mL syringe for anesthetic administration
- Sterile towels or drapes
- Specimen containers for urine analysis and culture
- Bandage
- Ultrasound (US) machine (recommended)
- Sterile US gel
- Sterile US probe covers
- 5 to 10 MHz linear US probe for neonates, infants, and children
- 2 to 5 MHz curvilinear abdominal US probe for adolescents and adults

PATIENT PREPARATION

Explain the risks, benefits, and alternative procedures to the patient and/or their representative. Obtain an informed consent for the procedure and place this in the medical record. When performing the procedure on a neonate or child, it is advisable to give the parent the option to leave the room or look away as the procedure can be disconcerting to some parents.

It is important to identify the distended bladder by palpation, percussion, transillumination, or ultrasonography. Transillumination of the full bladder may be conducted in the neonate. Place the patient supine (**Figure 143-2**). Ultrasonography should be used, if available, even if the bladder is readily palpable. Ultrasound can be used to identify the bladder, confirm the bladder is distended with urine, guide the needle aspiration, and increase the success of the procedure.[10–13] If the bladder is readily distended, it appears on ultrasound as an anechoic (black) square-like structure just below the abdominal musculature.[6] Placement of a gel-filled sterile glove

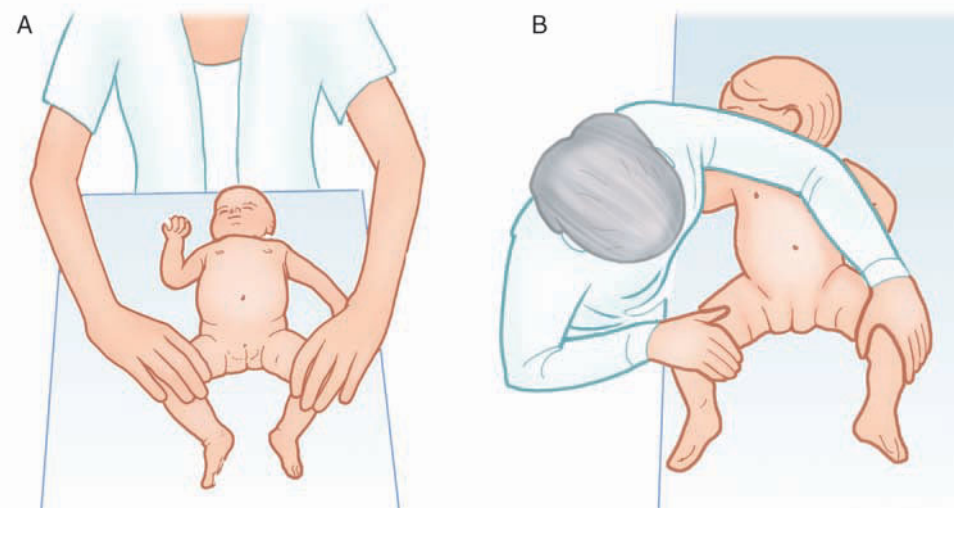


FIGURE 143-2. The frog-leg position. **A.** The infant. **B.** The older child.

over the probe maintains sterility during ultrasound-guided procedures. Identify and mark the skin location immediately above the bladder where it is closest to the skin.

Prepare and drape the abdomen in a sterile fashion from the umbilicus to the pubis. Clean the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes. Inject a local anesthetic agent, usually 1% lidocaine, to raise a subcutaneous wheal in the area of the intended skin puncture site. Many consider this step to be optional in the neonate as the amount of discomfort caused by placement of the anesthetic is similar to the actual puncture for bladder aspiration. Slight differences in technique are required for suprapubic bladder aspiration of the infant, child, and adult.

TECHNIQUES

NEONATES AND INFANTS

Have an assistant place and hold the infant supine in the frog-leg position (**Figure 143-2A**). Identify the needle insertion site in the midline and 2 cm cephalad to the pubic symphysis (**Figure 143-3**). The use of US is recommended to assist in determining the proper needle insertion site. Inject 1 mL of local anesthetic solution subcutaneously and into the abdominal wall musculature at the needle insertion site.

Place a 22 or 24 gauge spinal needle onto a 10 mL syringe. Occlude the urethra to prevent reflexive micturition. Apply manual pressure to the urethral meatus of the female (**Figure 143-4A**) or the glans penis in the male (**Figure 143-4B**). Insert the needle through the insertion site and at a 20° angle from the true perpendicular to the skin (**Figure 143-4**). Advance the needle cephalad while applying negative pressure to the syringe. Stop advancing

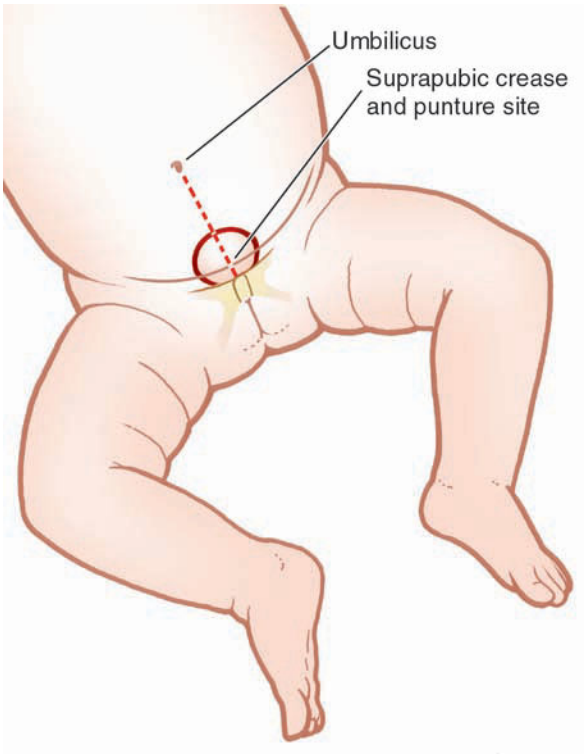


FIGURE 143-3. Anatomical landmarks for suprapubic bladder aspiration in the neonate and infant. A line is drawn from the umbilicus to the pubic symphysis (*dotted line*). The intersection of the line with the suprapubic crease is the landmark for insertion of the needle.

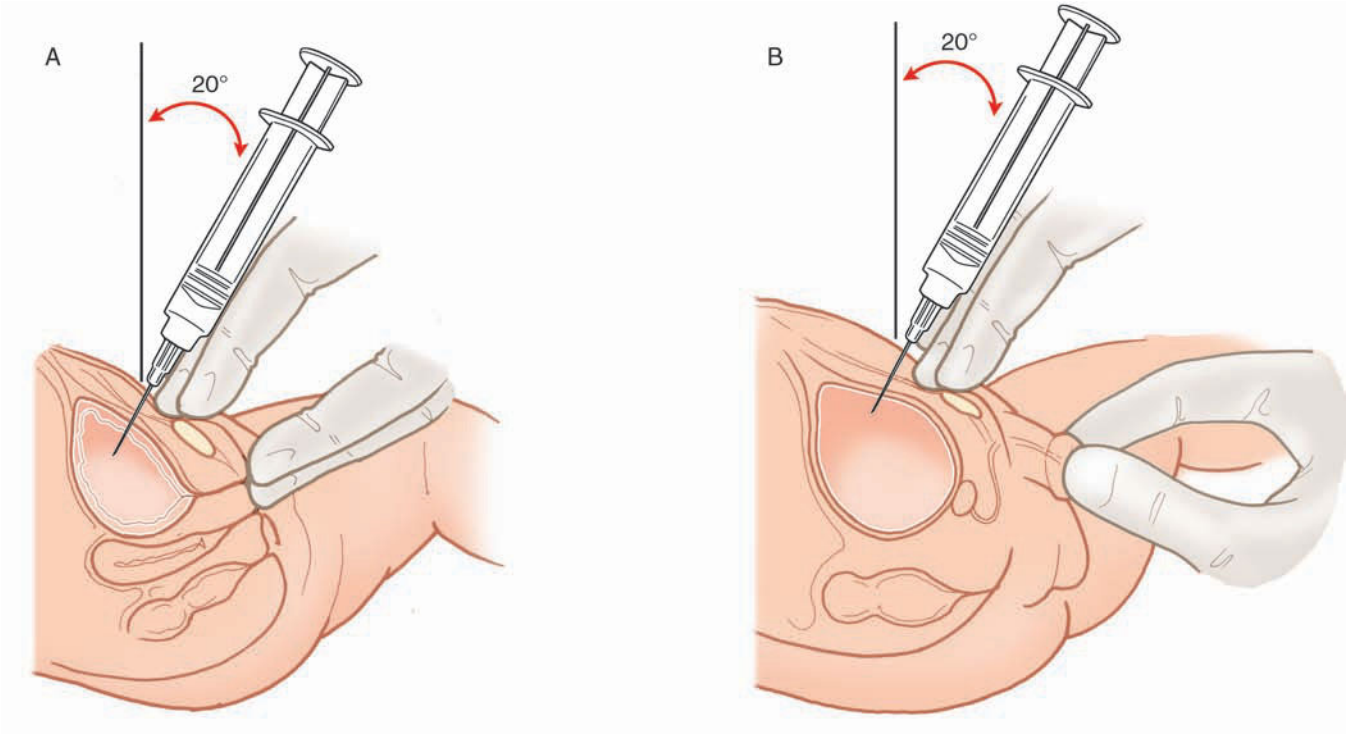


FIGURE 143-4. Suprapubic bladder aspiration in the infant. **A.** Digital pressure on the urethral meatus will prevent micturition in the female. **B.** Digital pressure on the glans penis will prevent micturition in the male.

the syringe when urine is aspirated. The bladder appears to tent as the needle pierces its anterior wall when ultrasonographic guidance is used.[6] If no urine is aspirated, withdraw the needle to the subcutaneous tissue and readvance it in a slightly different direction (e.g., 0° to 10° to the true perpendicular). If the procedure is unsuccessful on the second attempt, delay further attempts until the bladder is more distended, consult a Urologist, or obtain urine through urethral catheterization. After urine is obtained, remove the needle and apply a bandage to the skin puncture site.

OLDER CHILDREN

The positioning of the older child is similar to that of the neonate or infant (**Figure 143-2B**). The procedure is similar to that of the infant, although it is more important to identify the location of the distended bladder to assure a successful aspiration. The use of US is recommended to assist in determining the proper needle insertion site. The urinary bladder of the older child may be in the abdomen or may have migrated into the pelvis.

ADOLESCENTS AND ADULTS

Place the patient supine. Identify the bladder by palpation or ultrasonography. Identify the needle insertion site in the midline and 2 to 4 cm cephalad to the pubic symphysis. Inject 1 to 3 mL of local anesthetic solution subcutaneously and into the abdominal wall musculature at the needle insertion site.

Place a 3 inch, 22 to 24 gauge spinal needle onto a 10 mL syringe. Insert the needle through the insertion site and at a 60° angle to the skin of the abdominal wall (**Figure 143-5**). Advance the needle caudally while applying negative pressure to the syringe. Stop advancing the needle when urine is aspirated. If no urine is aspirated, withdraw the needle to the subcutaneous tissue and readvance it in a slightly different direction (e.g., 50° to the skin of the abdominal wall). After urine is obtained, remove the needle and apply a bandage to the skin puncture site.

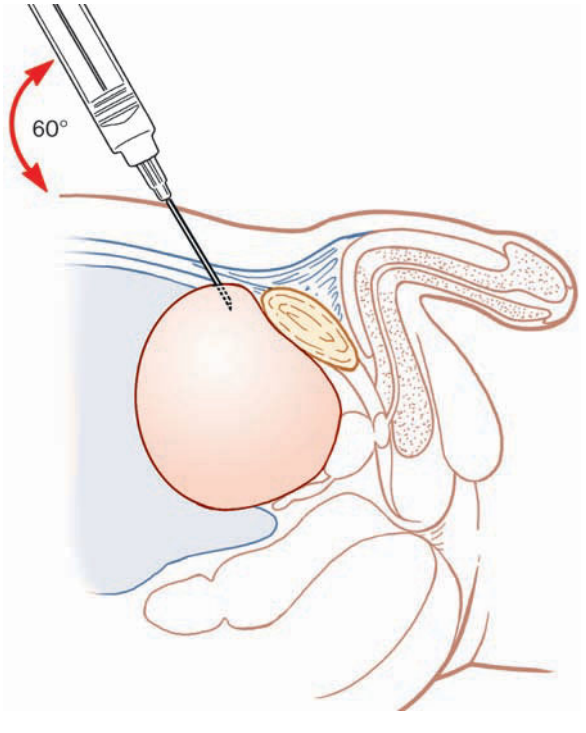


FIGURE 143-5. Suprapubic bladder aspiration in the adult.

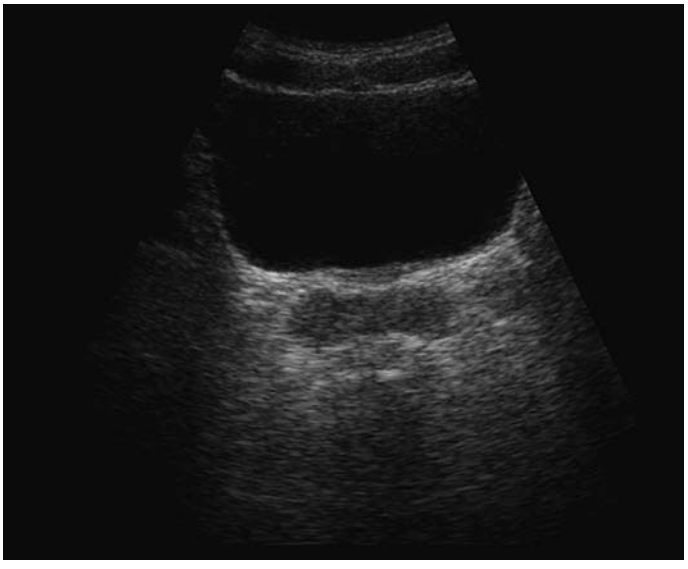


FIGURE 143-6. Transverse US view of the bladder.

ULTRASOUND TECHNIQUE

Ultrasound can ensure there is sufficient urine to aspirate and locate a bladder that is located off midline or deep in the pelvis. It is especially helpful in infants and toddlers, who have small bladders. There are no contraindications to using ultrasound other than those for the procedure itself. For adults, a general-purpose curvilinear abdominal or phased-array probe provides the best combination of penetration and field of view into the abdomen. A linear probe can be used for children. Either a static or dynamic (real-time) technique can be used. The static technique is preferred as it is the easier technique to learn and master. The dynamic technique will increase the success rate for small bladders with minimal urine.

Image the bladder to ensure there is sufficient urine to aspirate. Place the US probe transversely and just superior to the pubic symphysis. If the bladder is not immediately visible, slowly fan the probe cephalad and caudal until it appears. If the bladder is not visible, repeat the scan just off the midline. The bladder will appear anechoic (**Figure 143-6**). Moderate to large bladders are amenable to the static US technique. Bladders smaller than 2 cm in anteroposterior or transverse diameter have a lower success rates for aspiration and the dynamic US technique may be necessary to obtain urine.[11]

STATIC US TECHNIQUE

Identify the bladder using US and center the image on the US machine screen. Angle the US probe so that the largest dimensions of the bladder appear on the screen. **Note the angle of the US probe as this will correspond to the angle of entry for the needle.** Make sure that the bladder is centered on the screen. Move the probe off midline, if necessary, to minimize lateral angulation. This will prevent the need to angle the needle laterally to reach the bladder. Note the depth on the screen from the skin to the bladder in order to gauge the necessary needle length. Mark the entry point on the skin where the middle of the probe meets the skin. Prep the skin and proceed with procedure as described previously.

DYNAMIC US TECHNIQUE

Prepare the skin, apply sterile single-use US gel to the patient's skin, and apply a sterile US probe cover. Stand to the side of the



FIGURE 143-7. The US machine is positioned in the same sight-line as the procedure. The physician's dominant (*right*) hand is cephalad and controls the needle. Note, the US probe cover has been removed for clarity and should be used during the procedure.



FIGURE 143-8. The spinal needle is inserted under the cephalic side of the longitudinally oriented US probe and angled caudally. Note, the US probe cover has been removed for clarity and should be used during the procedure.

patient so that your dominant hand is cephalad (**Figure 143-7**). Position the US monitor on the opposite side of the patient so that it is easy to see (**Figure 143-7**). A longitudinal US probe orientation is preferred for the dynamic approach since it allows visualization of the entire needle as it courses toward the bladder. In infants and toddlers, there may not be enough space to place the US probe longitudinally and a transverse probe orientation may be necessary. In either case, place the US probe marker to your left. This will ensure that the left–right orientation on the US screen matches the real-world orientation.

Place the longitudinally oriented US probe in the suprapubic area and move it from side to side to locate the largest bladder dimension. Place the procedure needle on a 10 mL syringe. Position the procedure needle on the cephalad side of the US probe and angle it caudally (**Figure 143-8**). Insert and slowly advance the needle. Look for the needle on the US screen as it is inserted and advanced. If the needle is a narrow gauge and the US probe is low frequency, the needle will not necessarily be visible in the tissue. Rather, look for movements in the tissue as the needle is advanced (**Figure 143-9**). Adjust the needle and the US probe side to side as needed to keep the needle in the same plane as the US beam. Aspirate as the needle is advanced. When the needle appears to enter the bladder, aspiration should result in urine return. Remove the US probe once urine is aspirated. The remainder of the procedure can proceed as previously described.

For the transverse orientation, position the US probe so that the image of the bladder is centered on the screen. Position the procedure needle attached to a syringe just superior to the center of the US probe (**Figure 143-10**). Slowly advance the needle toward the bladder. Angle the needle slightly more caudal than the US probe since the entry point of the needle is superior to the US probe. The needle will be seen on screen in cross section and will appear as an echogenic point with a ring-down artifact or bright shadow (**Figure 143-11**). As the needle is advanced toward the bladder, the US probe may need to be fanned slightly cephalad or caudal to keep the needle tip in view. Aspirate as the needle is advanced. When the needle appears to enter the bladder, aspiration should result in urine return. Remove the US probe once urine is aspirated. The remainder of the procedure can proceed as previously described.

ASSESSMENT

If the first attempt at aspiration is unsuccessful, withdraw the needle to a subcutaneous position and redirect it at a different angle. This should be done only if the bladder is clearly identified. If the procedure is unsuccessful on the second attempt, the procedure should be delayed until the bladder is more distended. Consultation with a Urologist may be necessary.

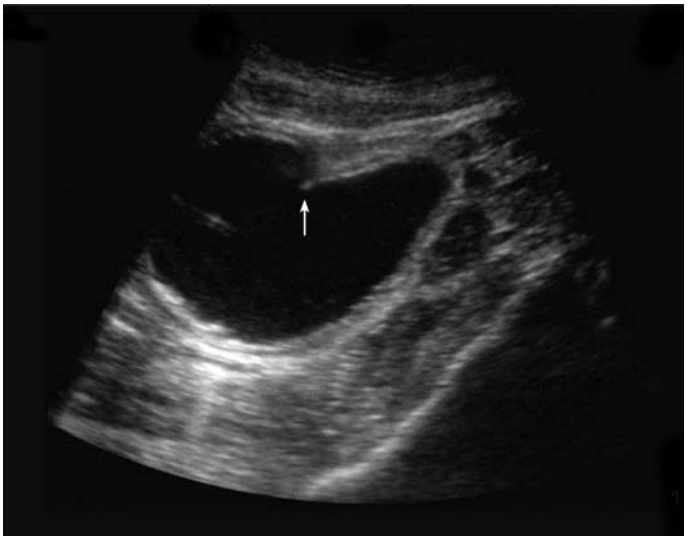


FIGURE 143-9. Longitudinal US appearance of the spinal needle. The anterior bladder wall is tenting as the needle is about to enter the bladder. The needle tip (*arrow*) is visible while the needle is not seen within the tissues.



FIGURE 143-10. The spinal needle is inserted under the cephalic side of the transversely oriented US probe and angled caudally. Note, the US probe cover has been removed for clarity and should be used during the procedure.

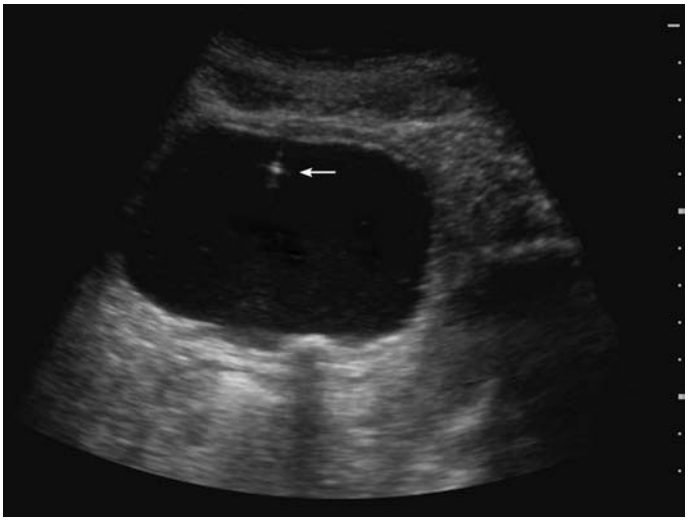


FIGURE 143-11. Transverse US appearance of the spinal needle. The hyperechoic needle tip (*arrow*) is visible with a small ring-down (*bright shadow*) artifact immediately below it.

AFTERCARE

No specific care is required after performing a suprapubic bladder aspiration. **Microscopic hematuria can occur following the procedure although gross hematuria is uncommon.** The patient may complain of mild pain or soreness in the suprapubic area. This can be relieved with acetaminophen or nonsteroidal anti-inflammatory drugs. The patient, if discharged, should be given specific instructions to return immediately if they develop gross hematuria, abdominal pain, fever, nausea, vomiting, or infection at the puncture site.

COMPLICATIONS

Numerous complications can be associated with suprapubic bladder aspiration.[1–16] Fortunately, these are rare occurrences. Bowel perforation, intraabdominal viscera injury, uncontrolled hemorrhage, and needle misplacement are the major complications of suprapubic bladder aspiration. Infectious complications include abdominal wall cellulitis, abdominal wall abscess, sepsis, and peritonitis. Hematomas of the abdominal wall, bladder wall, and pelvis are usually self-limited and require no treatment.

In the unfortunate situation when bowel contents or continuous blood is aspirated, the appropriate surgical consultant should be contacted. Generally, simple penetration of the bowel is considered harmless and requires no specific treatment. Observe the patient for the development of signs and symptoms of peritonitis.

To avoid complications, it is key that the bladder be clearly identified prior to inserting the spinal needle. The use of ultrasonography may aid in substantial reduction of complications arising from needle misadventure. The use of strict aseptic technique should avoid most infectious complications. Delaying the procedure for infants who have urinated within the last hour and the correction of any bleeding diathesis before performing the procedure can help avoid complications.

Do not mistake ascites as urine on ultrasonography. Ascites will outline the bowel and appears in many places around the abdomen. Fluid in the bladder has rounded borders and is localized. It is easy to lose sight of the needle tip and misdirect the needle as it advances through the tissue. Always fan the US probe to keep the tip of the needle in sight. In some cases, the needle may not be visible. Look instead for tissue movement.

SUMMARY

In those clinical situations when transurethral urine collection is not desired or possible, suprapubic bladder aspiration is an alternative. A thorough understanding of the pelvic and abdominal anatomy, along with a complete history and physical examination, is necessary to assure patient safety and avoid complications. This procedure is safe and effective to obtain urine as long as the bladder can be properly identified by palpation, percussion, or ultrasonography. Suprapubic bladder aspiration provides urine that is free from urethral contamination.

144 Suprapubic Bladder Catheterization (Percutaneous Cystostomy)

Richard Dean Robinson, Sam Hsu, and Eric F. Reichman

INTRODUCTION

Complaints involving the lower genitourinary system are among the most common urologic problems encountered by the Emergency Physician. The collection and evaluation of urine plays a critical role in the process of diagnosis and treatment. Volitional voiding and transurethral urinary catheterization are the preferred methods of bladder drainage and can be accomplished in most instances. There are situations when the transurethral route is contraindicated or technically not possible and alternate avenues must be explored. A percutaneous approach to urinary bladder drainage and decompression becomes the solution, offering both therapeutic and diagnostic results.[1–9] Suprapubic bladder catheterization has been used for decades as an effective means of accessing the bladder.

Suprapubic bladder catheterization, or percutaneous cystostomy, has become the treatment of choice for the patient with acute urinary retention regardless of the cause. It is commonly performed in the trauma patient with a known or suspected urethral injury. The catheters are well tolerated, easy to care for, and can easily be replaced and/or removed. The placement of a suprapubic catheter into the bladder is fast and may be performed under local anesthesia. It is a relatively safe procedure but does have potential complications that are significant.

ANATOMY AND PATHOPHYSIOLOGY

Residing in the retropubic space approximately 5 cm above the superior margin of the symphysis pubis, the adult urinary bladder has both retroperitoneal and intraperitoneal attachments. A working knowledge of this anatomy makes percutaneous bladder manipulation both safe and possible. The rectum lies just inferior and posterior to the urinary bladder and this relationship must be kept in mind when attempting percutaneous access. The bladder dome has peritoneal attachments and access in this area carries a risk of bowel injury and intraperitoneal bladder perforation.

Multiple vascular structures, including the common iliac and hypogastric vessels, reside in the bony pelvis alongside the bladder. These structures are lateral to the bladder and eccentric percutaneous access may result in troublesome hemorrhage.

INDICATIONS

Suprapubic bladder catheterization is indicated in cases when the transurethral route of bladder drainage or decompression is technically not possible or contraindicated. This includes patients with iatrogenic urethral injuries, obstructing urethral lesions, bladder neck lesions, enlarged prostates (e.g., benign hypertrophy or cancer), urethral strictures, urethral scarring, an obstructing phimosis, a urethral foreign body, and a suspected or known traumatic urethral or prostatic disruption. Continuous bladder irrigation can be accomplished via a combined suprapubic and transurethral route.

CONTRAINDICATIONS

Suprapubic catheterization is absolutely contraindicated in the absence of an easily palpable and distended or ultrasonographically localized and distended urinary bladder.[9] Under no circumstances should "blind" percutaneous access be attempted. The bladder must be distended to push the bowel away from the anterosuperior surface of the bladder.

Patients with a coagulopathy are at an increased risk for troublesome hemorrhage from any percutaneous procedure, including suprapubic bladder catheterization. Any coagulopathy, bleeding diathesis, platelet dysfunction, and/or thrombocytopenia should be corrected prior to performing this procedure.

In individuals with prior lower abdominal surgery or traumatic injury, the peritoneal cavity has been violated and the bowel may be displaced more caudal and to the level of the urinary bladder. The bowel may be adhesed to the anterior abdominal wall. This heightens the risk of inadvertent entry into the peritoneal cavity and injury to the bowel.

Relative contraindications to percutaneous bladder catheterization include patients who have a history of pelvic cancer or pelvic radiation therapy, ascites, urinary tract infections, or who are uncooperative. A history of pelvic cancer or irradiation will increase the risk of anatomical distortion, adhesions, and scarring. Attempts at suprapubic cystostomy increase the risk of peritoneal and/or bowel perforation. The return of ascitic fluid may lead the physician to a false sense of security when the catheter is actually intraperitoneal. Urine leakage in patients with a urinary tract infection may result in bacteremia, peritonitis, and/or sepsis. In these circumstances, consult a Urologist for an open suprapubic cystostomy or Interventional Radiology for a percutaneous cystostomy using fluoroscopic or ultrasonic guidance. An uncooperative patient will require parenteral sedation or procedural sedation prior to performing this procedure.

Any physical alteration, spinal deformities, extremity contractures, truncal obesity, or other conditions that would preclude patients from lying supine and inhibiting bladder palpation are also contraindications to performing a percutaneous cystostomy.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves
- Percutaneous cystostomy catheter kit
- Foley catheter, 14 to 16 French
- 60 mL catheter-tipped syringe
- 10 mL syringes
- 24 to 25 gauge spinal needle, 3 inches long
- #11 Surgical scalpel blade on a handle
- 3-0 nylon suture
- Needle driver
- Local anesthetic solution, with or without epinephrine
- 4 × 4 gauze squares
- 25 gauge needle, 1 inch long
- 18 gauge needle
- Urine meter or urine leg bag
- Sterile towels
- Sterile drapes
- Tincture of benzoin
- 2 inch tape
- Ultrasound machine (recommended)

The percutaneous cystostomy catheter kit is commercially available and prepackaged by several manufacturers. One type contains a cystostomy tube, an obturator, and connector tubing (**Figures 144-1, 144-2, & 144-4**). Another type uses a Seldinger-type kit with a peel-away sheath (**Figure 144-3**).

A commonly used suprapubic catheter kit is the Rutner Percutaneous Suprapubic Balloon Catheter Set (Cook Urological Inc., Spencer, IN). It consists of a 10 French catheter that is 22 cm long, a needle obturator, a connecting tube, and a 3 mL syringe (**Figures 144-1 & 144-2A**). The proximal end of the catheter has two ports (**Figures 144-1 & 144-2B**). One port is for the insertion of the obturator through the catheter. The obturator screws and locks into this port. The other port is an inflation port for the cuff of the catheter. A 3 to 5 mL syringe attaches to this port. The obturator is a hollow tube that tapers to a sharp point distally. When properly inserted and locked into the port, the obturator will project 2.5 mm from the distal end of the catheter (**Figures 144-1C & 144-2C**). The cuff is donut-shaped and centered 1 cm from the tip of the catheter (**Figure 144-2D**). The connector tube has a stopcock at its distal end that attaches to the catheter (**Figure 144-2E**). The proximal end of the connector tube has a flared flange to attach to a urine drainage system.

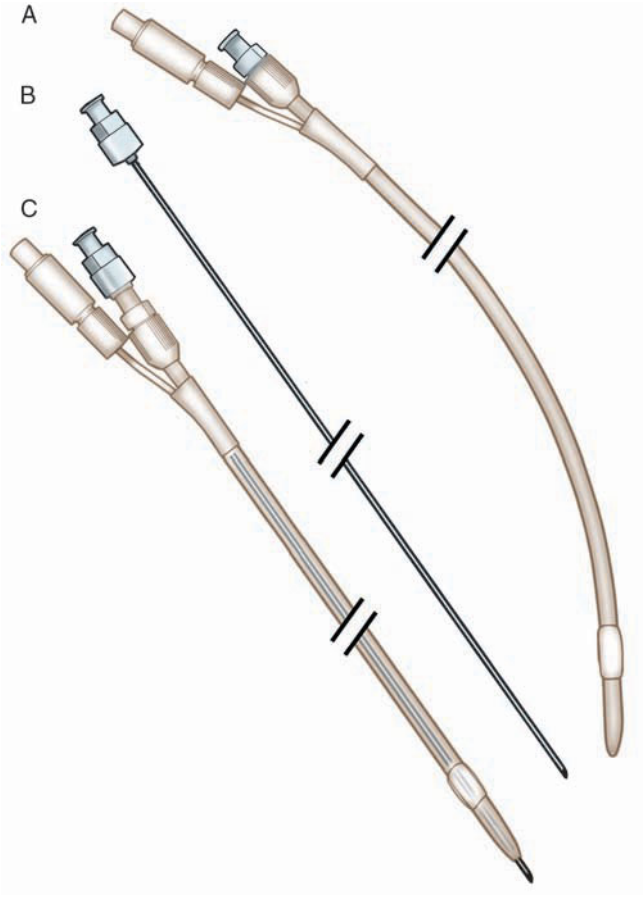


FIGURE 144-1. Schematic of a catheter and obturator system. **A.** The catheter. **B.** The obturator. **C.** The obturator within the catheter.

PATIENT PREPARATION

As with all procedures, the risks and benefits of suprapubic bladder catheterization should be discussed with the patient and/or their representative. Obtain an informed consent and place it in the medical record.

Place the patient supine. Clean any dirt and debris from the abdominal wall. Shave the lower abdomen if the patient is hirsute. Identify the bladder by palpation, percussion, and/or ultrasonography. Apply povidone iodine or chlorhexidine solution to the lower abdomen, from the umbilicus to the pubis, and allow it to dry. Consider the administration of parenteral analgesics, sedatives, or procedural sedation as this is a painful procedure.

Anesthetize the abdominal wall. Fill a 10 mL syringe with local anesthetic solution. Apply a 24 to 25 gauge spinal needle onto the syringe. Identify the insertion site in the midline and 4 to 5 cm above the pubic symphysis. The use of ultrasound to verify the bladder location and to ensure that no loops of bowel are present between the abdominal wall and bladder is recommended.[9] Make a skin wheal with the local anesthetic solution at the insertion site. Insert the spinal needle at a 20° to 30° angle from true vertical and aimed caudally (**Figure 144-3A**). Advance the needle through the subcutaneous tissue, rectus sheath, and retropubic space while simultaneously aspirating and injecting 5 to 10 mL of local anesthetic solution. A loss of resistance will be felt as the spinal needle traverses the rectus sheath and enters the retropubic space. Continue to aspirate while advancing the spinal needle until the bladder is entered and urine fills the syringe. The bladder appears to tent as the needle pierces its anterior wall when ultrasonographic guidance is used.[8] **Note the needle direction and depth of insertion required to enter the bladder.**

TECHNIQUES

SELDINGER TECHNIQUE WITH A PEEL-AWAY SHEATH

This method is similar to that of placing a central venous catheter. The needle is used to locate the bladder. Place the needle on a 10 mL syringe. Insert the needle through the skin wheal of local anesthetic solution located in the midline and 4 to 5 cm above the pubic symphysis. Direct the needle caudally and at a 20° to 30° angle from the true vertical (**Figure 144-3A**). **It is important to ensure that the needle enters, and is advanced, in the midline.** This area is avascular. If the needle is paramedian, it may traverse the rectus muscles and inferior epigastric vessels resulting in significant hemorrhage. Advance the needle caudally while applying negative pressure with the syringe. Stop advancing the needle when urine is aspirated into the syringe. Advance the needle an additional 2 to 3 cm into the bladder from the point at which urine is initially aspirated into the syringe. The aspiration of urine will confirm the proper position of the needle within the bladder.

Firmly hold the needle against the abdominal wall. Carefully remove the syringe from the needle. **Do not allow the needle to move as it may shear the bladder wall.** Advance the guidewire through the needle and into the bladder (**Figure 144-3B**). Withdraw the needle over the guidewire while leaving the guidewire in place. Make a superficial stab incision with the #11 scalpel blade adjacent to the guidewire. This will facilitate passage of the dilator and sheath. Insert the dilator through the peel-away sheath. Advance the dilator and peel-away sheath as a unit over the guidewire and into the bladder (**Figure 144-3C**). Remove the guidewire and dilator as a unit (**Figure 144-3D**), leaving only the peel-away sheath (**Figure 144-3E**).

Insert a Foley catheter through the peel-away sheath and completely into the bladder (**Figure 144-3F**). The Foley catheter should be two sizes (2 French) smaller than the size of the peel-away sheath. Urine should spontaneously flow from the Foley catheter. If not, insert a 60 mL catheter-tipped syringe into the Foley catheter and aspirate (**Figure 144-3G**). The flow of urine will confirm that the catheter is properly positioned within the bladder. Inflate the cuff of the Foley catheter. Attach a urine collection system to the proximal end of the Foley catheter (**Figure 144-3H**).

Remove the peel-away sheath. Grasp the free ends or arms of the peel-away sheath. Pull the free ends upward and opposite each other (**Figure 144-3H**). The peel-away sheath will split in half as it is withdrawn over the Foley catheter and out of the abdominal wall. Gently withdraw the Foley catheter to lodge the cuff against the bladder wall (**Figure 144-3I**).

OBTURATOR TECHNIQUE

Prepare the equipment. Insert the obturator through the catheter and lock it in position. Inflate the cuff with sterile saline and check its integrity. Deflate the cuff. Inflate and deflate the cuff two more times to soften the cuff. The spinal needle was previously used to infiltrate local anesthetic solution and locate the urinary bladder. This maneuver allows the operator to determine both the depth and angle needed for bladder entry.

Make a 3 to 4 mm stab incision in the midline and 4 to 5 cm above the pubic symphysis through the skin wheal of local anesthetic solution with a #11 scalpel blade. Place the tip of the obturator-catheter unit in the skin incision. **It is important to ensure that the unit enters, and is advanced, in the midline.** This area

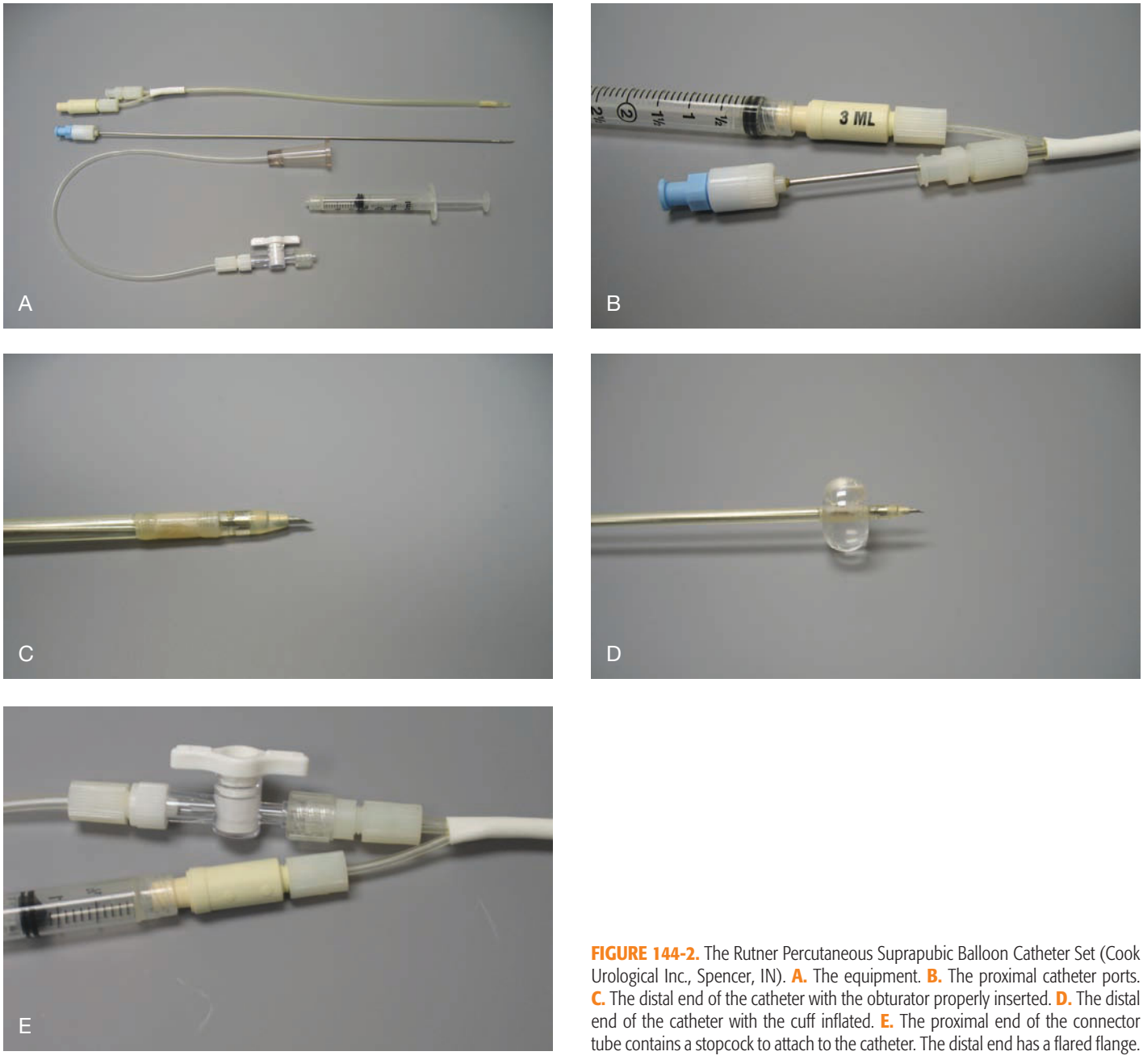


FIGURE 144-2. The Rutner Percutaneous Suprapubic Balloon Catheter Set (Cook Urological Inc., Spencer, IN). **A.** The equipment. **B.** The proximal catheter ports. **C.** The distal end of the catheter with the obturator properly inserted. **D.** The distal end of the catheter with the cuff inflated. **E.** The proximal end of the connector tube contains a stopcock to attach to the catheter. The distal end has a flared flange.

is avascular. If the unit is paramedian, it may traverse the rectus muscles and inferior epigastric vessels resulting in significant hemorrhage. Direct the unit caudally and at a 20° to 30° angle from true vertical (**Figure 144-4A**). Place the nondominant hand on the lower abdominal wall. Grasp the tip of the obturator-catheter unit with the thumb and index finger of the dominant hand. The hand and fingers will stabilize the unit and control the depth of insertion.

Advance the obturator-catheter unit with the dominant hand. Resistance may be felt as the trocar traverses the linea alba. Apply firm pressure to the unit to advance through the linea alba. **Do not plunge as the unit is advanced.** Continue to advance the unit through the retropubic space until resistance is felt. The tip of the trocar is now against the anterior bladder wall. Advance the unit with a short and rapid stabbing motion to enter the bladder (**Figure 144-4A**). Urine should spontaneously flow from the proximal end of the obturator. If not, attach a syringe to the obturator and aspirate. The flow of urine will confirm that the tip of the obturator-catheter unit is properly positioned within the bladder. Advance the unit an additional 2 to 3 cm into the bladder to ensure the cuff is completely within the bladder.

Inflate the cuff of the catheter (**Figure 144-4B**). Unscrew the obturator from the catheter. Securely hold the catheter, with the nondominant hand, as it exits the abdominal wall. Remove the obturator from the catheter (**Figure 144-4C**). Attach the stopcock at the distal end of the connector tube to the catheter (**Figure 144-4D**). Gently withdraw the catheter to lodge the cuff against the bladder wall. Attach a urine collection system to the proximal end of the connector tube.

ULTRASOUND TECHNIQUE

Ultrasound (US) can ensure there is sufficient urine to aspirate and locate a bladder that is located off midline or deep in the pelvis.[10] It is especially helpful in infants and toddlers, who

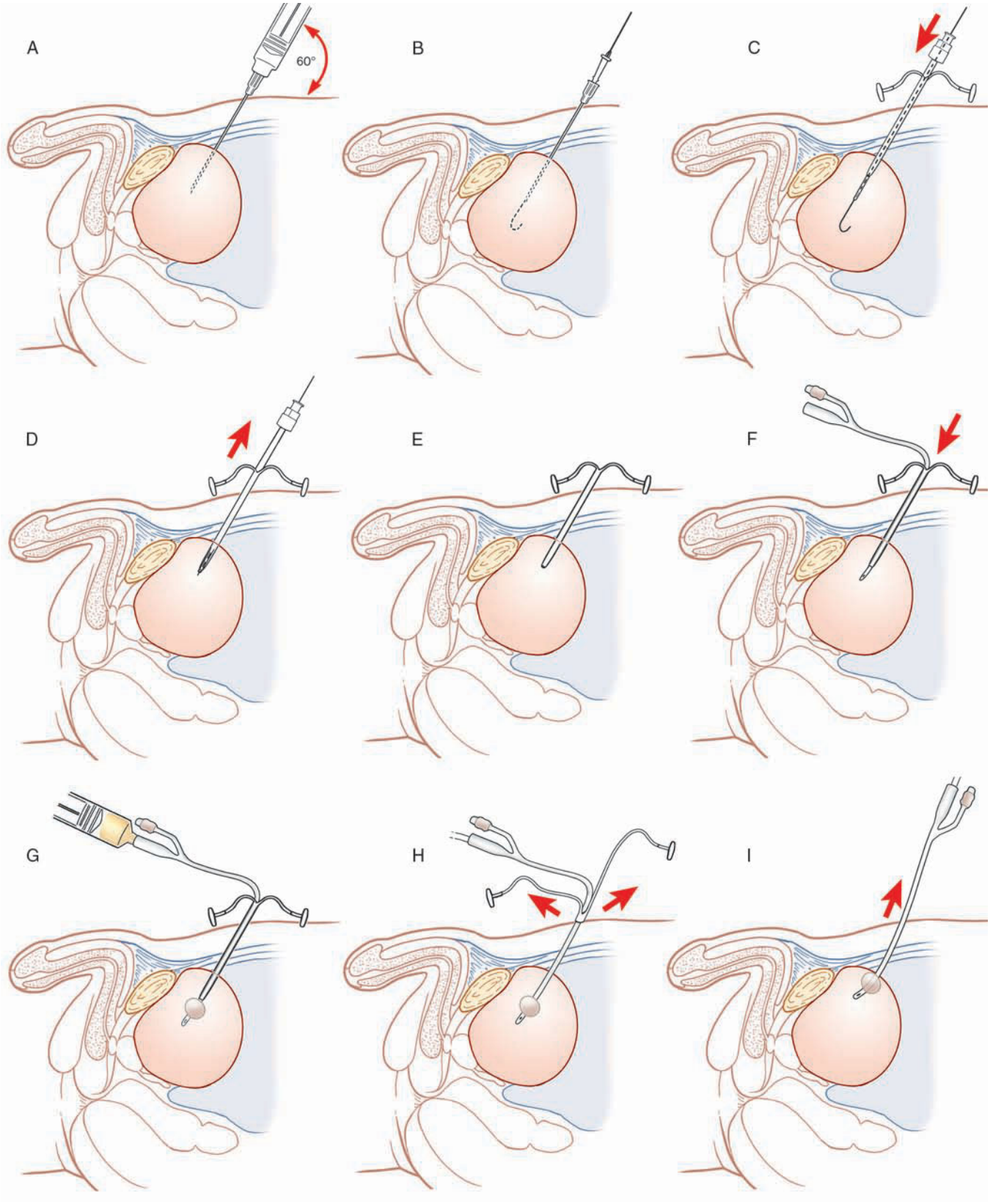


FIGURE 144-3. The Seldinger technique with a peel-away sheath. **A.** The finder needle is inserted 60° to 70° to the skin and advanced into the bladder. **B.** The syringe has been removed and the guidewire inserted through the needle. **C.** The needle has been removed. The dilator and peel-away sheath are inserted over the guidewire as a unit and into the bladder. **D.** The dilator and guidewire are removed. **E.** The peel-away sheath remains through the skin and into the bladder. **F.** A Foley catheter is inserted through the peel-away sheath and into the bladder. **G.** Urine is aspirated from the bladder. The cuff on the catheter is inflated. **H.** The arms of the peel-away sheath are pulled upward and apart to remove the sheath. **I.** The cuff is lodged against the dome of the bladder.

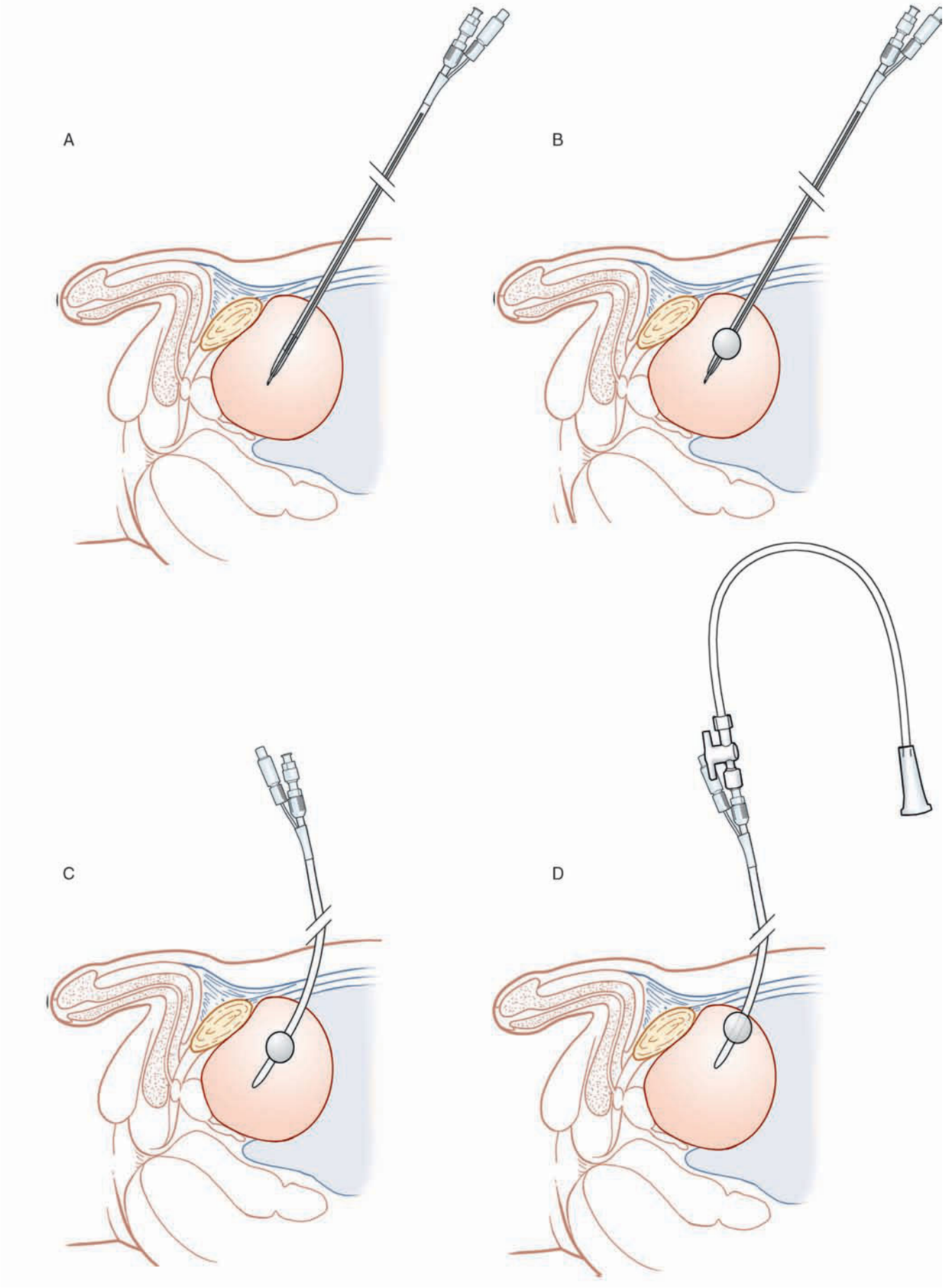


FIGURE 144-4. The obturator technique. **A.** The obturator is within the catheter. The system is inserted 60° to the skin and advanced into the bladder. **B.** The balloon is inflated. **C.** The obturator is removed while the catheter remains within the bladder. **D.** The collecting tube is attached to the catheter.

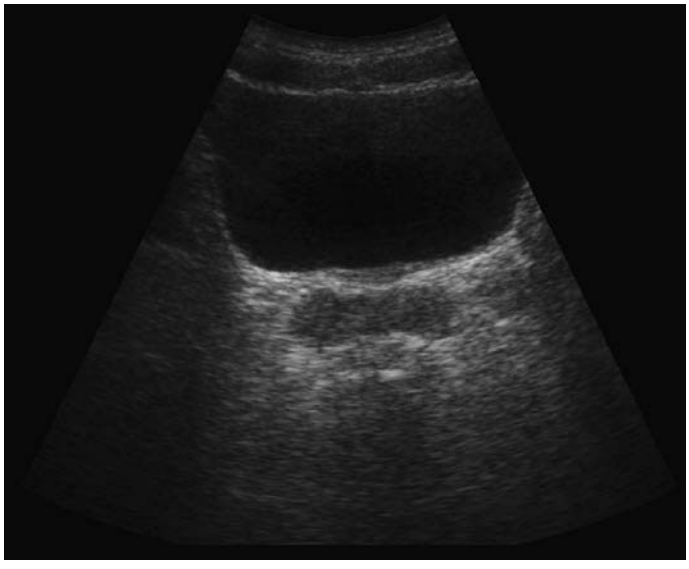


FIGURE 144-5. Transverse US view of the bladder.



FIGURE 144-6. The US machine is positioned in the same sight-line as the procedure. The physician's dominant (*right*) hand is cephalad and controls the needle. Note, the US probe cover has been removed for clarity and should be used during the procedure.

have small bladders. There are no contraindications to using ultrasound other than those for the procedure itself. For adults, a general-purpose curvilinear abdominal or phased-array probe provides the best combination of penetration and field of view into the abdomen. A linear probe can be used for children. Either a static or dynamic (real-time) technique can be used. The static technique is preferred as it is the easier technique to learn and master. The dynamic technique will increase the success rate for small bladders with minimal urine.

Image the bladder to ensure there is sufficient urine to aspirate. Place the US probe transversely and just superior to the pubic symphysis. If the bladder is not immediately visible, slowly fan the probe cephalad and caudal until it appears. If the bladder is not visible, repeat the scan just off the midline. The bladder will appear anechoic (**Figure 144-5**). Moderate to large bladders are amenable to the static US technique. Bladders smaller than 2 cm in anteroposterior or transverse diameter have lower success rates for aspiration and the dynamic US technique may be necessary to obtain urine.

STATIC US TECHNIQUE

Identify the bladder using US and center the image on the US machine screen. Angle the US probe so that the largest dimensions of the bladder appear on the screen. **Note the angle of the US probe as this will correspond to the angle of entry for the needle.** Make sure that the bladder is centered on the screen. Move the probe off midline, if necessary, to minimize lateral angulation. This will prevent the need to angle the needle laterally to reach the bladder. Note the depth on the screen from the skin to the bladder in order to gauge the necessary needle length. Mark the entry point on the skin where the middle of the probe meets the skin. Prep the skin and proceed with procedure as described previously for either the Seldinger or obturator technique.

DYNAMIC US TECHNIQUE

Prepare the skin, apply sterile single-use US gel to the patient's skin, and apply a sterile US probe cover. Stand to the side of the patient so that your dominant hand is cephalad (**Figure 144-6**). Position the US monitor on the opposite side of the patient so that it is easy to see (**Figure 144-6**). A longitudinal US probe orientation is preferred for the dynamic approach since it allows visualization of the entire needle as it courses toward the bladder. In infants and toddlers, there may not be enough space to place the US probe longitudinally and a transverse probe orientation may be necessary. In either case, place the US probe marker to your left. This will ensure that the left–right orientation on the US screen matches the real-world orientation.

Place the longitudinally oriented US probe in the suprapubic area and move it from side to side to locate the largest bladder dimension. Place the procedure needle on a 10 mL syringe. Position the procedure needle on the cephalad side of the US probe and angle it caudally (**Figure 144-7**). Insert and slowly advance the needle. Look for the needle on the US screen as it is inserted and advanced. If the needle is a narrow gauge and the US probe is low frequency, the needle will not necessarily be visible in the tissue. Rather, look for movements in the tissue as the needle is advanced (**Figure 144-8**). Adjust the needle and the US probe side to side as needed to keep the needle in the same plane as the US beam. Aspirate as the needle is advanced. When the needle appears to enter the bladder, aspiration should result in urine return. Remove the US probe once urine is aspirated. The remainder of the procedure for the Seldinger technique can proceed as previously described. The US procedure is the same if using the obturator technique; just substitute the catheter-obturator unit for the needle described above.

For the transverse orientation, position the US probe so that the image of the bladder is centered on the screen. Position the procedure needle attached to a syringe just superior to the center of the US probe (**Figure 144-9**). Slowly advance the needle toward the bladder. Angle the needle slightly more caudal than the US probe since the entry point of the needle is superior to the US probe. The needle will be seen on screen in cross section and will appear as an echogenic point with a ring-down artifact or bright shadow (**Figure 144-10**). As the needle is advanced toward the bladder, the US probe may need to be fanned slightly cephalad or caudal



FIGURE 144-7. The spinal needle is inserted under the cephalic side of the longitudinally oriented US probe and angled caudally. Note, the US probe cover has been removed for clarity and should be used during the procedure.

to keep the needle tip in view. Aspirate as the needle is advanced. When the needle appears to enter the bladder, aspiration should result in urine return. Remove the US probe once urine is aspirated. The remainder of the procedure for the Seldinger technique can proceed as previously described. The US procedure is the same if using the obturator technique; just substitute the catheter-obturator unit for the needle described above.

ASSESSMENT

The return of urine confirms the correct placement of the catheter into the bladder. If the catheter ceases to work after initially functioning properly, inspect it for kinks. Flush the catheter with sterile saline to remove any potential clots. A catheter that flushes easily but cannot be subsequently aspirated suggests that the tip has been withdrawn into the perivesical space of the pelvic cavity or that the catheter is kinked. The catheter is kinked if saline cannot be flushed through or aspirated. The catheter is properly positioned within the bladder if saline flushes and aspirates without difficulty. Consider the use of ultrasound to confirm catheter placement and presence of urine within the bladder.



FIGURE 144-9. The spinal needle is inserted under the cephalic side of the transversely oriented US probe and angled caudally. Note, the US probe cover has been removed for clarity and should be used during the procedure.

AFTERCARE

Secure the catheter to the abdominal wall (**Figure 144-11**). Place 4 × 4 gauze squares over the pubic symphysis to bolster the catheter as it exits the abdominal wall. Apply tincture of benzoin to the abdominal wall and allow it to dry. Tape over the catheter and gauze. The ends of the tape should be applied to the dried benzoin solution. Prophylactic antibiotics are not required unless a urinary tract infection is present.

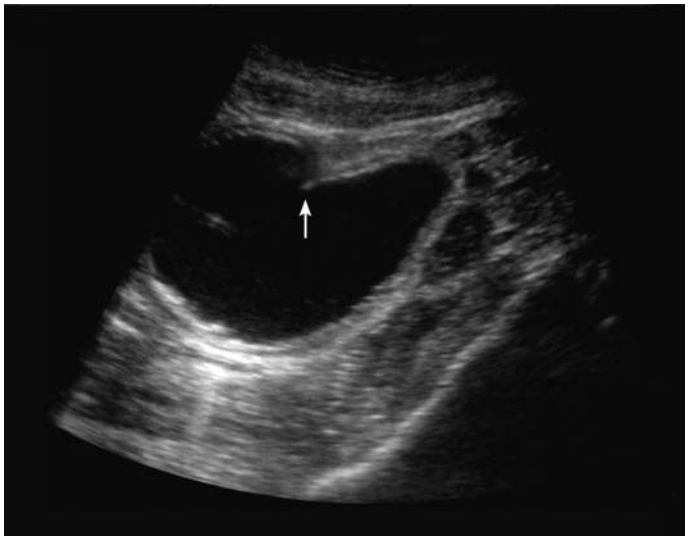


FIGURE 144-8. Longitudinal US appearance of the spinal needle. The anterior bladder wall is tenting as the needle is about to enter the bladder. The needle tip (*arrow*) is visible while the needle is not seen within the tissues.

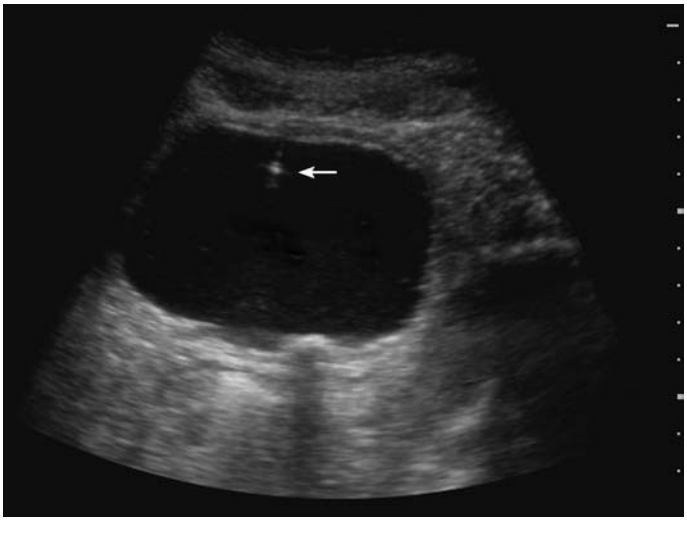


FIGURE 144-10. Transverse US appearance of the spinal needle. The hyperechoic needle tip (*arrow*) is visible with a small ring-down (*bright shadow*) artifact immediately below it.

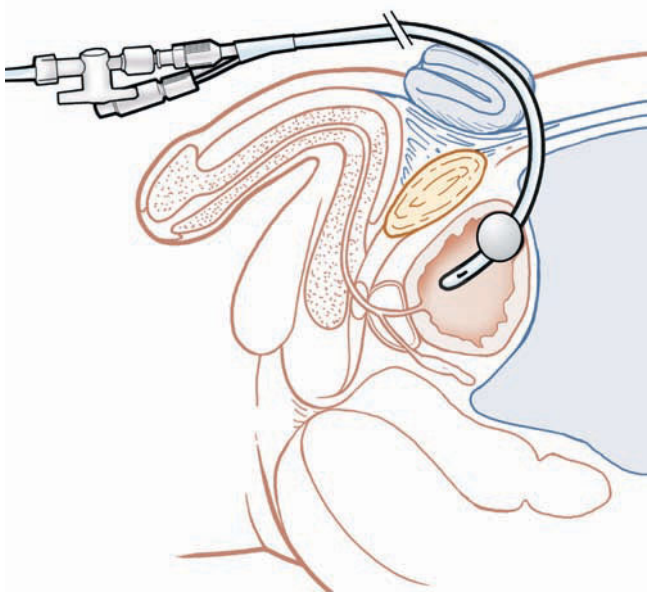


FIGURE 144-11. Secure the catheter. Place gauze squares on the skin to make a gentle curve in the catheter without kinks. Tape the catheter to the abdominal wall.

Examine the puncture site twice a day for any signs of infection. Routine wound care should be performed at the puncture site. If removed within 7 days, the bladder wall and abdominal wall will heal without complications. A transurethral catheter should be inserted to ensure urine egress through the urethra and not the bladder wall while the suprapubic catheter tract heals. After 10 to 14 days, the tract of the catheter is epithelialized and mature. The catheter may be exchanged through the mature tract if necessary. Suprapubic tubes should not be left in place for more than 4 weeks.[9]

COMPLICATIONS

Bowel perforation, intraabdominal visceral injury, uncontrolled hemorrhage, vascular injury, peritonitis, catheter misplacement, and catheter migration are the major complications of suprapubic cystostomy catheter placement.[1–11] Perforation of the bowel can be prevented by ensuring that the bladder is distended by palpation, percussion, or ultrasonography. Intraperitoneal perforation is more common in patients with ascites, a distended abdomen, or prior abdominal surgery. Gross hematuria is common and transient. Through-and-through perforation of the bladder can injure the rectum, vagina, and/or uterus. Other minor complications are associated with length of indwelling catheter time and include infections (e.g., cellulitis and abscesses), occasional bleeding, and stone formation.

When catheter placement is in doubt or when a previously draining tube no longer continues to drain, simple flushing and irrigation will usually suffice. Bedside ultrasound is a quick means to confirm catheter placement. However, if concern persists, a gravity cystogram under fluoroscopy is diagnostic. In the unfortunate situation when bowel contents or continuous blood is aspirated or flows from the catheter, the appropriate surgical consultations should be obtained.

SUMMARY

In those clinical situations when transurethral bladder decompression is no longer an option, percutaneous access is the preferred alternative. Years of experience have demonstrated suprapubic bladder catheterization to be an effective and relatively safe method of accessing the bladder. A prior understanding of the associated anatomy is paramount to avoid of adverse results.

145 Retrograde Urethrography and Cystography

Richard Dean Robinson and Eric F. Reichman

INTRODUCTION

Urinary tract injuries may result from blunt trauma, penetrating trauma, urologic procedures, or may arise spontaneously.[1–14] Bladder injuries occur in up to 15% of pelvic fractures.[1–3] Associated urethral injuries occur in up to 11% of males and up to 6% of females.[1–3] **The role of retrograde urethrography and cystography in the trauma patient is to rule out a partial urethral rupture, complete urethral rupture, or a bladder rupture.** On initial presentation to the Emergency Department there are clear indications for performing these procedures. The importance of proper training in these techniques must be stressed to avoid iatrogenic or secondary urologic injury.

The evaluation of a traumatically injured patient should include, if appropriate, an assessment of the bony pelvis and the genitourinary system. The identification of a pelvic fracture must be followed by an examination of the lower genitourinary tract to rule out associated injury. Patients with disruption of the pubic symphysis, pubic rami, or a vertically unstable pelvic fracture have a high incidence of concomitant bladder trauma. Those with an isolated acetabulum, femur, or iliac crest fracture have a low incidence of bladder injury or rupture.[13] Unfortunately, the lack of a pelvic fracture does not eliminate the possibility of a bladder or urethral injury.

The most common signs seen in patients with genitourinary tract injury are gross hematuria (82%) and abdominal tenderness (62%).[4] Other signs of genitourinary tract injury include blood at the urethral meatus, inability to void, swelling or ecchymosis of the perineum or penis, a boggy prostate, and a high riding prostate. In the presence of any of these signs, an evaluation of the genitourinary tract is indicated. These assessments should be made early and intervention instituted.

Traditional teaching suggests that urethral catheterization should be avoided if a potential injury to the bladder and/or urethra is suspected. This teaching requires a retrograde urethrogram and cystogram to be performed to rule out any injuries prior to urethral catheterization. A preliminary study suggests that blind urethral catheterization despite a potential injury may be safe.[15] Larger and additional studies are required before this change in practice can be safely recommended.

ANATOMY AND PATHOPHYSIOLOGY

The lower urinary tract in males consists of the urethra and bladder (**Figure 145-1**). The urethra is divided into the fossa navicularis, the penile urethra, the bulbar urethra, the membranous urethra, and the prostatic urethra based on its anatomic location. The bladder neck opens into the trigonal canal and funnels into the bladder. The male posterior urethra is 5.0 to 5.5 cm long, fixed to the urogenital diaphragm, and is the area most susceptible to injury.[2,5] The female urethra is short, not rigidly fixed to the pubis

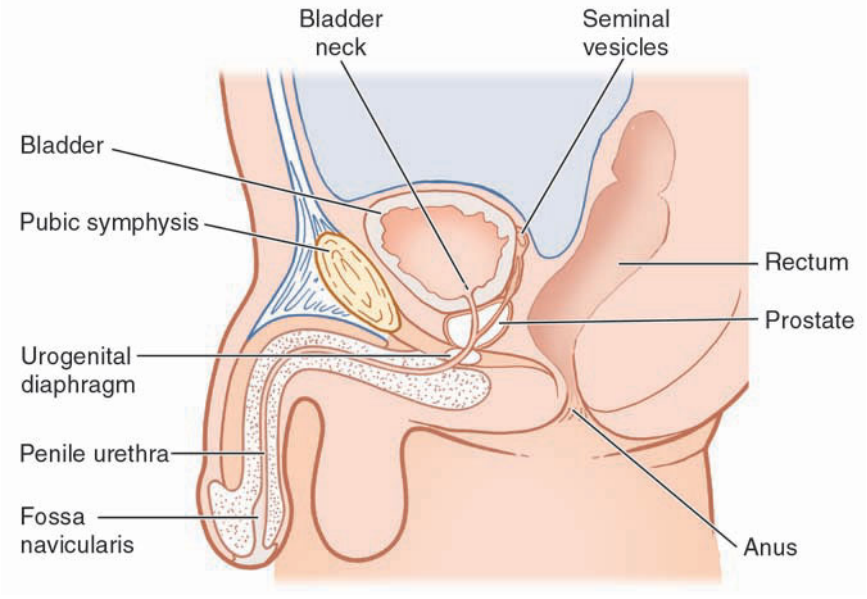


FIGURE 145-1. Anatomy of the male genitourinary tract.

or pelvic floor, mobile, and much less susceptible to injury.[3] The female urethra is equivalent to the membranous and prostatic (posterior) urethra in the male.[6]

The periurethral striated sphincter is composed of muscle from the urogenital diaphragm. This muscle layer unites with the distal smooth muscle at the intermuscular incisura. This is frequently seen on the voiding cystourethrogram and may be mistaken for a stricture or posterior urethral valves. The urogenital diaphragm surrounds the membranous urethra and may compress the urethra during voiding or on retrograde flow of contrast.[6]

The verumontanum and urethral crest protrude into the male prostatic urethral lumen and may extend into the membranous urethra. The prostatic gland ducts, prostatic utricle, ejaculatory ducts, and urethral gland ducts usually do not fill on voiding cystourethrogram; and when visible, filling usually denotes a distal obstruction. These structures, however, may fill during aggressive injection of contrast during the retrograde urethrogram.

On the lateral view of the bladder, the anterior and posterior baseplate (of which the trigone is part) is seen as a diagonal plane sloping downward from posterior to anterior. The bladder neck is visualized at the junction of the anterior one-third and the posterior two-thirds of the plane. Anteriorly, the pubis abuts the baseplate. The fundus of the bladder becomes more dome shaped as it fills with fluid. It may be compressed by the uterus or colon in the midline or on either side.[6]

INDICATIONS

The retrograde urethrogram is to be employed in blunt and penetrating traumatic presentations of males when there is any indication of a urethral injury. Indications include penetrating injury when involvement of the lower genitourinary tract is suspected, pelvic fractures, perineal or lower abdominal trauma with gross hematuria, blood at the urethral meatus, inability to void, swelling of the perineum or penis, ecchymosis of the perineum or penis, hematoma of the perineum or penis, a high riding prostate, or a boggy prostate.[7,8,13] Other indications include urethral strictures and obstructions, congenital abnormalities, periurethral or prostatic abscess, and fistulae or false passages. In females, it may be indicated if urethral diverticula are suspected.

Retrograde cystography should follow retrograde urethrography, especially in patients who recall having a full bladder at the time of trauma and are later unable to void or have small amounts of bloody urine.[9] Retrograde cystograms are nearly 100% sensitive for detecting rupture, provided that adequate distension is accomplished and that postvoid images are obtained.[13]

CONTRAINDICATIONS

There are few contraindications to retrograde urethrography and cystography. However, the patient's overall condition must be taken into consideration. The lifesaving procedures, such as securing an airway and stabilizing life- and limb-threatening injuries, must take precedence. Because septic shock and irreversible renal damage can occur, a relative contraindication in the setting of acute urethritis exists when the suspicion of genitourinary tract trauma is very low. **A urethral injury identified on the retrograde urethrogram is the only absolute contraindication to transurethral bladder catheterization and retrograde cystography**. Consult a Urologist if, in a patient with pelvic trauma, there is any difficulty in passing a urethral catheter into the bladder. **Do not try to advance a catheter against resistance as iatrogenic injury can result**. There is a small risk of allergic reactions to the contrast media. Patients with previous reactions should receive nonionic agents and be premedicated with corticosteroids and antihistamines.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Sterile gloves
- Sterile drapes
- Viscous lidocaine suspension
- Foley catheter, 5 to 18 French (**Table 145-1**)
- Brodney clamp
- Contrast material
- 60 mL catheter tip syringe
- Toomey syringe
- Christmas tree adaptor
- Surgical clamp
- Lead apron

TABLE 145-1 Estimated Foley Catheter Size Based on Patient Age

Patient age	Catheter size (French)
Premature or newborn	5
3–12 months	8
1–2 years	8–10
2–8 years	10
8–10 years	10–12
10–12 years	12
12–14 years	12–14
14+ years	16–18

A variety of contrast agents are available and may be used to perform retrograde urethrography and cystography. The agents used are specific to each institution. Most commonly used are full strength Hypaque (50% diatrizoate sodium), Renografin-60 (diatrizoate sodium), or Cystografin. Alternatively, the same agents can be diluted with sterile saline in a 1:10 dilution.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. While a formal consent is usually not obtained since this is an emergent procedure, document in the medical record that the "risks and benefits were explained to the patient." If not contraindicated, administer parenteral sedation. Place the patient in a 45° oblique position with their left side on the bed. Flex the left leg at the knee and abduct the hip. Place a radiolucent wedge or rolled towels under the patient to maintain the oblique position. Completely extend the right leg. This is the ideal patient position. The degree of patient mobility and the medical condition may dictate an alteration of this position. In patients with pelvic fractures, all radiographs should be taken with the patient in a supine position.

Prepare the penis and urethra. Clean any dirt and debris from around the penis. Retract the foreskin if the patient is uncircumcised. Apply povidone iodine or chlorhexidine solution to the penis and allow it to dry. Apply sterile drapes to delineate a sterile field. **The retrograde urethrogram must be performed under sterile conditions. Insert viscous lidocaine into the urethral meatus to anesthetize the urethra. Do not use lidocaine jelly as this may impede the flow of contrast material**. Allow the lidocaine to remain in the urethra for 2 to 4 minutes prior to performing the procedure to provide adequate analgesia.

Obtain a flat plate or KUB (kidney, ureters, and bladder) radiograph. This will be a baseline film for future reference. Carefully examine the radiograph for curvature of the spine, pelvic fractures, fractures of ribs 9 to 12, unilateral or bilateral loss of the normal psoas muscle shadow, or vertebral transverse process fractures. Any of these findings can signify a urinary tract injury. Observe and note any radiopaque material that may be present prior to the injection of contrast material.

The Emergency Physician should dress appropriately for the procedure. Since the Emergency Physician must be near the patient during the procedure and while radiographs are taken, put on a lead apron. Dress in a sterile gown and gloves. A cap and mask are not required.

RETROGRADE URETHROGRAPHY TECHNIQUES

FOLEY CATHETER TECHNIQUE

The Foley catheter technique is the preferred method. The Foley catheter causes little or no discomfort, is flexible, and the patient may be able to move if necessary. There is no leakage of contrast from the urethra and onto the patient, which can cause artifacts on the radiographs and make interpretation difficult. An advantage to using the Foley catheter is that it can subsequently be advanced into the bladder to perform the cystogram. The newer types of catheters have two cuffs; one at the tip and the other near the balloon inflation hub of the catheter. The proximal cuff will expand when the pressure in the distal cuff exceeds the maximum safe pressure during cuff inflation. This allows the excess pressure to be directed away from the distal cuff and not cause an iatrogenic urethral injury. There are some disadvantages to this method. The inflated cuff may conceal an injury of the distal urethra at the fossa navicularis. Air bubbles are difficult to eliminate from the catheter. This may impair the flow of the contrast material or produce artifacts due to air in the urethra. Air bubbles in the Foley catheter will alter the integrity of the study. Prime the tubing with contrast before inserting it into the urethra to eliminate any air. Place an X-ray plate under the patient's hips and pelvis.

Insert the catheter into the urethra. Advance it until the cuff is within the fossa navicularis (**Figure 145-2A**). Inflate the cuff with approximately 3 mL of sterile saline, or to the point that it is snug and does not cause pain to the patient.[10] Gently straighten the urethra by directing the tip of the penis toward the dependent shoulder or nipple and over the thigh. Avoid traction on the penis or the Foley catheter as it tends to narrow the urethra and/or dislodge the catheter. Attach a contrast-filled syringe to the proximal end of the Foley catheter (**Figure 145-2A**). Gently inject 50 to 60 mL of contrast material over 5 to 10 seconds.

Obtain a plain radiograph at or near the end of the injection. Have the film developed and review the image. The entire urethra should be visible in a lateral projection. Repeat the procedure if this is not achieved. Allow the contrast to drain from the urethra through the Foley catheter and into a container. Deflate the cuff and remove the catheter from the urethra. Obtain an additional plain radiograph of the pelvis as a washout image. Have the film developed and review the image for any abnormalities in the urethra. Although not necessary, fluoroscopy may aid in obtaining an adequate study.[10]

Great care should be taken so as not to allow any contrast to leak out of the catheter or urethra. Any spill of contrast material will cause distortions on the radiographs. The contrast may also cause skin irritation. It should be wiped and rinsed off the skin immediately if this occurs.

SYRINGE TECHNIQUE

If a proximal urethral injury is suspected, the alternative method is to use a 60 mL catheter-tipped Toomey syringe or a 60 mL syringe with a Christmas tree adaptor. Because it is not flexible and cannot be fixed inside the penis, the syringe must be held in place at all times during the procedure. The penile shaft must also be held to secure the tip of the syringe inside the urethra. There is a significant chance of contrast leakage from the urethra using this technique.

Clear, prep, and drape the penis as described previously. Place an X-ray plate under the patient's hips and pelvis. Grasp and cradle the patient's penis with the nondominant hand. Insert the tip of the contrast-filled syringe into the urethra. Firmly squeeze the glans penis between the thumb and the index and long fingers (**Figure 145-2B**). This will secure the catheter tip within the fossa navicularis. Do not squeeze the shaft of the penis with middle, ring, or little fingers as this can occlude the urethra. Gently straighten the urethra by directing the tip of the penis toward the dependent shoulder or nipple and over the left thigh. The

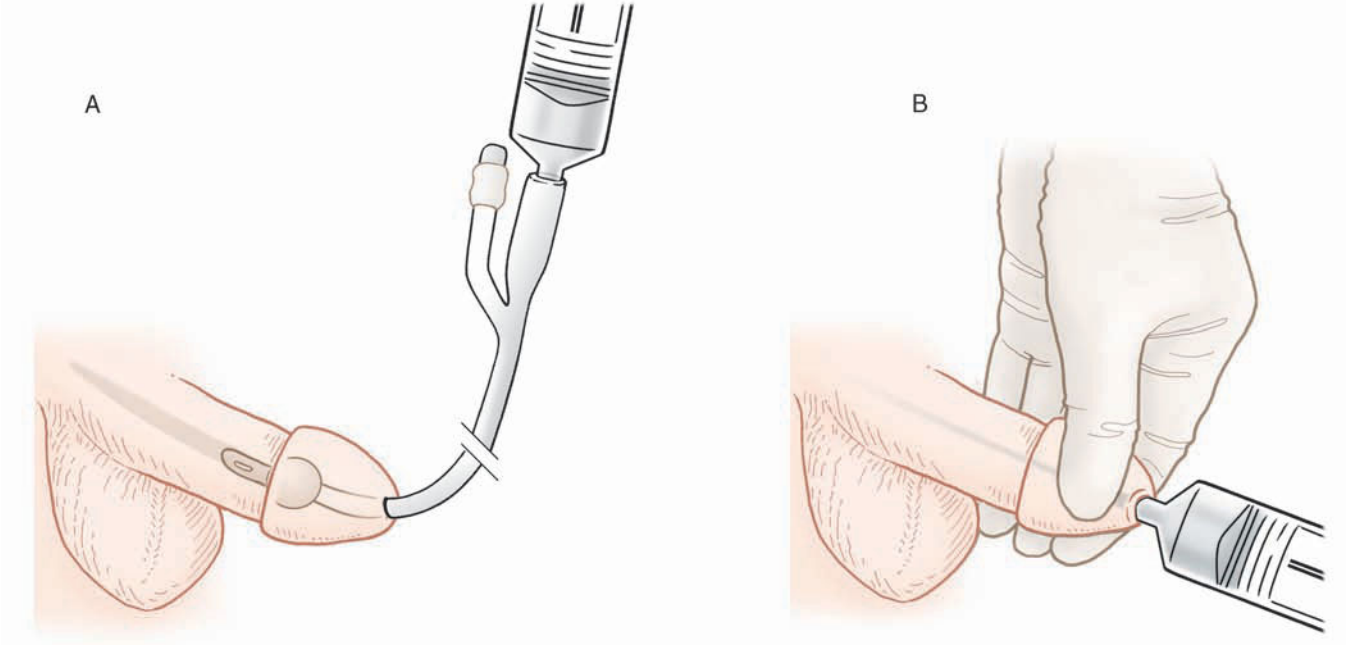


FIGURE 145-2. Retrograde urethrography. **A.** Foley catheter technique. **B.** Syringe technique.

remainder of the procedure is as described above in the Foley catheter section.

BRODNEY CLAMP TECHNIQUE

The Brodney clamp is a cage with rubber feet that clamp behind the corona of the glans.[10] In the center of the device there is a blunt-tipped obturator that inserts into and occludes the urethral meatus. It may be used instead of a Foley catheter or 60 mL syringe for the procedure. The advantage of this device is that both the fossa navicularis and the distal urethra are visible on the radiograph. Air bubbles are easily eliminated from the obturator. The disadvantages of the clamp are that it is not flexible and it is heavy. It must be held during the procedure and fluoroscopy is impossible. If the patient moves, the clamp tends to dislodge. The clamp is difficult to use in older children, adolescents, adults, and in the presence of a phimoses.[10] Brodney clamps are usually not stocked in the Emergency Department and may be difficult to obtain in a timely manner.

Clean, prep, and drape the penis as mentioned previously. Insert the blunt-tipped obturator of the clamp into the urethra. Rotate the feet of the clamp so that they are grasping the coronal sulcus of the penis. These should not be so tight as to occlude the urethra ventrally. The remainder of the technique is as described in the Foley catheter section.

RETROGRADE CYSTOGRAPHY TECHNIQUE

Any abnormalities in the retrograde urethrogram, such as extravasation of the contrast from the urethra or evidence of strictures, should prompt an urgent consult by a Urologist. If the study is normal, the retrograde cystogram should be performed. Gently advance and fully insert a Foley catheter into the bladder (**Figures 145-3A & B**). Inflate the cuff at the tip of the Foley catheter (**Figure 145-3B**). Gently pull on the Foley catheter to lodge the cuff at the bladder neck (**Figure 145-3C**). Attach a 60 mL catheter-tipped syringe, without the plunger, to the Foley catheter. Pour contrast material into the syringe and let it drain by gravity into the bladder to overdistend the bladder. Continue to allow contrast to fill the bladder until 300 to 400 mL of contrast material is in the bladder of an adult or any child older than 11. In younger children, the instilled volume (in mL) is estimated by the formula weight (kg) × 10 in children <1 year of age, (age in years + 2) × 30 in children >1 year of age, or to the point of initiating a bladder contraction.[11] If a bladder contraction occurs, refill the bladder to the volume that initiated the contraction and clamp the Foley catheter. Volumes less than these can result in a false-negative study. After the contrast is instilled, clamp the Foley catheter with a hemostat.

Obtain two plain radiographs. These are the anteroposterior (AP) and the oblique, or the lateral, views of the pelvis. Evaluate the radiographs for proper bladder filling with contrast and for extravasation of contrast. Release the hemostat and allow the contrast to drain out of the bladder through the Foley catheter and into the container. Obtain another AP radiograph of the pelvis (washout film). This film is often helpful in picking up obscured areas of extravasation not visible on the initial film. Review the radiographs for intraperitoneal and extraperitoneal bladder rupture.

ALTERNATIVE TECHNIQUE

A novel approach to the use of plain radiography may be the use of computed tomography (CT) retrograde urethrography.[16] Although this case report will not change current clinical practice, it may be an alternative in the trauma patient requiring a CT scan of the pelvis and may reduce the time for patient evaluation.

The technique is similar to the Foley catheter technique described previously. Place the Foley catheter into the distal urethra, inflate the balloon, and inject 10 mL of contrast material. Clamp the Foley catheter. Obtain a thin-cut CT scan through the pelvis, perineum, and penis. Instruct the CT technician to run a computerized three-dimensional reconstruction of the CT scan. Evaluate the CT reconstruction for contrast extravasation, urethral occlusion, and/or urethral narrowing.

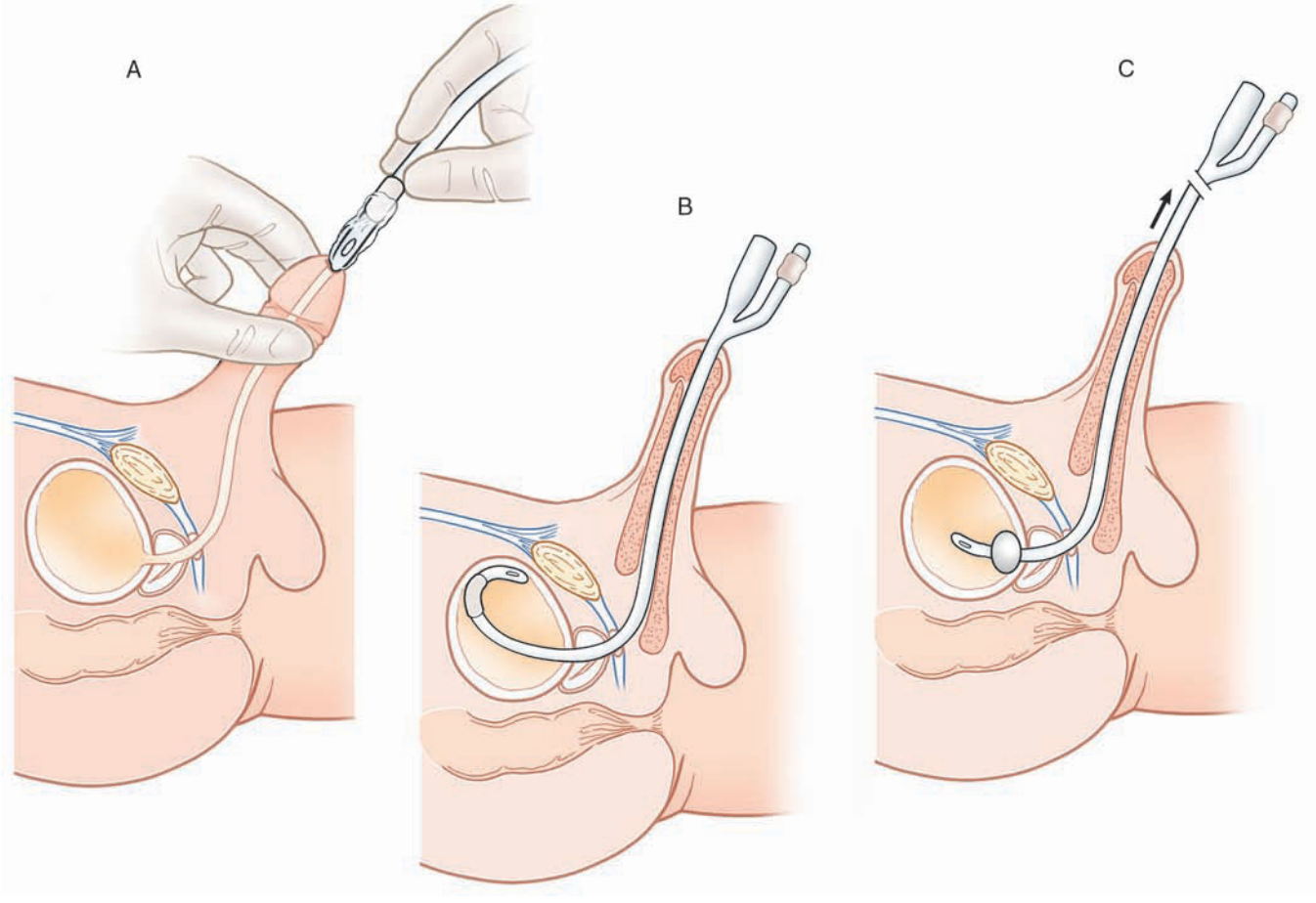


FIGURE 145-3. Retrograde cystography. **A.** The Foley catheter is inserted into the penis. **B.** The Foley catheter is advanced until it is inside the urinary bladder. **C.** The cuff is inflated. The catheter is then pulled until resistance is met to occlude the urethra with the cuff.

ASSESSMENT

In a normal retrograde urethrogram, the entire urethra should be visible. Some of the contrast material should also be seen within the bladder. Extravasation of contrast from the urethra will appear as a flame-like density outside the urethra. A partial urethral disruption will show extravasation of contrast as well as contrast within the bladder. In a complete urethral disruption, no contrast material will be visible within the bladder. Occasionally, contrast material may be seen in the venous plexus of the penis due to forceful injection of contrast into the urethra. This is a common phenomenon and should not be mistaken for extravasation. The venous flush will clear spontaneously on a postvoid film.

In the evaluation of the retrograde cystogram, intraperitoneal and extraperitoneal bladder injuries can be differentiated. The extravasation of the contrast material that appears as a flame-like projection confined to the pelvis constitutes the extraperitoneal injury. In patients with intraperitoneal injuries, the contrast tends to outline the intraperitoneal organs. This differentiation is important because each requires a different treatment. All intraperitoneal injuries are managed surgically whereas some extraperitoneal injuries can be managed with Foley catheter drainage or suprapubic cystostomy (Chapter 144).[7]

AFTERCARE

Because of the hypertonicity of the contrast material and urethral stretching, patients may experience burning and dysuria. After a normal study, ensure that the patient is well hydrated. The flow of urine will wash the contrast out of the bladder and urethra.

COMPLICATIONS

Several complications can result from retrograde urethrography and cystography. Mechanical trauma from the catheter or balloon can result in bleeding, urethral injury, bladder perforation, and the conversion of a partial urethral disruption into a complete urethral disruption. Adverse reactions to the contrast agents can occur.[17–20] These may be due to local reactions or absorption of contrast into the blood. These reactions can range from itching and skin rashes to anaphylaxis and Stevens–Johnson syndrome. Treat any adverse reactions as any other allergic or hypersensitivity reaction.

SUMMARY

The retrograde urethrogram should be performed in any male with a pelvic fracture, lower abdominal trauma with gross hematuria, inability to void, hematoma of the perineum, or a high riding or boggy prostate on physical examination. The cystogram should follow to evaluate potential bladder injuries. The cystogram is used to evaluate and differentiate intraperitoneal and extraperitoneal bladder injuries.

Retrograde urethrography and cystography are diagnostic procedures that are easy to perform and have the potential to avoid major complications related to urine leakage. Both of these procedures are safe and simple to perform. With basic equipment, invaluable information can be collected with very little time investment. The early recognition of disruption of the lower genitourinary tract can prevent significant morbidity.

146 Anesthesia of the Penis, Testicle, and Epididymis

Eric F. Reichman

INTRODUCTION

A wide range of urologic procedures are performed using local or regional anesthesia. This includes an orchiectomy, inspection of the painful testis, release of a paraphimosis, dorsal slit, circumcision, and even a hydrocelectomy or varicocelectomy done in the Operating Room. Emergency Physicians can utilize some of the same anesthetic techniques, namely the penile or spermatic cord blocks, to safely and painlessly perform many procedures in the Emergency Department. These techniques are easy to learn, simple to perform, and have a low risk of serious complications.

ANATOMY AND PATHOPHYSIOLOGY

Innervation of the penis arises from the pudendal nerve that is derived from sacral levels 2 to 4. The pudendal nerve divides into the perineal and the inferior rectal nerves. The perineal nerve further divides into the right and left dorsal nerves of the penis. The dorsal nerves of the penis pass under the pubic symphysis to penetrate the suspensory ligament of the penis.[1] They travel under Buck's fascia to supply sensory innervation to the entire penis (**Figure 146-1**).

The primary nerve supply of the testis and epididymis are from the ilioinguinal and genitofemoral nerves. The ilioinguinal nerve is derived from the first lumbar spinal nerve. It arises slightly inferior and medial to the anterior superior iliac spine and courses toward the pubic tubercle, between the internal and external oblique muscles.[1,2] It enters the inguinal canal on the anterior surface of the spermatic cord. The ilioinguinal nerve provides sensory innervation to the skin of the upper thigh, base of the penis, and the upper scrotum.[3] It also provides sensory innervation to the spermatic cord and testicle. The genitofemoral nerve is derived from the first two lumbar spinal nerves. It divides into the genital branch and the femoral branch. The genital branch enters the inguinal canal at the external inguinal ring and travels with the spermatic cord. It provides sensory innervation to the lower scrotum, cremaster muscle, spermatic cord, and scrotum. The femoral branch supplies the skin of the anteromedial thigh.[3]

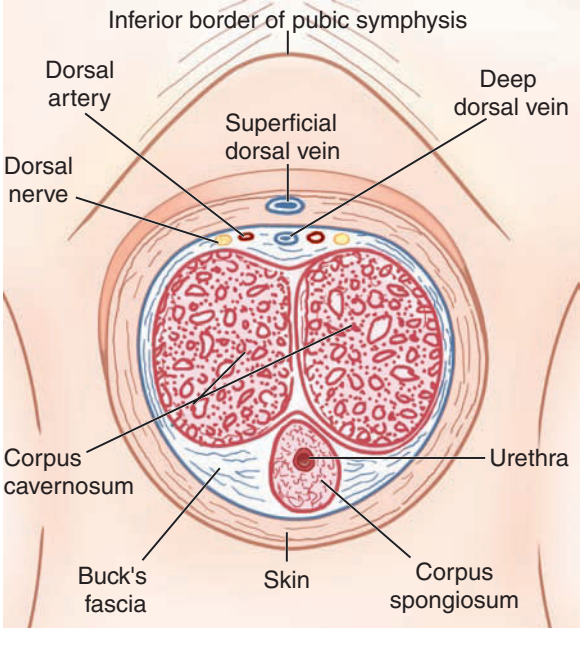


FIGURE 146-1. Transverse section through the base of the penis.

INDICATIONS

Emergency Department procedures that are facilitated by local anesthesia of the penis include a dorsal slit of the foreskin, release of a phimosis or paraphimosis, repair of penile lacerations, and the release of penile skin entrapped in zippers. Local anesthesia can also be used before performing a circumcision. However, this procedure is usually not performed in the Emergency Department.

The Emergency Department indications for a spermatic cord block include the relief of epididymal pain, the facilitation of a manual or ultrasound examination when differentiating between torsion and epididymitis, and to inspect the testis following trauma. Manual detorsion of a testis may be enabled by local anesthesia when a patient cannot tolerate the pain of palpation. **This should be performed only if the patient will be taken immediately to the operating room for confirmation of detorsion and an orchiopexy.** However, the risk of compromising the blood supply to the testis and the loss of patient assessment of pain in determining the success of detorsion are often cited as contraindications to spermatic cord blockade when testicular torsion is suspected.

CONTRAINDICATIONS

Local anesthesia is contraindicated in testicular torsion, as there is a risk of compromising the testicular blood supply. The anesthetic effect will also eliminate the patient's assessment of pain that is needed to determine the success of manual detorsion. Agents containing epinephrine are not to be used in or around the penis.[4] The arteries of the penis are end arteries and vasoconstriction can result in tissue ischemia and sloughing. To minimize the spread of infection, local anesthetic should not be directly injected into an area of local infection.

EQUIPMENT

- 25 and 27 gauge needles
- Syringes (3, 5, and 10 mL)
- Povidone iodine or chlorhexidine solution
- Alcohol pads
- 4 × 4 gauze squares
- Local anesthetic solution without epinephrine

Several local anesthetic agents are commonly used for genitourinary anesthesia. These include lidocaine, bupivacaine, mepivacaine, and chloroprocaine (**Table 146-1**). **The anesthetic agent, concentration, and technique must be chosen so that the maximum safe dose is not exceeded. This is especially important when performing anesthesia in children.**

TABLE 146-1 Local Anesthetic Agents Commonly used for Genitourinary Anesthesia

Anesthetic agent	Strength (%)	Onset of action (min)	Duration of action (min)	Maximum dose (mg/kg)
Lidocaine	0.5, 1.0, 1.5, 2.0	5–15	45–90	4.5
Bupivacaine	0.25, 0.50	10–15	120–240	2.5
Mepivacaine	1.0, 1.5	10–15	120–240	4.0
Chloroprocaine	2.0, 3.0	10–15	20–40	11.0

PATIENT PREPARATION

The patient must be informed of the procedure, including its risks and benefits. The explanation must include the risks of local anesthetic injection and the possibility that the anesthetic may not effectively eliminate pain. The risks associated with the injection include pain, hematoma formation, and bleeding. Infection is a late risk that can be reduced by prepping the skin and using sterile technique. Obtain an informed consent for the anesthetic procedure in addition to the consent for the procedure that will be performed under anesthesia.

The patient's ability to cooperate with the planned procedures must be assessed. Consider oral or parenteral sedation, especially in anxious patients or children. Midazolam (0.02 to 0.04 mg/kg IV) or diazepam (2.5 to 5 mg IV) are often good choices in adults. Children may benefit from midazolam parenterally (0.05 to 0.15 mg/kg IV) or orally (0.5 to 0.7 mg/kg). Ketamine (1.0 to 1.5 mg/ kg IV or 2 to 5 mg/kg IM) combined with atropine (0.01 mg/kg) to reduce respiratory secretions is an alternative, especially in children younger than 10.

Clean any dirt and debris from the skin. Identify the anatomic landmarks required to perform the anesthetic injection. Apply povidone iodine or chlorhexidine solution to the area where the anesthetic is to be injected. The povidone iodine or chlorhexidine may also be applied to the penis and scrotum if an invasive procedure is subsequently to be performed. Apply sterile drapes to delineate a surgical field. Allow the povidone iodine or chlorhexidine to dry. Put on sterile gloves and reidentify the anatomic landmarks. Infiltrate with local anesthetic solution using sterile technique.

TECHNIQUES

LOCAL INFILTRATION

Local anesthetic infiltration of the skin of the penis is useful for the repair of superficial lacerations, dorsal slits of the foreskin, or freeing entrapped skin from a zipper. Local infiltration circumferentially around the penis will provide adequate anesthesia distal to the anesthetic injection site. The circumferential subcutaneous injections can be performed directly on the penis or on the abdominal wall and scrotum surrounding the penis. While not contraindicated, some authors avoid direct infiltration of the foreskin as tissue sloughing may result.[2] **Local infiltration of anesthetic agents is often extremely painful for the patient. Consider premedicating the patient with parenteral benzodiazepines and/or narcotic agents**.

Local anesthetic agents can be injected subcutaneously into the penis to provide distal anesthesia. If performing a dorsal slit of the foreskin, raise a skin wheal of local anesthetic solution at the base of the foreskin in the 12 o'clock position (**Figure 146-2A**). Insert the needle through the skin wheal aimed distally. Inject local anesthetic solution subcutaneously as the needle is advanced to the distal edge of the foreskin. Alternatively, local anesthetic solution can be circumferentially infiltrated around the penis (**Figure 146-2B**). This block usually requires 6 to 10 mL of local anesthetic solution in the adolescent or adult and 2 to 3 mL in a child.

PENILE BLOCK

The objective of a penile block is to anesthetize the right and left dorsal nerves of the penis that provide sensation to the penis (**Figure 146-1**). **The dorsal nerves should be blocked as close to the base of the penis as possible. If the block is performed too distal to the pubic bone, the posterior branches of the dorsal nerves will not be anesthetized and the ventral surface of the penis will retain sensation.**[5,6] Multiple effective techniques will be described to perform a penile block. The technique chosen should depend on the specific procedure to be performed, the level of patient cooperation, and the preference of the Emergency Physician.

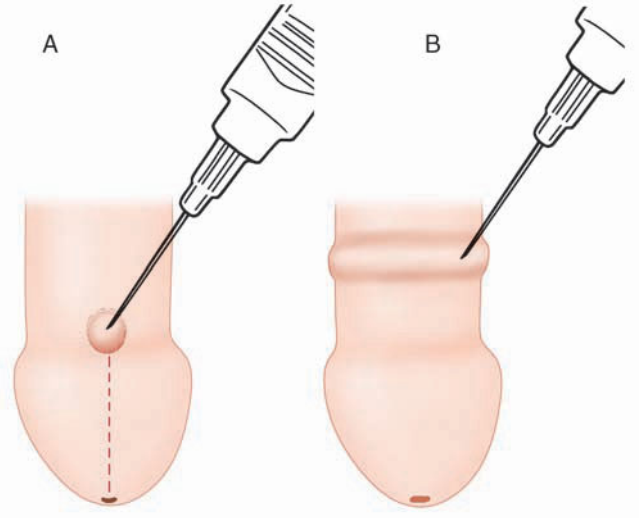


FIGURE 146-2. Local anesthetic infiltration into the penis. **A.** A skin wheal is raised and local anesthetic is injected distally (*dotted line*). **B.** Circumferential infiltration of local anesthetic solution.

The penis may be anesthetized where it forms along the abdominal wall.[2] This block anesthetizes the nerves to the penis before they reach the penis. Form three skin wheals using local anesthetic solution on the abdominal and scrotal skin, 0.5 to 1.0 cm from the base of the penis, at the 2 o'clock, 6 o'clock, and 10 o'clock positions (**Figure 146-3**). Infiltrate subcutaneously with local anesthetic solution between the skin wheals to form a triangle of local anesthetic that surrounds the base of the penis. This block usually requires 8 to 12 mL of local anesthetic solution in the adolescent or adult and 3 to 5 mL in a child.

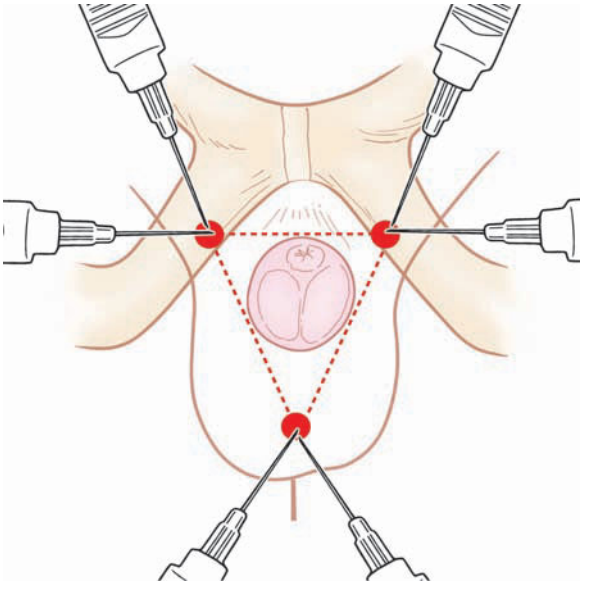


FIGURE 146-3. Local anesthetic infiltration around the base of the penis. Black dots represent the locations of the skin wheals.

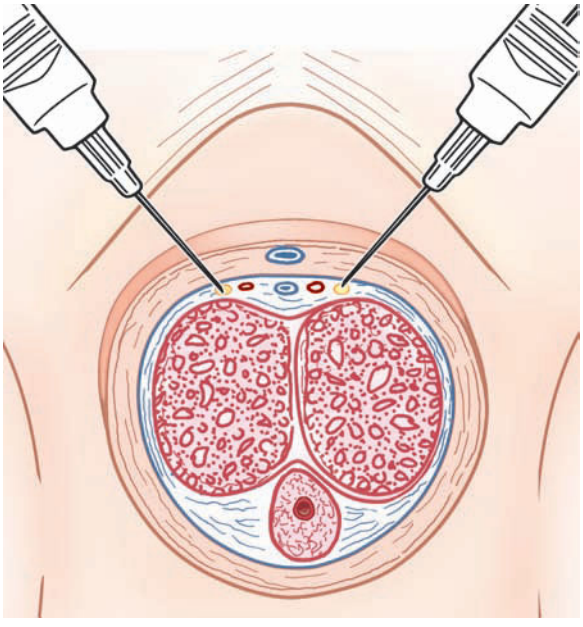


FIGURE 146-4. The penile block anesthetizes the left and right deep dorsal nerves of the penis.

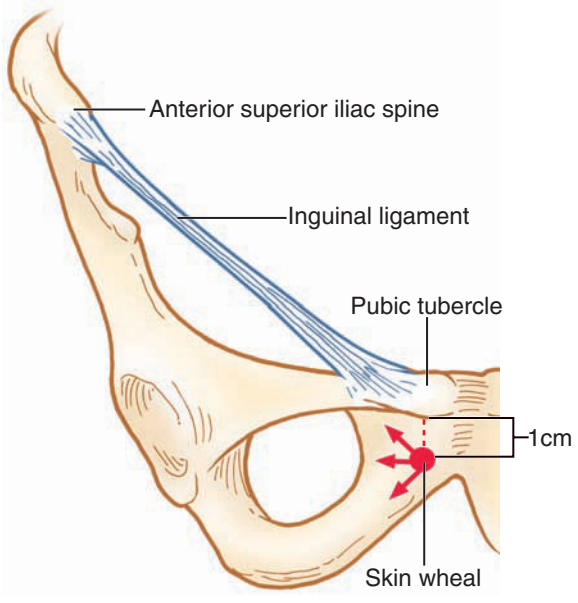


FIGURE 146-5. The spermatic cord can be anesthetized just below the pubic tubercle, if the tubercle is palpable. The arrows represent the three different directions required to inject local anesthetic solution.

The dorsal nerves of the penis can be anesthetized as they course onto the penis. Place a skin wheal of local anesthetic solution at the 1 o'clock and 11 o'clock positions. Slowly insert a 27 gauge needle through the skin wheals until there is a slight loss of resistance indicating penetration of Buck's fascia (**Figure 146-4**). Aspirate to ensure that the needle is not within a blood vessel. Inject 1 mL of local anesthetic solution at each site in the adolescent or adult and 0.3 to 0.5 mL in a child.[1]

Another technique blocks the dorsal nerves as they pass through the triangular space bordered by the pubic symphysis, the corpora cavernosa, and Buck's fascia. Place a skin wheal of local anesthetic solution at the dorsal base of the penis. Insert the needle through the skin wheal and to the pubic symphysis. Withdraw the needle slightly and advance it caudally until a loss of resistance is felt, indicating that it has penetrated Buck's fascia. Aspirate to ensure that the needle is not within a blood vessel. Inject 10 mL of local anesthetic solution on each side of the suspensory ligament (midline) in the adolescent or adult and 2 to 3 mL in a child. Alternatively, the same block can be accomplished with a separate injection on each side of the midline.[1,7]

SPERMATIC CORD BLOCK

As the spermatic cord exits the external inguinal ring, it passes over the pubic tubercle and continues medially toward the scrotum. In this same location, the ilioinguinal nerve travels on the anterior surface of the spermatic cord and the genital branch of the genitofemoral nerve on the posterior surface. These two nerves supply sensation to the spermatic cord, epididymis, and testicle. Anesthesia of the spermatic cord in the region of the pubic tubercle will provide anesthesia to the testis and its covering, the epididymis, and the vas deferens.[6] **The spermatic cord block does not provide anesthesia to the skin of the scrotum.** Additional subcutaneous infiltration is necessary for an incision of the scrotal skin.

This first spermatic cord block technique is useful in thin patients with a palpable pubic tubercle. Identify the pubic tubercle by palpation. Inject local anesthetic solution to make a skin wheal just medial and 1 cm below the pubic tubercle (**Figure 146-5**). Gently advance a 25 gauge needle laterally through the skin wheal and spermatic cord until bone is contacted. Aspirate to ensure that the needle is not within a blood vessel. Inject 3 to 4 mL of local anesthetic solution as the needle is slowly withdrawn in the adolescent or adult and 1 to 2 mL in a child. Repeat the procedure two more times using the same skin puncture site, each time passing through the cord at a slightly different angle. This block requires a total of 10 to 12 mL of local anesthetic solution in the adolescent or adult and 3 to 5 mL in a child.[6]

A modified technique is used for the patient in whom the pubic tubercle is difficult to palpate. Grasp the spermatic cord between the nondominant thumb and index finger as it enters the scrotum (**Figure 146-6**). Place a wheal of local anesthetic solution between the fingers and above the spermatic cord. Insert a 25 gauge needle through the skin wheal. Direct the needle anterior to the spermatic cord. Aspirate to ensure that the needle is not within a blood vessel. Inject 3 to 4 mL of local anesthetic solution in the adolescent or adult and 1 to 2 mL in a child. Repeat the process on the medial and lateral side of the spermatic cord.

Alternatively, palpate the spermatic cord as it enters the scrotum.[8] Trace the spermatic cord superiorly to the pubic tubercle where it exits the external inguinal ring. Trap the spermatic cord between the second and third fingers of the nondominant hand and the pubic tubercle. Place a wheal of local anesthetic solution between the fingers and above the spermatic cord. Insert a 25 gauge needle through the skin wheal. Aspirate to ensure that the needle is not within a blood vessel. Inject local anesthetic solution anteriorly, medially, and laterally to the spermatic cord as described above. Injection of local anesthetic solution around the spermatic cord as it exits the inguinal canal may be less painful than injection as it enters the scrotum.

ASSESSMENT

Allow 10 to 15 minutes for the local anesthetic solution to take effect for a penile block. Test the level of anesthesia by pinching the skin with a forceps or by pin-prick with a needle. The patient

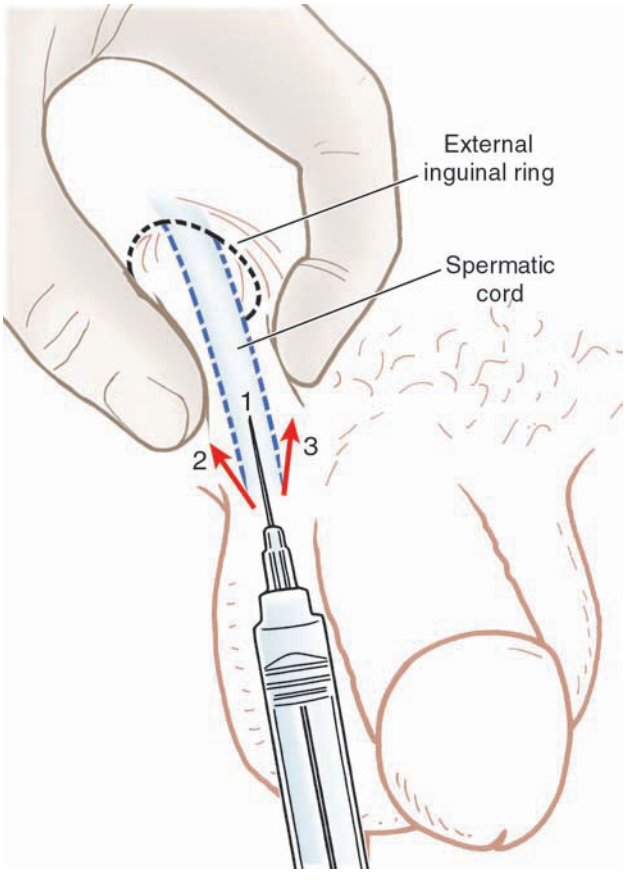


FIGURE 146-6. The spermatic cord block at the base of the scrotum. Local anesthetic solution is injected anteriorly (1), laterally (2), and medially (3) to the spermatic cord.

may feel a pressure sensation, but should not feel pain. If the test stimulus is painful, repeat the block or use additional anesthetic techniques prior to performing the procedure.

Spermatic cord blocks require 10 to 15 minutes for maximal effectiveness. The patient should be warned that, despite an effective block, traction on the spermatic cord might cause nausea and a tugging sensation. These will resolve upon release of the traction.[6] Additional anesthesia must be applied to the scrotal skin for any incisions or procedures as a spermatic cord block does not anesthetize the scrotal skin.

AFTERCARE

Minimal aftercare is required for these local anesthetic techniques. Depending on the agent used, sensation may return in as little as 1 to 2 hours with lidocaine and chloroprocaine or up to 4 hours with bupivacaine. The skin may reawaken with a pins-and-needles sensation. Patients should use caution when zipping their pants so as not to catch the penis, foreskin, or scrotum as they will not feel the injury. Patients should be warned that the site of a spermatic cord block might remain tender for as long as 10 days.[6] The application of cool compresses to the injection site and oral nonsteroidal anti-inflammatory drugs will provide adequate analgesia for injection site pain. Patients should inspect the injection site and surrounding area three to four times a day for any signs of infection. They should return to the Emergency Department immediately if any problems or concerns arise.

COMPLICATIONS

The most procedure-specific complication of a penile block is sloughing of the penile skin. This is more common in the region of the glans. Performing the penile block at the base of the penis and using solutions without epinephrine minimizes this risk.

Hematomas can be quite large in spermatic cord blocks because the venous plexus is usually pierced. The use of a smaller needle and careful application of pressure can help prevent hematomas. Blood loss from puncturing a vascular structure is easily controlled with direct pressure. A Urologist should be consulted urgently in the rare occasion that bleeding does not resolve with pressure. Most hematomas will resolve within 1 to 2 weeks. The application of warm compresses to the hematoma several times a day may result in quicker resorption.

Local infection at the injection site is possible. Patients should be warned about the signs of infection including fever, erythema, warmth, induration, increased pain, and purulent drainage. Patients should seek immediate medical attention for any of these symptoms.

Toxic levels of anesthetic agents can affect multiple organ systems, most notably the central nervous and cardiovascular systems. Anesthetic agents block the inhibitory neurons of the brain producing a state of neuroexcitation. Initial symptoms may include tinnitus, premolar numbness, disorientation, lightheadedness, or nystagmus. This may progress to seizures that can be accompanied by slow or absent breathing, acidosis, aspiration, and cardiovascular instability. Intravenous diazepam (2.5 to 5 mg) at the first sign of symptoms may stop the cascade.[2] Significantly higher doses of diazepam are required to treat seizures. Very high levels of local anesthetics are cardiotoxic and may result in heart block. Heart block from bupivacaine toxicity is associated with resistance to resuscitative maneuvers. The onset of all local anesthetic toxicities is faster with intravascular injection versus toxic tissue concentrations.

SUMMARY

Local anesthesia allows many painful genitourinary procedures to be performed in the Emergency Department. The techniques are simple and easy to perform with little to no experience. Local anesthetic solutions containing epinephrine should never be used to anesthetize the penis, scrotum, or spermatic cord.

147 Priapism Management

Steven Go

INTRODUCTION

Priapism was first described in the English literature in an 1824 case report by Callaway.[1,2] It is defined as a prolonged engorgement or erection of the penis or clitoris that lasts greater than 4 hours and occurs beyond or apart from sexual stimulation or arousal.[3,4] The term "priapism" derives its origin from the name of a minor Greek god of fertility and luck named Priapus.[5] He was said to have been cursed by Hera by having out of proportion genitals, ugliness, salaciousness, and ironically, impotence. A famous Pompeiian fresco graphically illustrates Priapus' plight as he weighs his massive phallus with a hanging scale.[5] Male priapism is far more common than the extremely rare female form. This chapter will focus on the male priapism.

TABLE 147-1 The Etiologies of Ischemic Priapism[9–17]

Etiology	Incidence	Specific conditions or substances
Drug induced	Uncommon	Androgens Anticoagulants Antihypertensives Antipsychotics Erectile dysfunction agents Ethanol Sympathomimetics
Hematologic disorders	Common	Anemia Leukemia Multiple myeloma Polycythemia Sickle cell disease
Iatrogenic	Common	Intracavernous erectile dysfunction drug therapy Surgery
Idiopathic	Common	
Malignancies	Rare	Metastatic cancer to penis Primary penile cancer Prostate cancer
Miscellaneous	Rare	Amyloidosis Fabry's disease G6PD deficiency Gout Hemodialysis Total parenteral nutrition
Neurologic	Rare	Spinal cord lesions or stenosis
Traumatic	Uncommon	Usually causes high-flow priapism

TABLE 147-2 The Etiologies of Nonischemic Priapism[19,20]

Drug-induced: cocaine, androgens
Idiopathic
Metastatic malignancies
Miscellaneous causes: Fabry's disease, neurological conditions
Traumatic:
Iatrogenic (e.g., postsurgical)
Incidental

Priapism affects an estimated 1.5 cases per 100,000 person-years in the general population and 29% to 42% of sickle cell patients during their lifetimes.[6–8] The most common form of priapism is often an excruciatingly painful and prolonged erection. This is frequently embarrassing to the patient and results in delays in seeking medical attention. Without swift and expert intervention, priapism can sometimes lead to permanent scarring and impotence.

Priapism is generally classified into two major subtypes, ischemic and nonischemic, although other less common subtypes exist.[3] It is critical that the Emergency Physician determines which subtype the patient is presenting with because emergent management and prognosis differs considerably between them.

The most common priapism subtype is ischemic priapism. This condition is also known as low flow or vaso-occlusive priapism. This subtype of priapism poses the greatest risk of permanent penile dysfunction. It is generally thought to result primarily from an impediment to blood emptying from the penis and has a large number of associated etiologies (**Table 147-1**). These patients present with a very painful, rigid penis, with engorgement of both corpora cavernosa. The corpus spongiosum and the glans are usually spared, although those structures also may be involved in rare instances[18] If left untreated, this condition forms a type of compartment syndrome which results in fibrosis and scarring, loss of function, and in extreme cases tissue necrosis. Even with treatment, the outcomes are often poor. Reported rates of complete erectile dysfunction after ischemic priapism range from 30% to 90%.[3,7]

Stuttering or intermittent priapism is a variant of ischemic priapism in which the patient suffers intermittent priapism episodes over time. This particular variant is difficult to definitively treat in the long term as the episodes tend to reoccur. This condition sometimes resolves prior to the patient's arrival at the Emergency Department and can fool the Emergency Physician into making a misdiagnosis of malingering.

The second subtype of priapism is known as nonischemic, high flow, or arterial priapism. This subtype is far less common than the ischemic subtype. It is thought to result from penile arterial blood flow being unregulated, often secondary to genital trauma. The number of etiologies is far fewer than in ischemic priapism (**Table 147-2**). Because arterial blood is freely flowing through the penis, the outcomes of nonischemic priapism tend to be more favorable than those of ischemic priapism, although subsequent erectile dysfunction can occur.[21] The Emergency Department management of this subtype is generally supportive and requires no procedural intervention in most cases.

ANATOMY AND PATHOPHYSIOLOGY

RELEVANT ANATOMY

The penis is primarily composed of the dual dorsal corpora cavernosa and a single ventral corpus spongiosum (**Figure 147-1**). The corpora cavernosa surround the cavernous and helicine arteries and are the structures engorged during most cases of priapism. The corpus spongiosum surrounds the urethra and forms the glans of the penis distally. The cavernosa and spongiosum are encased by Buck's fascia, a fibrous sheath that constricts to limit venous outflow during an erection. A superficial and deep neurovascular bundle is located on the dorsal surface of the penis.

The corpora of the penis consist of spongy sinusoidal networks of smooth muscle, collagen, nerves, vascular structures, and endothelial tissue.[22] The primary arterial supply to the penis arises from the internal pudendal artery, which gives rise to the cavernous artery, which supplies the lacunar spaces in the cavernosa. Another two other branches of the internal pudendal artery, the bulbourethral and dorsal arteries mainly supply blood to the corpus spongiosum, glans, and related structures. The dilation of the cavernous artery and its branches is primarily responsible for engorging the penis during an erection. During an erection, the sinusoidal spaces in the corpora fill with blood and the corpora expand. The corpora are covered by a strong fibrotic outer layer, the tunica albuginea, that produces a rigid penis when engorged. An important functional anatomic feature is that blood flows freely between both corpora cavernosa due to the incomplete septum between them.

Venous outflow regulation plays an equally important role in maintaining an erection. The venous drainage is complex, with paired branches running with the arteries. An additional major drainage system enters into the deep dorsal vein via multiple emissary veins and circumflex veins. The extensive subtunical plexus of veins feeds into the emissary veins that perforate the tunica albuginea and drain into the circumflex veins. During an erection, the increasing distention of the corpora with arterial blood causes the compression of the subtunical venous plexus and obstructs drainage

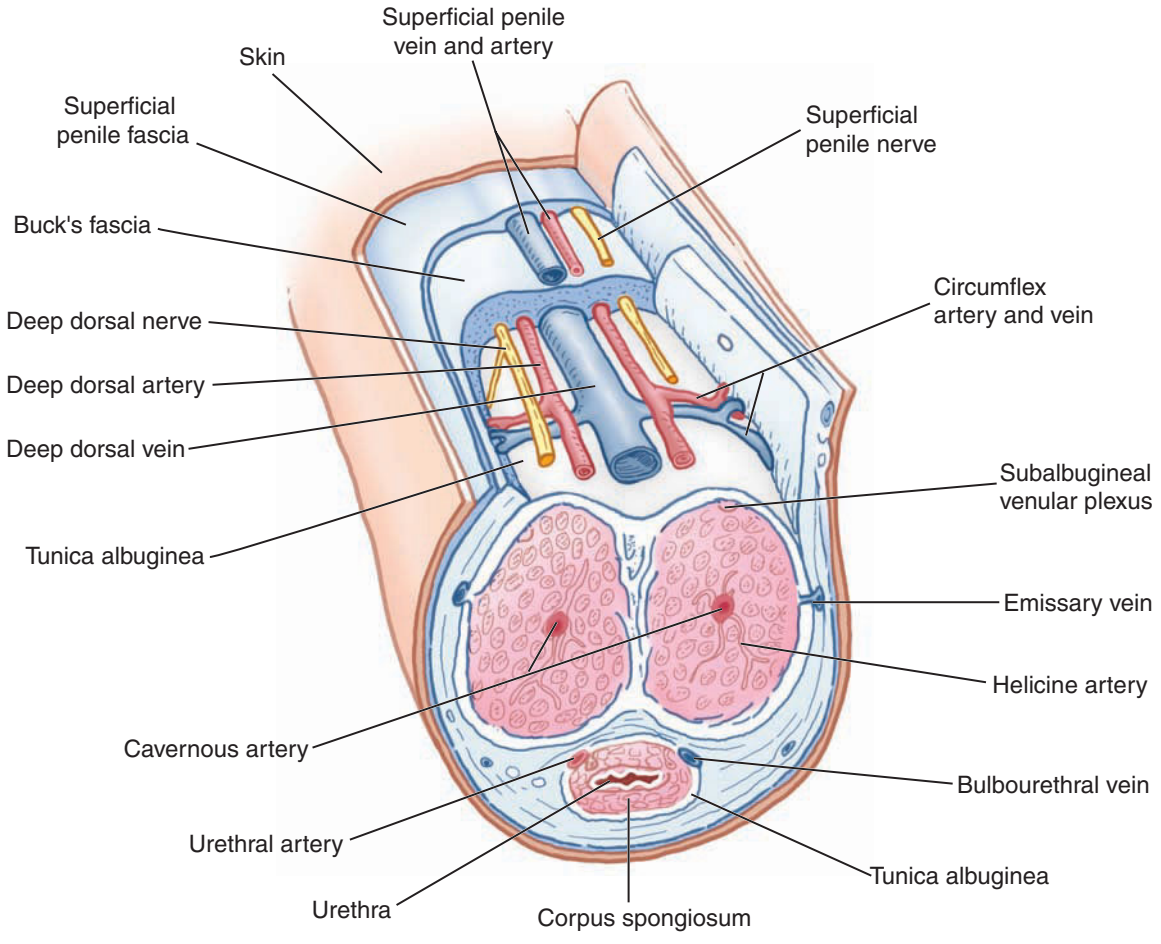


FIGURE 147-1. Cross section of the penis demonstrating the anatomy.

through the emissary veins with both in-flow and out-flow decreasing. There is no obstruction to the glans and corpus spongiosum drainage and this system does not typically develop the higher pressure of the corpora cavernosa.

NORMAL ERECTION PHYSIOLOGY

The relative simplicity of the function anatomy belies the complexity of the physiology underlying tumescence.[22–24] In the last decade, much research has emerged to shed light on the mechanisms of both a normal erection and priapism. An erection begins when the parasympathetic nervous system releases acetylcholine and nitric oxide. This begins a multifaceted cascade of neurotransmitter events that culminates in the efflux of calcium from smooth muscle cells and results in the relaxation of the smooth muscle in the corpora and the arterial walls of the penis.[24] Detumescence occurs when the sympathetic nervous system releases norepinephrine. This eventually results in the constriction of smooth muscle which reduces arterial inflow, reduces corpora volume, and promotes venous outflow. In addition, α_1-adrenergic receptors play an important role in keeping the smooth muscle relaxed by promoting the accumulation of calcium ions within the cells.[22]

ISCHEMIC PRIAPISM PATHOPHYSIOLOGY

The pathophysiology of ischemic priapism can be separated into peripheral pharmaceutical-induced ischemic priapism and nonpharmaceutical-induced ischemic priapism.[24] The three major underlying processes that characterize both mechanisms are hypoxia, glucopenia, and acidosis.[23]

Pharmaceutical-induced ischemic priapism is secondary to the offending pharmaceutical altering the physiological balance of the penile smooth muscle toward relaxation.[24] This prolongs the erection, which over time, causes the oxygen partial-pressure in the trapped blood to decrease resulting in local hypoxia. The hypoxia induces arterial relaxation and venous contraction by an endothelin-1 mediated mechanism. Hypoxia also decreases α_1-adrenergic receptor ability to induce smooth muscle contraction. This helps explain why α-agonists become less efficacious in prolonged priapism. Anaerobic metabolism ensues, causing local glucopenia. Metabolic byproducts build up in the penis causing acidosis. These processes work together to cause the tissue edema, fibrosis, and eventually erectile dysfunction with prolonged priapism.

Nonpharmaceutical-induced ischemic priapism occurs secondary to a derangement in vascular homeostasis, such as blood dyscrasias (e.g., sickle cell disease, leukemia), by a mechanism that has not yet been fully delineated.[24] It is thought that a deficiency in endothelial nitric oxide in the penis decreases the activity of a RhoA/Rho-kinase mediated vasoconstrictive pathway.[24] This malfunction causes the smooth muscle contraction system to respond in an exaggerated manner and prolong the erection. This results in the hypoxia, glucopenia, and acidosis. The presence of these three processes worsens the conditions that led to the priapism in the first place. For example, the resultant penile hypoxia tends to worsen the sickling of erythrocytes which worsens the

compromised vascular outflow, which worsens the hypoxia. Thus, a vicious cycle occurs that exacerbates the overall disease process.

NONISCHEMIC PRIAPISM PATHOPHYSIOLOGY

In contrast, nonischemic priapism generally results from a trauma-induced arteriovenous communication between the cavernous artery and the sinusoidal spaces, bypassing the high resistance helicine arteries. This results in unrestrained arterial flow. Because there is no increased venous constriction in this form of priapism, the penis is not at risk for ischemia. The penis is generally without pain or tenderness and is softer than in low-flow priapism.

DETERMINING THE PRIAPISM SUBTYPE

The initial evaluation by the Emergency Physician must be quick, aggressive, and accurate. There are several differences in the presentation of ischemic and nonischemic priapism that differentiate these subtypes (**Table 147-3**). The clinical features that characterize ischemic priapism are generally detected with a careful history and physical examination. **However, it is recommended that clinical impression be confirmed on every priapism patient by either sampling the penile blood for arterial blood gas analysis or by a color Doppler ultrasound.** Penile blood can be readily sampled at the same time therapy is initiated. The sampling is somewhat invasive and can be painful. Color Doppler ultrasound is less invasive but can delay definitive therapy if it is not readily available. Ultimately, the choice of a confirmatory test must be driven by the clinical situation and setting.

Some authors have recommended beginning treatment of ischemic priapism medically with agents such as terbutaline and pseudoephedrine.[27–30] The data to support such strategies are not very copious and are sometimes contradictory.[30,31] The most current American Urological Association priapism guideline recommends that cases of ischemic priapism require emergent aspiration and irrigation of the corpora cavernosa and this should not be delayed by ancillary treatments.[3]

This general recommendation is true even in the modern management of sickle cell patients with ischemic priapism. Traditionally, sickle cell-related priapism was treated only with conservative treatment. This included aggressive hydration, alkalization, analgesics, blood transfusion, and occasionally exchange transfusion. These systemic treatments have resulted in 35% of these patients developing subsequent erectile dysfunction.[3,8] These ancillary treatments should only be given in sickle cell patients while quickly and simultaneously gathering the materials for the intracavernous treatment described in the techniques section of this chapter.

TABLE 147-3 Features that Distinguish Ischemic Versus Nonischemic Priapism[3,7,23]

	Ischemic priapism	Nonischemic priapism
Clinical features	Usually atraumatic	Often traumatic
	Very painful	Minimal pain if any
	Rigid penis	Less tense penis
Penile blood characteristics	Dark appearance	Bright red appearance
	Thick consistency	Thin consistency
	pH < 7.25	pH > 7.25
	paO_2 < 30 mmHg	paO_2 > 30 mmHg
	$paCO_2$ > 60 mmHg	$paCO_2$ < 60 mmHg
Color Doppler flow pattern	Low arterial flow	High arterial flow

Some authors have recommended various additional diagnostic tests in patients who present with first time priapism.[3,7,32] This includes such as a CBC with manual differential to diagnose blood dyscrasias, urinalysis as an infection screen, and various drug screens if indicated. These studies should not delay seeking definitive diagnosis and treatment of ischemic priapism.

INDICATIONS

The key diagnostic decision to be made in a patient presenting with priapism is to determine whether the priapism is ischemic or nonischemic.[3] This salient point cannot be overemphasized. Ischemic priapism is the only subtype where emergent interventional treatment is indicated.[25,26]

CONTRAINDICATIONS

If a patient has trauma-induced priapism and has concurrent serious life-threatening injuries, the patient must be stabilized prior to dealing with the priapism. The medical risks making priapism therapy inappropriate will occasionally occur and have to be weighed against the fact that the natural course of priapism does not cause mortality. Patients with significant hypertension, unstable angina, dysrhythmias, and other high-risk cardiac conditions should not receive α-adrenergic agonists. They are also contraindicated if the patient is taking β-blockers or monoamine oxidase inhibitors.

EQUIPMENT

- 19 gauge butterfly or straight needles
- 21 gauge butterfly or straight needles
- Arterial blood gas syringe
- Syringes (1, 3, 10, and 20 cc)
- Povidone iodine or chlorhexidine solution
- 4 × 4 gauze squares
- Sterile drapes
- Sterile basin
- Three-way stopcock (optional)
- Phenylephrine, 10 mg/mL in 1 mL vials
- 1% lidocaine without epinephrine
- Sterile normal saline, 1 L bottle
- Sterile normal saline, 10 mL vial
- Blood pressure monitoring equipment
- Cardiac monitoring equipment

PATIENT PREPARATION

Informed consent is extremely crucial in the treatment of ischemic priapism. Even with appropriate treatment, the outcomes can be poor. There are recommendations in the literature that the procedures described below should only be performed by a Urologist.[33] There is no literature to support this recommendation. To help mitigate these legal risks, discuss the procedural risks and benefits, any alternatives, and being treated by an Emergency Physician versus a Urologist in the Emergency Department or being transferred to a facility with a Urologist if one is not immediately available. Allow time for questions so that the patient can make an informed and voluntary decision. An emergency consult by a Urologist should be obtained immediately when the presence of ischemic priapism is determined. Delays in the Urologists arrival should not delay the procedure if the Emergency Physician

is comfortable performing the procedure. The informed consent process including the patient's capacity to consent, the potential risks and benefits, alternatives discussed, and the medical decision making should be thoroughly documented in the patient's chart and a signed consent obtained.

Prepare the patient. Intravenous access should be obtained for pain control. The patient should have vital signs and cardiac rhythm monitoring before, during, and after the procedure as adverse events have been reported. This is especially true in patients with a history of hypertension, coronary artery disease, or cardiac dysfunction. These procedures can be extremely painful. Perform a penile nerve block if there are no contraindications (Chapter 146). Alternatively, consider the use of parenteral analgesics, sedatives, and/or procedural sedation (Chapter 129). After adequate analgesia has been achieved, gently clean the penis, scrotum, and surrounding area of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the shaft of the penis and scrotum and allow it to dry. Apply sterile drapes to delineate a sterile field.

TECHNIQUES

PENILE ASPIRATION AND IRRIGATION

Insert a 19 gauge butterfly needle into the lateral mid-shaft of the penis at the 3 o'clock or 9 o'clock position (**Figure 147-2**). This will be used for draining or aspirating the penis. The tubing can be capped with a syringe or three-way stopcock. The 19 gauge needle usually provides free drainage with no aspirating being necessary. **The needle should always be inserted straight in and directed toward the center of the corpora.** If a difficult procedure is anticipated (priapism duration > 24 hours), a 21 gauge butterfly needle can also be inserted in the base of the penis and left in place for either injection or irrigation. **The fewer the injections, the less the chance for a hematoma formation.** Send a sample of the initial aspirated blood for blood gas analysis. This may be accomplished by attaching an arterial blood gas syringe to the tubing of the butterfly needle.

Place the catheter end of the butterfly into a sterile basin and allow the blood to drain from the penis. If blood does not spontaneously drain, attach a 10 or 20 mL syringe to the catheter end and aspirate blood from the penis. Cap the butterfly catheter after draining enough blood to significantly soften the penis. Since the cavernosa communicate across the incomplete septum, both cavernosa will decompress through the single drainage needle. It has been reported that aspiration alone is effective in inducing detumescence in approximately 30% of cases.[3]

If there is difficulty with the drainage, a 21 gauge butterfly needle should be inserted in the proximal shaft area. Begin gentle irrigation with normal saline through the 21 gauge needle with outflow through the 19 gauge needle. This will help to irrigate out the old blood. **Only normal saline should be used because the endothelium can be damaged if the solution is not isotonic**. Massaging the penis to "milk out" sludge can be helpful. Placement of additional 19 gauge butterfly needles may be used to improve drainage in difficult cases.

INTRACAVERNOUS SYMPATHOMIMETIC INJECTION

Intracavernous injection is recommended if aspiration and irrigation fail to resolve the priapism. Phenylephrine is the agent most commonly recommended.[3] Although other agents for this purpose do appear in the literature, such as epinephrine, no adequate controlled data yet exist comparing one agent to another.[29] Untoward side effects with some agents, such as epinephrine, have been reported.[34]

Prepare the phenylephrine. It is purchased in sterile 1 mL glass vials with a concentration of 10 mg/mL. Place 10 mg (1 mL) of phenylephrine into a syringe containing 9 mL of sterile normal saline. This provides a solution of 1 mg/mL that allows easy calculation of the doses. Other dilutions can be used, as this is physician-dependent, and the concentration should be clearly marked on the syringe.

Inject 0.25 to 0.5 mL (250 to 500 μg) of the phenylephrine solution with an insulin syringe through the butterfly catheter and into the penis. Observe the penis for up to 10 minutes. Repeat the procedure if the erection returns or does not resolve. There is no definite limit to the amount of phenylephrine used. Most

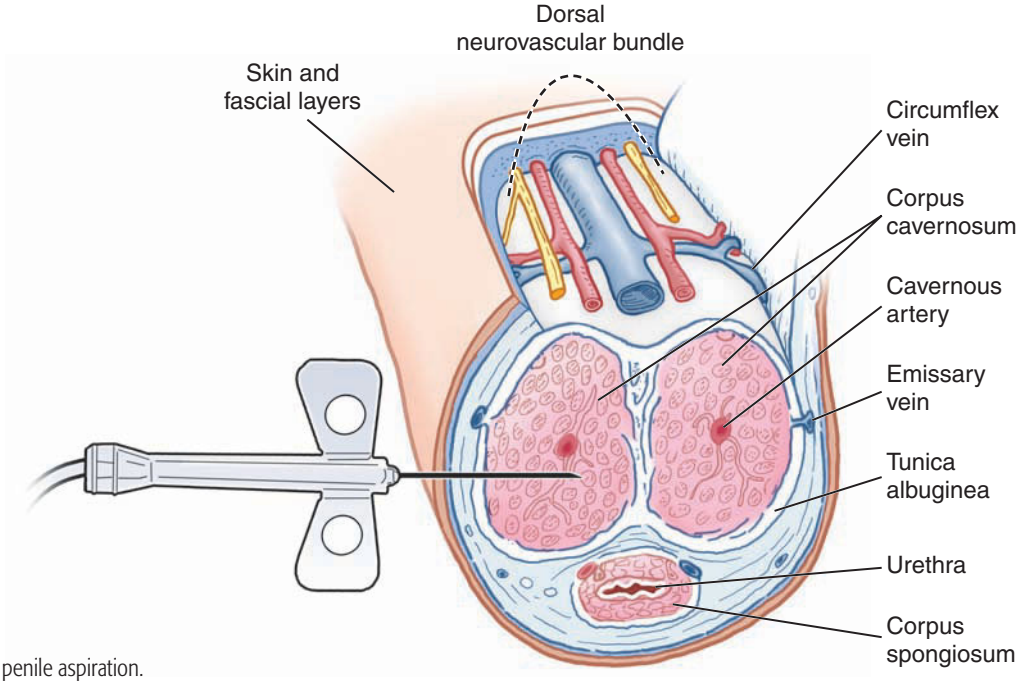


FIGURE 147-2. The technique of penile aspiration.

physicians inject up to 1 mg of phenylephrine, but up to 2.5 mg has been suggested.[2] Current recommendations suggest not concluding intracavernous injections have failed until the patient has been treated for 1 hour as long as no untoward cardiovascular effects have occurred.[3]

Compression of a puncture site must be done every time a needle is withdrawn from the penis to avoid a hematoma. The penis should resume a soft state. Partial detumescence might occur in some patients. If in doubt and pressure equipment is available, a cavernous pressure below 40 mmHg is considered acceptable. If this has been unsuccessful, venous shunting has to be considered. A Winter procedure using a Tru-Cut biopsy needle through the glans to remove a piece of corporal tissue can be performed in the Emergency Department by a Urologist. Familiarity with this procedure is necessary in order to establish an effective shunt. Other venous types of shunts are performed in the Operating Room to decompress the corpora cavernosa.

AFTERCARE

The patient should be observed for at least 30 minutes before assuming successful detumescence. **Do not apply a compression dressing to the penis.** A pressure or circumferential dressing can result in ischemia and pressure necrosis. Referral to an appropriate specialist depends upon the cause of the priapism. If an underlying condition or medication is the suspected cause, the offending mechanism should be treated (or medication discontinued), the treating physician notified, and an appropriate disposition and follow-up ensured. Follow-up with a Urologist within 24 hours is necessary for all patients. A detailed procedure note as well as a precise statement of the discharge information given to the patient should be meticulously documented in the chart.

There are no randomized controlled data to support the use of prophylactic antibiotics after aspiration, irrigation, and/or intracavernous therapy. Some physicians will prescribe an antibiotic whose spectrum covers skin flora, such as cephalexin. The benefits of the antibiotic must be weighed against the possible adverse effects of the antibiotic such as allergic reactions, diarrhea, and clostridium difficile colitis to name just a few. The decision to prescribe or not prescribe an antibiotic should be based on the particular patient circumstances, Emergency Physician preference, and the consulting Urologists preference.

COMPLICATIONS

The long-term sequelae to unresolved priapism are fibrosis of the corporal tissue and loss of erectile function. Erectile dysfunction may still occur in patients despite successful detumescence. Varying degrees of fibrosis may be found on physical examination at a later date. Treatment by aspiration and irrigation can be associated with hematoma formation, urethral or vascular injury, and infection. The use of alpha-adrenergic agonists can have the systemic effects of headache, hypertension, flushing, reflex bradycardia, tachycardia, and other dysrhythmias. Deaths have been recorded with agents other than phenylephrine. The use of phenylephrine has not been reported to give rise to serious complications and is the agent of choice.

A prophylactic antibiotic, compression of needle puncture sites, care in alpha-adrenergic agonist dosing, observing the patient, and monitoring the blood pressure and pulse can help prevent untoward outcomes. The patient needs to be fully informed of the long-term risk of sexual dysfunction, even if detumescence is successful. Recurrence of the priapism is common and the patient should be warned to seek immediate care.

SUMMARY

Priapism is an uncommon but vexing complaint in the Emergency Department. The two major subtypes of priapism are ischemic (low flow) and nonischemic (high flow). The key decision for the Emergency Physician is to determine what type of priapism is present. Ischemic priapism requires prompt treatment to reduce the possibility of permanent damage to the penile tissue and subsequent erectile dysfunction. It is imperative to confirm the diagnosis with either color Doppler flow ultrasound or penile aspiration. Ischemic priapism, suspected or confirmed, requires an emergent Urology evaluation. Treatment should be performed in a stepwise fashion beginning with penile aspiration followed by irrigation if necessary. If unsuccessful, the intracavernous injection of phenylephrine should be attempted if no contraindications exist. If these bedside strategies fail, a Urologist should perform more invasive surgical procedures.

148 Paraphimosis Reduction

Ann P. Nguyen

INTRODUCTION

A paraphimosis is defined as the inability to reduce a proximally positioned foreskin over the glans penis and back to its normal anatomic position. The most common causes for a paraphimosis are iatrogenic. Following examination or instrumentation of the penis, medical personnel may forget to reduce the foreskin over the glans. This is particularly true of patients who are sedated, confused, demented, delirious, or in a nursing home. Patients may fail to reduce their foreskin after intercourse or urination. In infants and toddlers, the foreskin does not become fully mobile until after 3 years of age. This predisposes them to a paraphimosis when well-meaning caregivers forcibly retract the foreskin during cleaning. A paraphimosis may also occur when a narrowed (phimotic) foreskin is retracted and unable to be reduced.

A patient with a paraphimosis usually presents with severe pain in the distal penis. The process may have a more indolent presentation in persons with impaired pain sensation, such as the elderly or diabetics. As they are often unable to complain of pain, patients with altered mental status are at risk for complications of a paraphimosis. This includes penile ulceration, infection, gangrene, and partial penile autoamputation.[1] A careful and complete physical examination is mandatory in these patients. Penile edema secondary to a paraphimosis must be differentiated from edema due to infection, trauma, or allergic reactions.

ANATOMY AND PATHOPHYSIOLOGY

The foreskin is composed of a double layer of epidermis overlying subcutaneous tissue. It is attached to the skin at the base of the glans penis. The foreskin covers the glans to a variable degree and can usually be completely pulled over the glans. In a paraphimosis, the foreskin is retracted behind the glans and becomes edematous. The base of the foreskin is the location of the constricting or phimotic ring (**Figures 148-1 & 148-2**).

Arterial supply to the foreskin is derived from superficial branches of the external pudendal artery, which originates from the femoral artery. These superficial arteries do not communicate with the deep



FIGURE 148-1. The anatomy of a paraphimosis.

arteries of the penis. Arterial supply to the glans penis is derived from the paired dorsal arteries of the penis, which originate from the penile artery. These dorsal penile arteries run deep to Buck's fascia to enter the glans at the coronal sulcus. Arterial supply to the glans penis is thus entirely separate from that of the foreskin.

A retracted foreskin will block lymphatic drainage from the distal penis. As arterial inflow continues, lack of lymphatic drainage will cause a progressive edema of the penis distal to the retracted foreskin. As the foreskin continues to swell the phimotic ring becomes progressively tighter, and if not reduced, will eventually obstruct venous outflow. The distal penis will become painful and hyperemic. The edema will progress to ultimately obstruct arterial inflow resulting in penile ischemia, necrosis, and gangrene. This series of events, from retraction of the foreskin to arterial inflow obstruction, can occur over a few hours to 1 to 2 days. To relieve the obstruction, the phimotic ring must be advanced (reduced) over the glans of the penis.





FIGURE 148-2. A paraphimosis. **A.** Superior view. **B.** Inferior view.

INDICATIONS

All paraphimoses require reduction. The earlier a reduction is attempted, the less edematous the tissues will be and the easier it will be to perform the reduction. **Nonsurgical techniques should be attempted first. Surgical techniques are indicated if nonsurgical techniques are unsuccessful or the skin is compromised by infection, ulceration, or gangrene.**[2]

CONTRAINDICATIONS

There are no absolute contraindications to the reduction of a paraphimosis. While all paraphimoses must be reduced, certain techniques are contraindicated in specific patient subgroups. Nonsurgical techniques are contraindicated in patients with ulcerated or necrotic foreskins as they may cause iatrogenic injury.[2] Some authors feel that surgical reductions in children should be reserved for Pediatric Urologists.[3,4] **A surgical reduction should not be performed until noninvasive and lesser invasive techniques have been attempted.** The hyaluronidase technique is contraindicated in penile cancers or infections due to the possibility of spreading infected or malignant cells through the tissue planes.[5]

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Lidocaine jelly
- Water-soluble lubricant
- Local anesthetic solution (1% lidocaine or 0.5% bupivacaine) without epinephrine
- 18 gauge needles
- 27 gauge needles
- 10 mL syringe
- 4 × 4 gauze squares
- Crushed ice
- Surgical gloves
- Babcock clamps (6 to 8)
- 2-inch wide roll of elastic bandage (Ace Wrap or Elastoplast)
- Sterile drapes
- Sterile surgical gloves
- Suture scissors
- Two straight hemostats
- #15 surgical blade with handle
- Needle driver
- 3-0 synthetic absorbable suture or chromic catgut suture
- Granulated (table) sugar
- Hyaluronidase, 150 units or 1 cc
- Tuberculin syringe
- Antibiotic ointment, topical
- Petrolatum gauze

PATIENT PREPARATION

Reduction of a paraphimosis can be painful and somewhat distressing to patients. Explain to the patient and/or their representative the risks and benefits of the procedure. Also explain that the progression from nonsurgical to surgical techniques may be required. Obtain an informed consent from the patient. If the patient has an indwelling urinary catheter, it should be left in place during the reduction.

While premedication is rarely necessary, some patients may benefit from mild sedation. Procedural sedation (Chapter 129) and general anesthesia may be required in children.[3,4] Analgesia can sometimes be achieved with the topical application of lidocaine jelly or EMLA cream (2.5% prilocaine and 2.5% lidocaine) applied liberally and held in place for 45 to 60 minutes by a biofilm dressing. If this does not provide adequate patient comfort, a ring block or dorsal penile nerve block can be performed with 0.5% bupivacaine and/or 1% lidocaine.[6] Refer to Chapter 146 for the complete details regarding penile anesthesia.

TECHNIQUES

The techniques described below to reduce a paraphimosis begin with manual compression and progress to incision of the phimotic ring. They should be attempted in a stepwise manner from least invasive to most invasive in the order presented below.

MANUAL REDUCTION

This method has been extensively described.[3,7–10] Liberally apply an anesthetic jelly or water-soluble lubricant to the glans and foreskin. Do not coat the penile shaft or else it will be too slippery to facilitate an easy reduction.

Apply manual compression directly to the glans and edematous foreskin by grasping them with the palm of a gloved hand (**Figure 148-3**). Apply slow and steady pressure for 5 to 10 minutes. Many physicians do not have the time or the strength to apply pressure to a patient's penis for 5 to 10 minutes. In children, the parent may be asked to provide the manual compression. Compression may also be provided by circumferentially wrapping a bandage around the penis beginning at the glans and working toward the base of the penis. Apply the bandage so that it places more pressure distally and less proximally. This will mobilize the edematous fluid from distal to proximal. The bandage can be an Ace Wrap or Elastoplast,[10] a gauze sponge soaked in lidocaine jelly, or a gauze sponge soaked in cold water.[7]



FIGURE 148-3. Manual compression of the glans and foreskin to reduce the edema of the foreskin.

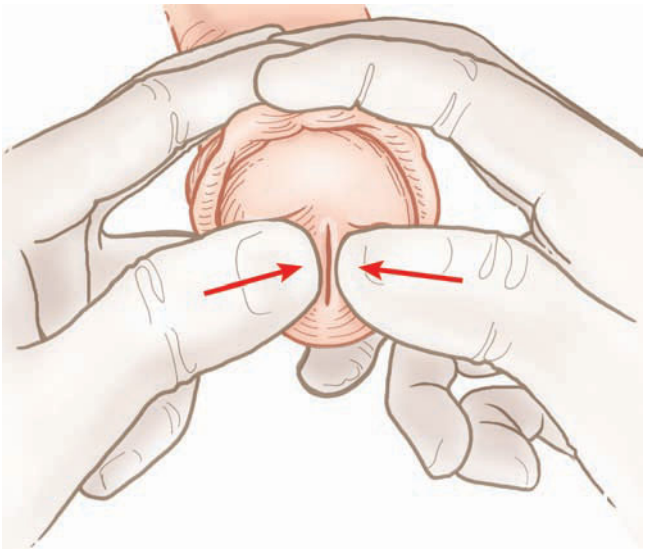


FIGURE 148-4. Manual reduction of a paraphimosis. The thumbs push the glans proximally (*arrows*) while the fingers provide countertraction to slip the phimotic ring over the glans.

Remove the bandage or release manual compression after it has been applied for 5 to 10 minutes. Apply the index and middle fingers of both hands to surround the top of the penile shaft proximal to the phimotic ring and the ring fingers underneath the penile shaft (**Figure 148-4**). Place both thumbs adjacent to the urethral meatus (**Figure 150-3**). Push the glans proximally with the thumbs while the fingers simultaneously provide countertraction to pull the phimotic band over the glans. Apply continuous force until the phimotic band moves distal to the glans. This same technique can be applied if the patient has an indwelling urinary catheter (**Figure 148-5**).

Alternatively, encircle the entire foreskin in one hand and pull distally while simultaneously pushing the glans proximally with the thumb of the opposite hand.[8] It is important to be very deliberate in the first attempt as the patient will become more anxious on subsequent attempts. This same technique can be applied if the patient has an indwelling urinary catheter.

ICED GLOVE TECHNIQUE

This technique combines cold to induce vasoconstriction and compression to reduce swelling.[2,8] It uses a glove to provide a circumferential ice pack to the foreskin to reduce edema. Half-fill a size 8 surgical glove with crushed ice and cold water. Squeeze the air from the glove and tie a knot in the wrist of the glove. Invaginate the thumb into the body of the glove. Liberally lubricate the glans and foreskin. Insert the penis into the invaginated thumb of the glove. Apply manual pressure with a clenched fist or bandage for 5 to 10 minutes. Attempt manual reduction as described previously.[2,3,4,8]

BABCOCK CLAMP TECHNIQUE

This technique can be used when manual reduction has been unsuccessful. It has a high rate of success in reducing a paraphimosis.[3,8,11] **This technique requires penile anesthesia (Chapter 146). Use only Babcock clamps. All other surgical clamps will crush and devitalize tissue.**

Apply 6 to 8 Babcock clamps circumferentially around the phimotic ring (**Figure 148-6A**). Place one edge of each clamp just proximal to the phimotic ring and the other edge just distal to the phimotic ring. **It is important to grasp a sufficient amount of**

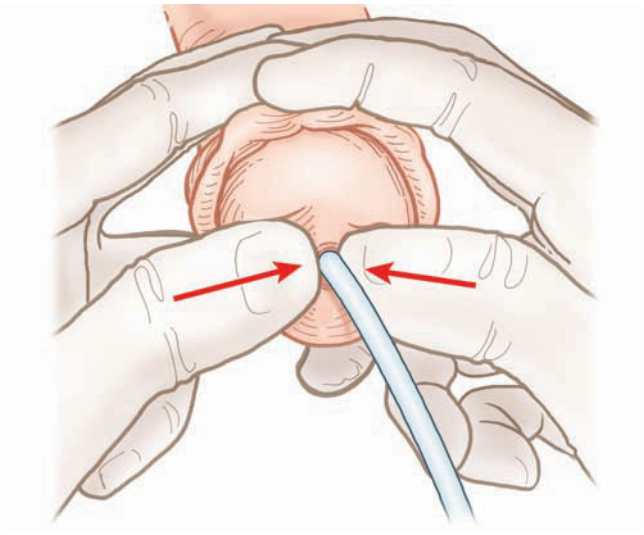


FIGURE 148-5. Manual reduction of a paraphimosis in the patient with an indwelling urinary catheter.

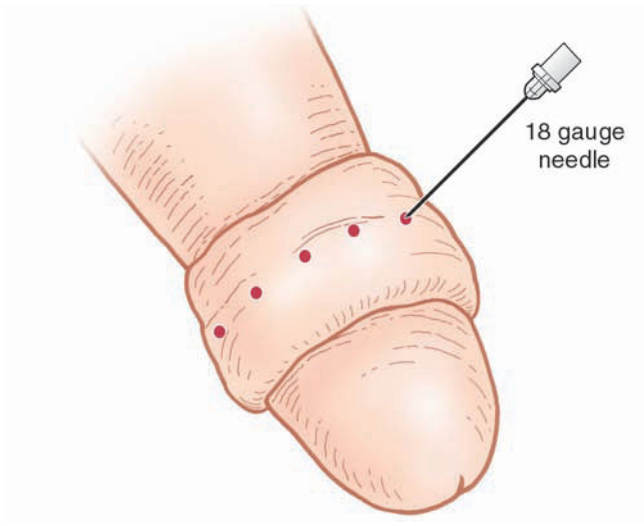


FIGURE 148-7. The needle decompression technique. An 18 gauge needle is used to circumferentially puncture the edematous foreskin 8 to 12 times.

the constricting ring to avoid tearing the skin once traction is applied. Space the clamps evenly around the circumference of the penis. Grasp all of the Babcock clamps in one hand. Simultaneously and slowly apply distal traction to the clamps to pull the phimotic ring over the glans (**Figure 148-6B**). After reduction, remove the Babcock clamps. Examine the foreskin for any signs of traumatic injury from the clamps.

A variation of this technique uses two operators and two Adson forceps in place of Babcock clamps.[12,13] This method is briefly described for completeness but is not recommended even though it is described in the medical literature. Adson forceps are toothed forceps. Traction with an Adson forceps can result in the teeth pulling through the phimotic ring and tearing the foreskin. One operator applies an Adson forceps to the phimotic ring at the 3 o'clock position and a second at the 9 o'clock position. The first operator pulls the foreskin distally via the forceps, while a second operator compresses the glans and pushes it proximally.

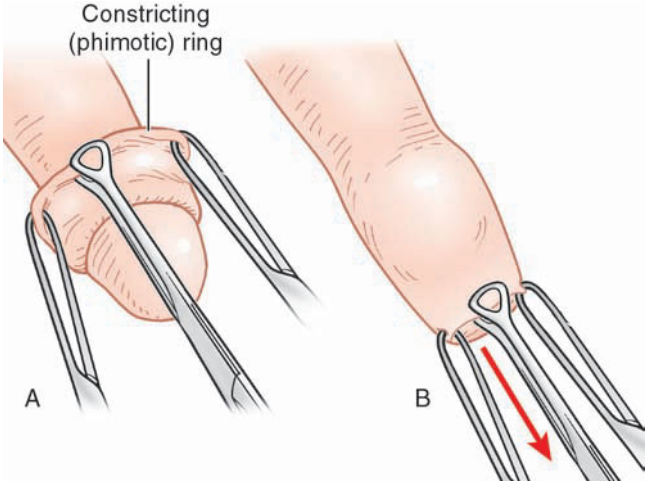


FIGURE 148-6. The Babcock clamp technique. **A.** Place six to eight Babcock clamps along the phimotic ring. Note that only three Babcock clamps are seen in the illustration for the sake of clarity. **B.** Gentle traction is simultaneously placed on all the clamps to advance the phimotic ring over the glans.

NEEDLE DECOMPRESSION TECHNIQUE

This technique mechanically expresses fluid from the edematous foreskin via a series of puncture holes in the foreskin.[3,9,14–17] Penile anesthesia is required with this technique. Clean the penis of any dirt or debris. Drape and isolate a sterile field around the penis. Apply povidone iodine or chlorhexidine solution to the penis and allow it to dry. Perform a penile block (Chapter 146).

Insert a sterile, hollow-bore 18 gauge needle 3 to 5 mm deep into the edematous foreskin. The use of needles as large as 18 gauge to as small as 26 gauge have been described. An 18 gauge is preferred as it makes a hole large enough to allow blood and fluid to escape from the tissues and not close or clot closed. Continue to puncture holes circumferentially around the edematous foreskin (**Figure 148-7**). An average of 8 to 12 holes are required. Different recommendations to use as few as 1 to as many as 20 punctures have been made.[15,16] Wrap a gauze square around the foreskin and glans. Grasp the glans and foreskin in the palm of a gloved hand and apply manual compression. Edema fluid and blood will be expressed from the puncture holes allowing the foreskin to decompress. The gauze square will allow the Emergency Physician to maintain a grasp as the penis becomes slippery with blood and edema fluid. After the foreskin is decompressed, reduce it manually or with Babcock clamps.

DORSAL SLIT OF THE FORESKIN

The Emergency Physician must always be prepared to perform surgical techniques if nonsurgical reduction is unsuccessful. This technique involves the incision of the phimotic ring under strict aseptic technique.[2,6,8] Place the patient supine and anesthetize the penis (Chapter 146), if it has not been done previously. Apply povidone iodine or chlorhexidine solution to the penis and let it dry. Apply sterile drapes to isolate a surgical field. Consider the administration of parenteral sedation prior to performing this procedure to alleviate the patient's anxiety.

Clamp a straight-blade hemostat over the foreskin and phimotic ring at the 11 o'clock and 1 o'clock positions. Place one jaw of each hemostat beneath the phimotic ring and the other jaw on top of it. **Be careful not to clamp the skin on the shaft of the penis.** Pull the foreskin taut between the hemostats. Grasp the hemostats with the nondominant hand or have an assistant hold them. Incise the

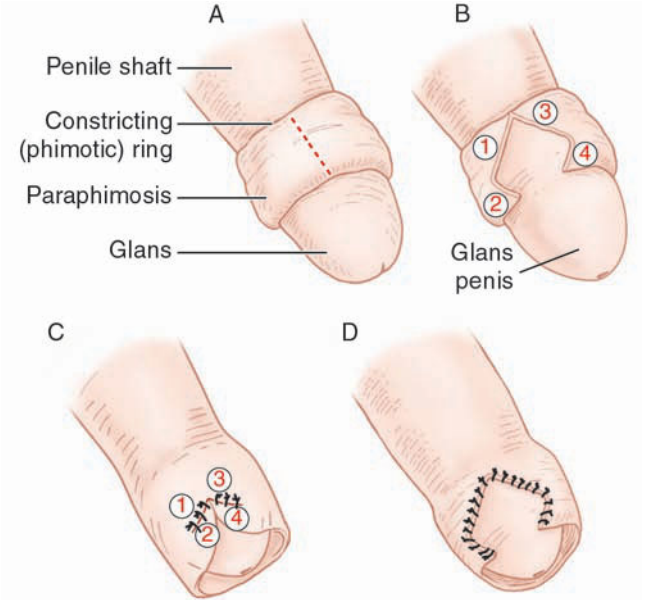


FIGURE 148-8. The dorsal slit of the foreskin. **A.** The dotted line represents the incision line. **B.** The foreskin opens after the incision is made. The numbers represent the edges of the incision. **C.** The foreskin has been reduced and the edges of the incision sewn shut. A small gap should remain in the midline that is free of sutures. **D.** Alternatively, sew the edges closed with a simple running stitch.

foreskin and phimotic ring at the 12 o'clock position with a scissors or a #15 scalpel blade (**Figure 148-8A**). **Be careful not to cut the skin on the shaft of the penis.** Remove the hemostats. The incision will open into a pentagonal shape (**Figure 148-8B**). Reduce the foreskin over the glans. Cover the penis with sterile gauze and allow the edges of the incision to ooze for 10 to 15 minutes.

This technique can be technically difficult for the non-Surgeon. As an alternative to the two-hemostat technique, a one-hemostat technique may be performed. Place one hemostat over the foreskin and phimotic ring at the 12 o'clock position (**Figure 148-8A**). Remove the clamp after 1 to 2 minutes. Cut the crushed tissue with scissors through the phimotic ring. **Be careful not to cut the skin on the shaft of the penis.** The foreskin will then open up as described above (**Figure 148-8B**).

After the foreskin has been incised and reduced over the glans, approximate the cut edges with 3-0 chromic suture using a simple interrupted stitch (**Figure 148-8C**). Sew edge 1 and edge 2, on the illustration, together. Sew edge 3 and edge 4, on the illustration, together. A gap will remain at the 12 o'clock position that corresponds to the area of the initial incision. Alternatively, sew the cut edges with a simple running stitch (**Figure 148-8D**). Loosely apply petrolatum gauze and gauze squares over the wound. Apply a piece of tape to hold the dressing on the penis. **Do not apply the tape circumferentially as this can result in penile ischemia.**

MODIFIED DORSAL SLIT OF THE FORESKIN

A modified dorsal slit technique has been described where only the phimotic ring is cut rather than the entire foreskin.[4,8] Clean, prep, anesthetize, and drape the penis as above. A penile block is the preferred method of anesthesia as injection onto the distal penis is extremely painful (Chapter 146). As an alternative to a penile block, infiltrate immediately under the phimotic ring at the 12 o'clock position with local anesthetic solution without epinephrine using a 27 gauge needle. Be sure to raise a wheal both proximally and distally to the phimotic ring (along the dotted line in **Figure 148-9A**).

Incise the phimotic ring with a #15 scalpel blade. **Incise only the phimotic ring. Do not extend the cut more than 3 mm proximally or distally to the phimotic ring.** Once incised, the foreskin will spring open into a diamond-shaped defect (**Figure 148-9B**). Reduce the foreskin. Cover the penis with gauze and allow the cut edges to ooze for 10 to 15 minutes to decompress the foreskin. Approximate the edges of the wound with 3-0 chromic suture in a running pattern (**Figure 148-9C**). Apply a bandage of petrolatum gauze and gauze squares over the wound. Apply a piece of tape to hold the dressing on the penis. **The tape should not be applied circumferentially as this can cause ischemia to the penis.**

ALTERNATIVE TECHNIQUES

A variety of alternative techniques have been described in the literature.[5,9,14,18,19,21] These techniques are variations on the basic principles previously discussed. We will briefly review the osmotic (sugar), hyaluronidase, and glans aspiration techniques.

OSMOTIC (SUGAR) TECHNIQUE

An alternative to surgical techniques is the osmotic technique.[9,18,19,21] It is an innovative, painless, but time-consuming method. The glans and foreskin are immersed in sugar. An osmotic gradient is formed between the edematous foreskin and the sugar. The hypertonicity of the sugar draws the edema fluid out of the foreskin. The deflated foreskin can then be manually reduced over

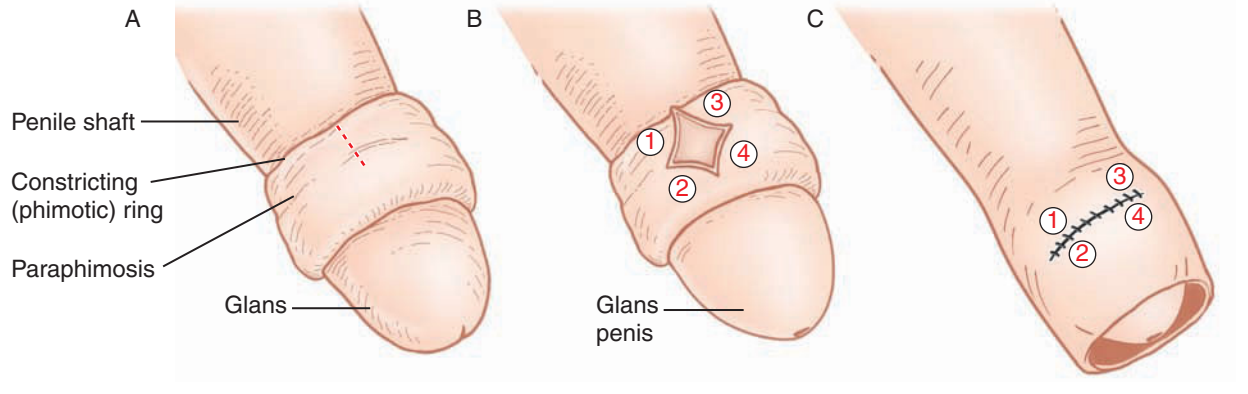


FIGURE 148-9. The modified dorsal slit of the foreskin. **A.** The dotted line represents the incision line. **B.** The foreskin opens after the incision is made. The numbers represent the edges of the incision. **C.** The foreskin has been reduced and the edges of the incision sewn shut.

the glans. This technique should not be performed if the foreskin or the glans is infected, gangrenous, or ulcerated.

Place ordinary table sugar into the invaginated thumb of a large surgical glove. Insert the penis into the thumb of the glove, like in the iced glove method described above.[17] The penis may also be wrapped distally to proximally in a gauze square saturated with a 50% dextrose solution.[9,19] In all reports, the sugar was left on the penis for 1 to 2 hours before manual reduction was successful. The maximum time reported before successful reduction was 4 hours.[18]

HYALURONIDASE METHOD

Hyaluronidase (Amphadase, Amphastar Pharmaceuticals Inc., Rancho Cucamonga, CA; Hydase, PrimaPharm Inc., San Diego, CA; Hylenex, Halozyme Therapeutics, San Diego, CA; Vitrase, Ista Pharmaceuticals Inc., Irvine, CA) is a commercially available mammalian enzyme that degrades the intercellular ground substance of connective tissue. It is widely used in ophthalmologic and plastic surgery as a spreading agent. When injected into an edematous foreskin, hyaluronidase disperses the extracellular edema fluid, facilitating reduction of the paraphimosis.[5,14]

Clean, prep, drape, and anesthetize the penis. Inject hyaluronidase subcutaneously using a tuberculin syringe at various points around the circumference of the edematous foreskin. A total of 150 units, or 1 cc, of hyaluronidase should be used. An alternative is to inject the hyaluronidase into the puncture holes previously made from the needle decompression technique.[9,14] The edema should resolve almost immediately. Manual compression may be applied to the foreskin for 1 to 2 minutes to help mobilize the fluid. After the edema has decreased, manually reduce the foreskin.

The advantage of this technique is the rapidity with which the edema resolves. However, hyaluronidase is contraindicated in patients with penile infections or cancer as it may spread bacteria or malignant cells through the tissue planes. It is also contraindicated if the foreskin or glans is gangrenous or ulcerated.

GLANS ASPIRATION TECHNIQUE

This method is based on techniques used to treat priapism.[20] The author reports using this technique on four patients with paraphimoses with a 100% success rate and no complications. He recommended it for use when the foreskin is very friable and not amenable to vigorous manipulation. This technique is described for the sake of completeness but is not recommended.

Clean, prep, drape, and anesthetize the penis. Apply a sterile tourniquet to the penile shaft proximal to the phimotic ring. Use either umbilical tape or a Penrose drain. Insert a 20 gauge needle on a 10 mL syringe into the midline of the glans, halfway between the meatus and the corona. Keep the needle and syringe parallel to the urethra. Advance the needle while aspirating with the syringe. Once blood is encountered, stop advancing the needle. Continue to aspirate blood until the glans collapses completely. It is estimated that approximately 3 to 12 mL of blood will need to be aspirated, depending on the size of the glans. Remove the needle. Grasp and firmly squeeze the glans with the nondominant hand. While maintaining this pressure, release the tourniquet and manually reduce the foreskin over the collapsed glans with the dominant hand.

ASSESSMENT

The successfully reduced paraphimosis should have the general appearance of a normal uncircumcised penis. The patient usually notes immediate pain relief. It is normal for residual edema to be present. Reassure the patient that the edema will spontaneously resolve over hours to days.[3,8] If invasive techniques were utilized, observe the patient in the Emergency Department for 45 to 60 minutes to confirm hemostasis. Observe the patient for full recovery from any sedation or procedural sedation techniques as per hospital policy.

AFTERCARE

Wound care following a surgical reduction is the same as that for any sutured laceration. Many physicians do not dress the site at all. But if desired, the site may be covered with antibiotic ointment or petrolatum gauze followed by a dry sterile gauze.[6] The patient should be counseled on proper wound care. The patient should inspect the glans and foreskin three to four times a day if Babcock clamps, needle decompression, or surgical techniques were used to reduce the paraphimosis. They should return immediately to the Emergency Department if any signs of infection develop. Advise them to avoid intercourse or masturbation for 4 to 6 weeks.[6]

Antibiotics should be prescribed if the foreskin is abraded, infected, ulcerated, or torn by the Babcock clamp technique. They should also be prescribed if the foreskin was reduced by an invasive technique (e.g., needle decompression, dorsal slit, modified dorsal slit, hyaluronidase, or glans aspiration). Oral antibiotics whose spectrum covers skin flora should be prescribed. Cephalexin, 500 mg orally four times a day, is usually adequate.

All patients must follow up with a Urologist in 1 to 2 days. The definitive treatment is circumcision. This is typically delayed 7 to 10 days until any edema, inflammation, or ulceration has resolved.[7,8]

COMPLICATIONS

Incomplete reduction and pain are possible complications of manual reduction. With that in mind, it is important to allow enough time for adequate dispersion of edema. Manual reduction may also be associated with glans contusion and even glans ischemia if manual pressure is too great.[4] The iced glove method may produce cold injury if not properly monitored during use.[3] Compromised penile skin may be torn during manual or Babcock clamp reduction. The treatment is to suture any tears that occur.[8]

If surgical techniques are performed, bleeding is a common complication in this very vascular tissue. Venous bleeding can be profuse. It is important to have good control of the tissue edges so that adequate hemostatic stitches can be placed. A compressive dressing may aid in hemostasis. If the penile shaft is lacerated during a surgical reduction, it too should be sutured. And as with all invasive procedures, infection may be a complication of the needle decompression, dorsal slit, modified dorsal slit, hyaluronidase, and glans aspiration techniques.

The glans aspiration method runs the risk of transecting the urethra if the needle is not advanced parallel to the urethra. Complications of the hyaluronidase method may range from minor ecchymoses at the injection site to anaphylaxis and shock if the hyaluronidase is inadvertently injected intravascularly.[5,14]

SUMMARY

A paraphimosis is a problem that is best prevented. Replacement of the foreskin after urethral catheterization or glans cleaning is important. Early intervention is necessary and can prevent disastrous tissue loss. The reduction techniques should be attempted in a stepwise manner beginning with noninvasive techniques and progressing to increasingly invasive techniques.

149 Phimosis Reduction

Eric F. Reichman and Natana Peres

INTRODUCTION

A phimosis is a condition in which the foreskin cannot be retracted behind the glans of the penis.[1–19] It interferes with cleaning under the foreskin, allows the accumulation of secretions and debris (i.e., smegma) under the foreskin, and may predispose the patient to infections and possible malignancy.[18] It is classified into two subgroups: physiologic and pathologic. Physiologic phimoses occurs naturally in newborns. In males younger than 4 years of age, it is normal for the foreskin to not be retractable. In older boys and adults, the foreskin can usually be retracted without difficulty.[1] Pathologic phimoses is the inability to retract the foreskin after it was previously retractable or after puberty, usually secondary to scarring of the foreskin. Surgical treatment for a phimosis has been known for hundreds of years.[2] A Byzantine surgeon by the name of Oribasius, in the fourth century AD, gave a seemingly well-acquainted description of a technique involving forced dilation of the constrictive foreskin, scalloping out of its inner surface, then stretching it over a parchment-wrapped lead tube placed between the filleted skin and the glans.[2] Current techniques for the management of a phimosis in the Emergency Department are simple and remain an important intervention directed to relieving urinary obstruction.

ANATOMY AND PATHOPHYSIOLOGY

At birth there is a physiologic phimosis in the majority of male neonates. This is due to natural adhesions that exist between the foreskin and the glans of the penis. During the first 3 to 4 years of life, as the penis grows, epithelial debris (i.e., smegma) accumulates under the foreskin and gradually separates the foreskin from the glans. Intermittent penile erections aid in allowing the foreskin to eventually become retractable. The foreskin of most males will retract easily by the age of four. Forcible retraction should be categorically discouraged as this can result in scarring and constriction.[1] For a nonobstructive phimosis in children, topical steroids and topical conjugated equine estrogen have shown excellent results in releasing the stubborn physiologic adhesions between the foreskin and the glans.[3,4]

A phimosis can be the cause of other problems or be a result of other medical conditions. Recurrent infections such as balanitis or balanoposthitis, repeated urinary catheterization, forceful foreskin retraction, and poor hygiene can lead to scarring of preputial orifices causing a pathologic phimosis. Pathologic phimosis may also arise in diabetics due to the presence of glucose in their urine giving rise to an infection of the foreskin. Once acquired, a phimosis can become a paraphimosis if the foreskin is retracted and not promptly reduced. It can result in urinary tract infections from bacterial colonization of the phimosis or secondary to urinary obstruction. Some males may report painful erections, hematuria, preputial pain, or a weakened urinary stream. Other complications of a phimosis include recurrent balanitis, other local infections, urinary retention, carcinoma of the penis, and easy growth of venereal warts and other sexually transmitted diseases. It may also be due to local trauma (known as Tristram Shandy syndrome) or the congenital lack of conversion to a mobile foreskin.[5] Penile carcinoma deserves special mention. Coexistent phimosis is seen in up to 52% of cases of penile carcinoma. The need for timely follow-up should be impressed upon the patient regardless of the intervention required in the Emergency Department.[6]

INDICATIONS

The sole indication for the surgical release of a phimosis is urinary obstruction that cannot be relieved by passing a urethral catheter. A dorsal slit of the foreskin should be performed only after failure of noninvasive techniques. Most patients with a phimosis rarely require any emergency intervention and should be referred to a Urologist on an outpatient basis.

CONTRAINDICATIONS

The ability to pass a urinary catheter (Foley or coudé) into the bladder eliminates the acute need for the reduction of a phimosis. Patients with bleeding disorders, gross infections of the foreskin, who are immunocompromised, or who have lesions of the foreskin should have a urinary catheter placed into the bladder rather than an incision of the phimotic foreskin. If a catheter cannot be inserted into the urethra in these patients, a Urologist should be consulted prior to any invasive procedures. Patients with a nonobstructing phimosis should be referred for an elective circumcision and not have a dorsal slit procedure.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Gauze squares
- Sterile drapes
- 1% lidocaine without epinephrine
- Lidocaine Uro-jet
- 27 gauge needle
- 5 mL syringes
- Hemostats, straight or straight Kelly clamps
- Urinary catheters (Foley, coudé)
- Sterile gloves
- Sterile drapes
- Scissors
- #15 scalpel blade on a handle
- 3-0 or 4-0 chromic catgut or Vicryl on a noncutting needle
- Needle driver
- Petrolatum gauze
- 1 to 2 inch bandage
- Topical antibacterial ointment

The use of tissue glue of the type normally found in Emergency Departments has been studied in children undergoing circumcision.[7] It was shown to increase infection, bleeding, and wound dehiscence when compared to suture. The use of suture must be recommended at this time to close the wound edges.

PATIENT PREPARATION

Explain the benefits, risks, potential complications, and aftercare of the procedure to the patient and/or their representative. An informed consent should be obtained and placed in the medical record.

Place the patient supine with their genitalia exposed. Prepare the penis for any intervention. Clean the penis of any dirt, debris, and discharge. Apply drapes to isolate the penis. Apply povidone iodine or chlorhexidine solution onto the penis. If possible, apply the solution under the foreskin using a cotton-tipped applicator if necessary. If the patient has pain in the area of the foreskin, or if

a procedure other than catheter insertion is to be performed, the penis should be anesthetized. Refer to Chapter 146 for the complete details regarding penile anesthesia. Alternatively, infiltration of local anesthetic solution can be used to anesthetize the foreskin. Draw up 5 mL of local anesthetic solution without epinephrine into a syringe armed with a 27 gauge needle. Inject a subcutaneous wheal of local anesthetic solution 2 cm proximal to the distal end of the foreskin. Continue subcutaneous infiltration circumferentially around the penis with the local anesthetic solution. The patient may require intravenous sedation or procedural sedation prior to the injection of local anesthetic solution into the penis.

The use of topical anesthetics such as lidocaine jelly, prilocaine creams, or combinations (EMLA, LET, and LAT) is not recommended.[8] The application of these mixtures requires an occlusive dressing and 60 to 90 minutes for the anesthetic effect, which may then be inadequate.

TECHNIQUES

TOPICAL CORTICOSTEROIDS

Up to 85% of pathologic phimoses that are mild to moderate will respond to the application of topical steroids to the preputial orifice. It is reasonable for the Emergency Physician to prescribe 0.1% to 0.05% betamethasone dipropionate applied twice daily for 4 to 6 weeks with appropriate Urologic follow-up if there is no urinary obstruction or a urinary catheter can be placed.[11] The application of topical corticosteroids is the most cost-effective treatment if the circumstances permit.[19]

URETHRAL CATHETERIZATION

Attempt to pass a size 16 or 18 French Foley or coudé catheter into the bladder. If this is too large, attempt to pass the largest possible catheter. Please refer to **Table 145-1** for an age-based list of proper catheter sizes. **Care should be taken to avoid forceful placement of the catheter between the foreskin and the glans.** Correct catheter placement will be confirmed by an outflow of urine. Refer to Chapter 142 for a complete discussion of urethral catheterization.

FORESKIN DILATION

Most simply, the opening of the prepuce can be stretched. The patient's penis should be thoroughly anesthetized prior to performing this procedure (Chapter 146). Consideration should also be given to administering intravenous analgesics, intravenous sedation, or procedural sedation (Chapter 129).

Insert the jaws of a closed hemostat just inside the foreskin. Slowly open the arms of the hemostat 2 to 3 mm. **Palpate the foreskin to feel both jaws of the hemostat. If the jaws are not palpable, immediately remove the instrument as one of the jaws may be in the urethra.** If both jaws of the hemostat are palpable, open the arms to dilate the opening of the foreskin. Remove the hemostat. Clean the glans and undersurface of the foreskin with povidone iodine or chlorhexidine solution. Insert, using strict aseptic technique, a urinary catheter if required (Chapter 142).

This approach is not the ideal technique as it carries significant risk of injury to the patient. Inadvertent placement of the hemostat jaw in the urethra can lacerate the urethra and glans of the penis. Dilating the foreskin can cause irregular tears. Injury may require operative intervention and circumcision to correct any iatrogenic trauma.

DORSAL SLIT OF THE FORESKIN

The preferred method to correct an obstructing phimosis in the Emergency Department is the dorsal slit procedure. The patient's penis should be thoroughly anesthetized prior to performing this procedure (Chapter 146). Consideration should also be given to administering intravenous analgesics, intravenous sedation, or procedural sedation (Chapter 129).

Insert the bottom jaw of a straight hemostat between the foreskin and glans at the 12 o'clock position (**Figure 149-1A**). For those individual patients or cultural situations where dorsal incision of the foreskin, much less excision, is cosmetically unacceptable, a ventral approach may be substituted which will yield an apparently uncircumcised penis without obstructive symptoms.[9] Advance the hemostat until the tip of the jaw is at the coronal sulcus (**Figure 149-1A**). The coronal sulcus is where the foreskin attaches to the penis. Depending on the etiology of the phimosis, adhesions may be encountered. These should be gently broken as the hemostat is advanced. The skin of the foreskin is relatively thin and the jaw of the hemostat should be easily palpated. The tip of the jaw should be seen to tent the skin at the coronal sulcus when properly placed (**Figure 149-1B**). **It cannot be overemphasized that the Emergency Physician must be confident that the instrument has not been inadvertently placed in the urethra. If the jaw of the hemostat cannot be felt and cannot be seen tenting the skin of the foreskin, remove the hemostat and reinsert it.**

Once properly placed, close the hemostat to crush the foreskin at the 12 o'clock position. Allow the hemostat to remain closed for 2 to 3 minutes to thoroughly crush the foreskin. Remove the

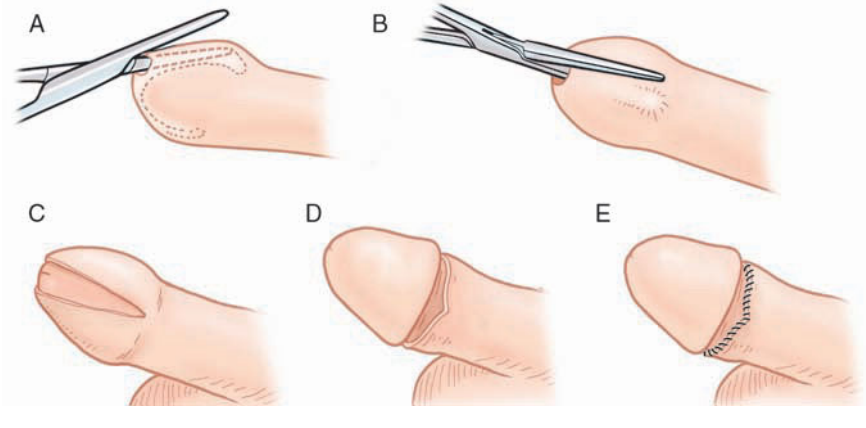


FIGURE 149-1. Dorsal slit of the foreskin. **A.** A hemostat is inserted under the foreskin and advanced to the coronal sulcus. **B.** The hemostat is elevated to tent the skin and confirm it is properly placed. **C.** The dorsal slit has been made. **D.** The foreskin is retracted. **E.** Interrupted sutures are placed in the cut edge of the foreskin.

hemostat. Insert a scissors and advance it with the same attention to position the tip at the coronal sulcus. Incise the crushed tissue to the level of the coronal sulcus (**Figure 149-1C**). If straight scissors are not available, a #15 blade may be used to cut the crushed skin after another instrument is placed underneath the foreskin to protect the glans from injury. **This method of using a scalpel blade is dangerous and not recommended because control is reduced and the potential for error is unnecessarily increased.**

Retract the cut foreskin. This will leave an open wound edge on both sides of the midline (**Figure 149-1D**). Suture the open wound edges using 3-0 or 4-0 chromic gut suture in an interrupted or running pattern. Begin suturing from the midline to the distal end of the incision (**Figure 149-1E**).[5] Return the foreskin to its "resting" position to guard against a newly acquired iatrogenic paraphimosis. Generously apply a topical antibacterial ointment over the suture line and loosely cover it with a bandage of petrolatum gauze and gauze squares. Apply a piece of tape to hold the dressing on the penis. **The tape should not be applied circumferentially as this can cause ischemia to the penis.**

Should it be desired, a complete circumcision can be performed after the dorsal slit incision. Using two hemostats, make a series of crushing bites along the foreskin at the level of the coronal sulcus. **Use caution not to crush the skin on the shaft of the penis.** Using scissors, cut the foreskin along the crushed tissue. Approximate the wound edges using 3-0 or 4-0 chromic gut in an interrupted pattern. Carcinoma should always be considered as an etiology of a phimosis and all excised tissue sent to pathology for histologic evaluation.[18]

ALTERNATIVE TECHNIQUE

PREPUTIOPLASTY

The preputioplasty is an alternative surgical treatment to the more radical dorsal slit and circumcision. This tissue-sparing surgical technique can achieve full resolution of a phimosis. Although not typically performed in the Emergency Department, the preputioplasty is a conservative, less traumatic, and less invasive procedure. The procedure consists of one or more short longitudinal incisions which release the stenosis and they are then closed transversely allowing a widening of the phimotic ring and loosening of foreskin (**Figure 149-2**).[13]

Clean, prep, anesthetize, and prepare the penis as described previously. Retract the foreskin until it is completely proximal to the glans (**Figure 149-2B**). The phimotic ring will constrict the penile shaft (**Figure 149-2B**). Carefully make a superficial incision in the phimotic ring with a #15 scalpel blade or fine scissors (**Figure 149-2B**). The phimotic ring will open. Allow the wound to ooze for a few minutes. Close the wound using 3-0 or 4-0 chromic gut suture in an interrupted pattern (**Figure 149-2C**). Return the loosened foreskin over the glans (**Figure 149-2D**). Generously apply a topical antibacterial ointment over the suture line and loosely cover it with a bandage of petrolatum gauze and gauze squares. Apply a piece of tape to hold the dressing on the penis. **The tape should not be applied circumferentially as this can cause ischemia to the penis.**

ASSESSMENT

Regardless of the technique, observe the patient in the Emergency Department for 45 to 60 minutes to confirm hemostasis. Observe the patient for full recovery from any sedation or procedural sedation techniques as per hospital policy.

AFTERCARE

The patient may be discharged with Urologic follow-up within 48 hours. Instruct the patient to return to the Emergency Department immediately if the wound is red, has a discharge, is swollen, or if fever develops. The patient should be given oral analgesics for pain control. Patients should be discharged on oral antibiotics whose spectrum covers skin flora. Cephalexin, 500 mg orally four times a day, is usually adequate. Between discharge and examination by a Urologist, the patient should practice gentle daily washing of the penis with soap, avoid placing any powders or creams in the area, and check the wound three to four times daily for signs of infection. Sexual intercourse and masturbation should be avoided until the incisions have completely healed.

The dorsal slit procedure will result in a "beagle-ear" like deformity. While not problematic in most cases, it may increase the chance of getting the foreskin entrapped in a zipper. The Urologist will often perform an elective circumcision for cosmetic purposes.

COMPLICATIONS

Direct mechanical injury to the glans or urethra by inadvertent placement of instruments into the urethra could be devastating but is easily avoidable by following proper technique. Increased bleeding may result if the skin is not crushed by the hemostat before it is cut with the scissors.[5] It is also important to avoid advancing the clamp, and therefore the incision, beyond the comfortable limitation of the coronal sulcus. Otherwise, the skin on the penile shaft will be cut. This can result in a cosmetic defect and possibly skin sloughing requiring a skin graft. Lacerations to the penile shaft skin should be sutured with an absorbable suture.

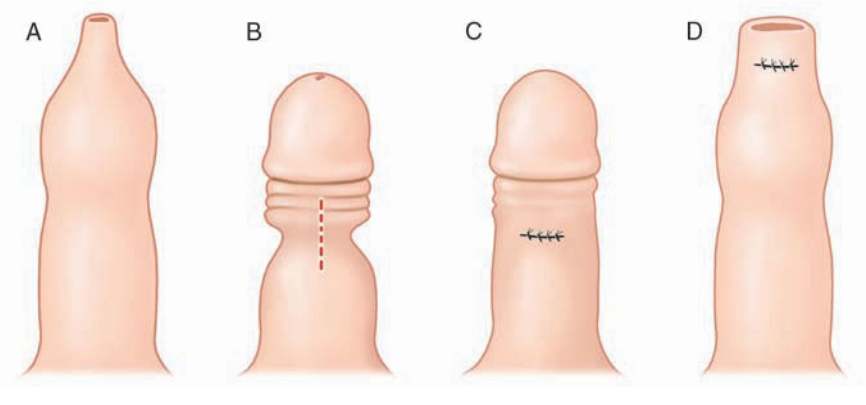


FIGURE 149-2. The preputioplasty. **A.** Penis with tight phimotic ring making it difficult to retract the foreskin. **B.** Foreskin retracted under anaesthetic with the phimotic ring or stenosis constricting the shaft of the penis and creating a "waist." The dotted line represents the vertical incision line. **C.** Incision closed laterally with interrupted sutures. **D.** Penis with the loosened foreskin replaced over the glans.

Wound infection and dehiscence are a possibility with any incision and greatly reduced in conscientious patients.

SUMMARY

From a variety of disease processes, the endpoint of a phimosis causing urinary obstruction lends itself to simple correction by the Emergency Physician. If there is not complete urinary obstruction, a trial of topical corticosteroids is simple, cost effective, and may result in the resolution of the phimosis. Careful performance of the described techniques will result in an excellent functional and aesthetic foreskin repair.

150 Dorsal Slit of the Foreskin

Carlos J. Roldan

INTRODUCTION

Acute conditions affecting the foreskin that must be recognized in the Emergency Department include a phimosis and a paraphimosis. The Emergency Physician must be able to accurately identify and manage these conditions as well as recognize when an urgent Urology consultation is necessary. A dorsal slit of the foreskin can be performed primarily in the Emergency Department. This technique is used to relieve strangulation of the glans by a paraphimosis or to aid in the visualization of the urethral meatus in patients with a phimosis.[1] The techniques are easy to learn and simple to perform.

ANATOMY AND PATHOPHYSIOLOGY

The prepuce, or foreskin, is the skin originating just proximal to the corona that encircles the glans and often extends beyond it.[2] It may be incomplete, primarily at the ventral midline or the frenulum. The frenulum is the fusion site of the preputial and urethral folds. The glans is composed of the corpus spongiosum that enlarges to cover the tips of the corpora cavernosa. It has less erectile tissue than the corpora cavernosa and contains the urethra.[2]

The blood supply to the foreskin and glans is provided by the left and right superficial penile arteries. The arteries are derived from the inferior external pudendal arteries, which are branches of the femoral arteries. The penile arteries travel in the superficial fascia of the penis and above Buck's fascia.[3] The left and right superficial penile arteries freely communicate over the midline. Superficial veins accompany the arteries and ultimately drain to the saphenous veins in the thighs. The lymphatics travel deep to Buck's fascia and ultimately empty into the inguinal chain of lymph nodes. The somatic nerves to the foreskin are derived from the pudendal nerves.[4]

A dorsal slit is performed to reduce a paraphimosis or phimosis when other less invasive techniques are unsuccessful. A paraphimosis is the inability to replace the retracted foreskin over the glans into its naturally occurring position. It is considered an emergency since prolonged retraction of the foreskin creates a constricting ring that quickly compromises vascular and lymphatic circulation with eventual engorgement and necrosis of the glans and foreskin. A phimosis is the inability to retract the distal foreskin over the glans penis.[5,6] Once the foreskin can be retracted so that the glans penis partially appears, a phimosis is no longer present. A more detailed description of the anatomy and pathophysiology of the penis, a paraphimosis, and a phimosis can be found in Chapters 148 and 149.

INDICATIONS

A dorsal slit of the foreskin should be performed to release a paraphimosis or a phimosis if noninvasive and lesser invasive techniques are unsuccessful. A paraphimosis is considered an emergency since prolonged retraction of the foreskin leads to swelling of the prepuce resulting in strangulation injury to the glans.[1] A phimosis should be released if it causes urinary retention. The phimotic foreskin should not be forcibly retracted as this can result in a tearing of the foreskin.

CONTRAINDICATIONS

There are no absolute contraindications to the reduction of a paraphimosis. A dorsal slit in children should be performed by a Pediatric Urologist, a Urologist, or after consultation with a Urologist. A dorsal slit for the relief of a paraphimosis should be performed only after noninvasive and lesser invasive techniques have been unsuccessfully attempted (Chapter 148).[7–9]

The ability to pass a urinary catheter (i.e., Foley, coudé, filiforms, and followers) into the bladder eliminates the acute need for reduction of a phimosis. Refer to Chapter 142 for the complete details regarding the techniques of urethral catheterization. Patients with bleeding disorders, gross infections of the foreskin, who are immunocompromised, or who have lesions of the foreskin should have a urinary catheter placed into the bladder rather than an incision of the phimotic foreskin if possible. If a catheter cannot be inserted into the urethra in these patients, a Urologist should be consulted prior to any invasive procedures. Patients with a nonobstructing phimosis should be considered for topical corticosteroids and referred for elective circumcision and not have a dorsal slit procedure.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Local anesthetic solution without epinephrine
- 5 mL syringe
- 27 gauge needle
- Hemostats, straight or straight Kelly
- #15 scalpel blade on a handle
- Needle driver
- 3-0 or 4-0 chromic catgut, Dexon, or Vicryl
- Petrolatum gauze
- Metzenbaum scissors
- Suture scissors
- 4 × 4 gauze squares
- Sterile gloves
- Sterile drapes
- Topical antibacterial ointment

The use of tissue glue of the type normally found in Emergency Departments has been studied in children undergoing circumcision.[11] It was shown to increase infection, bleeding, and wound dehiscence when compared to suture. The use of suture must be recommended at this time to close the wound edges after the release of a paraphimosis or a phimosis.

PATIENT PREPARATION

Explain the benefits, risks, potential complications, and aftercare of the procedure to the patient and/or their representative. An informed consent should be obtained and placed in the medical record.

Prepare the penis for any intervention. Clean the penis of any dirt, debris, and discharge. Apply drapes to isolate the penis. Apply povidone iodine or chlorhexidine solution onto the penis. If possible, apply the solution under the foreskin using a cotton-tipped applicator if necessary. If the patient has pain in the area of the foreskin, or if a procedure other than catheter insertion is to be performed, the penis should be anesthetized. Refer to Chapter 146 for the complete details regarding penile anesthesia. Alternatively, infiltration of local anesthetic solution can be used to anesthetize the foreskin. Draw up 5 mL of local anesthetic solution without epinephrine into a syringe armed with a 27 gauge needle. Inject a subcutaneous wheal of local anesthetic solution 2 cm proximal to the distal end of the foreskin. Continue subcutaneous infiltration circumferentially around the penis with the local anesthetic solution. The patient may require intravenous sedation or procedural sedation (Chapter 129) prior to the injection of local anesthetic solution into the penis.

The use of topical anesthetics such as lidocaine jelly, prilocaine creams, or combinations (EMLA, LET, and LAT) is not recommended.[10] The application of these mixtures requires an occlusive dressing and 60 to 90 minutes for the anesthetic effect, which may then be inadequate. Their use will also delay the performance of the procedure.

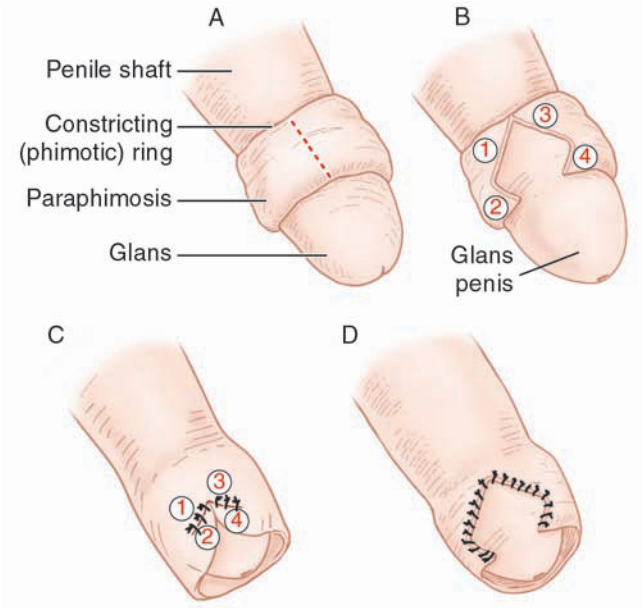


FIGURE 150-1. Dorsal slit of the paraphimotic foreskin. **A.** The dotted line represents the incision line. **B.** The foreskin opens after the incision is made. The numbers represent the edges of the incision. **C.** The foreskin has been reduced and the edges of the incision sewn shut. A small gap should remain in the midline that is free of sutures. **D.** Alternatively, sew the edges closed with a simple running stitch.

TECHNIQUES

DORSAL SLIT OF THE PARAPHIMOTIC FORESKIN

One must always be prepared to perform surgical techniques if nonsurgical reduction is unsuccessful. This technique involves the incision of the phimotic ring under strict aseptic technique.[12,14,15] Place the patient supine and anesthetize the penis, if it has not been done previously. Apply povidone iodine or chlorhexidine to the penis and let it dry. Apply sterile drapes to isolate a surgical field. Consider the administration of parenteral sedation prior to performing this procedure to alleviate the patient's anxiety.

Clamp a straight-blade hemostat over the foreskin and phimotic ring at the 11 o'clock and 1 o'clock positions. Place one jaw of each hemostat beneath the phimotic ring and the other jaw on top of it. **Be careful not to clamp the skin on the shaft of the penis.** Pull the foreskin taut between the hemostats. Grasp the hemostats with the nondominant hand or have an assistant hold them. Incise the foreskin and phimotic ring at the 12 o'clock position with a scissors or #15 scalpel blade (**Figure 150-1A**). **Be careful not to cut the skin on the shaft of the penis.** Remove the hemostats. The incision will open into a pentagonal shape (**Figure 150-1B**). Reduce the foreskin over the glans. Cover the penis with sterile gauze and allow the edges of the incision to ooze for 10 to 15 minutes.

This technique can be technically difficult for the non-Surgeon. As an alternative to the two-hemostat technique, a one-hemostat technique may be performed. Place one hemostat over the foreskin and phimotic ring at the 12 o'clock position (**Figure 150-1A**). Remove the clamp after 1 to 2 minutes. Cut the crushed tissue with scissors through the phimotic ring. **Be careful not to cut the skin on the shaft of the penis.** The foreskin will then open up as described (**Figure 150-1B**). Once the incision is made bloody edematous fluid will ooze out and this can be sponged. Reduce the foreskin over the glans. A total reduction of paraphimosis has to be accomplished to obtain satisfactory results. Cover the penis with sterile gauze and allow the edges of the incision to ooze for 10 to 15 minutes.

After the foreskin has been incised and reduced over the glans, approximate the cut edges with 3-0 chromic suture using a simple interrupted stitch (**Figure 150-1C**). Sew edge 1 and edge 2, on the illustration, together. Sew edge 3 and edge 4, on the illustration, together. A gap will remain at the 12 o'clock position that corresponds to the area of the initial incision. Alternatively, sew the cut edges with a simple running stitch (**Figure 150-1D**). Loosely apply petrolatum gauze and gauze squares over the wound. Apply a piece of tape to hold the dressing on the penis. **The tape should not be applied circumferentially as this can cause ischemia to the penis.**

MODIFIED DORSAL SLIT OF THE PARAPHIMOTIC FORESKIN

A modified dorsal slit technique has been described where only the phimotic ring is cut rather than the entire foreskin.[12,13] Clean, prep, anesthetize, and drape the penis as described previously. A penile block is the preferred method of anesthesia because injection onto the distal penis is extremely painful. As an alternative to a penile block, infiltrate under the phimotic ring at the 12 o'clock position with local anesthetic solution without epinephrine using a 27 gauge needle. Be sure to raise a wheal both proximally and distally to the phimotic ring (along the dotted line in **Figure 150-2A**).

Incise the phimotic ring with a #15 scalpel blade. **Incise only the phimotic ring. Do not extend the cut more than 3 mm proximally or distally to the phimotic ring.** Once incised, the foreskin will spring open into a diamond-shaped defect (**Figure 150-2B**). Reduce the fore-skin. Cover the penis with gauze and allow the cut edges to ooze for 10 to 15 minutes to decompress the foreskin. Approximate the edges of the wound with 3-0 chromic suture in an interrupted

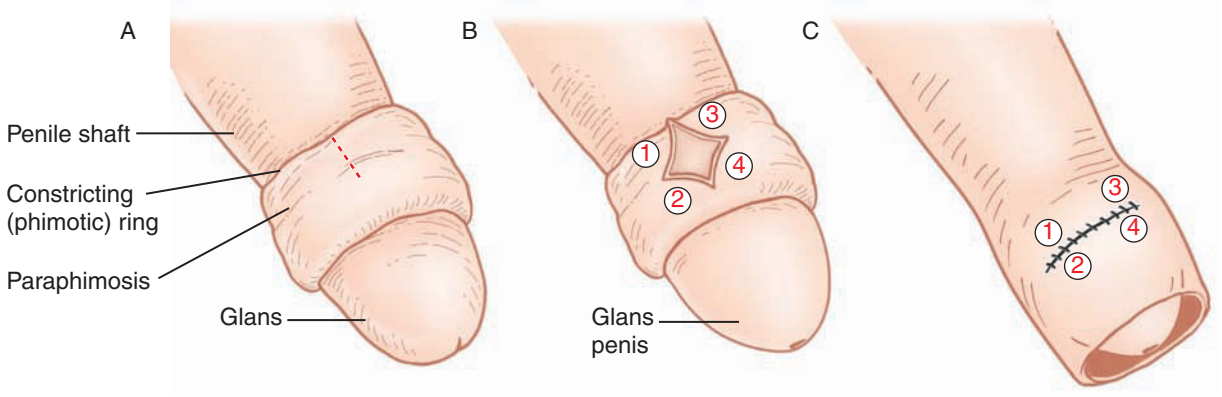


FIGURE 150-2. Modified dorsal slit of the paraphimotic foreskin. **A.** The dotted line represents the incision line. **B.** The foreskin opens after the incision is made. The numbers represent the edges of the incision. **C.** The foreskin has been reduced and the edges of the incision sewn shut.

or running pattern (**Figure 150-2C**). Apply a bandage of petrolatum gauze and gauze squares over the wound. Apply a piece of tape to hold the dressing on the penis. **The tape should not be applied circumferentially as this can cause ischemia to the penis.**

DORSAL SLIT OF THE PHIMOTIC FORESKIN

The preferred method to correct an obstructing phimosis in the Emergency Department setting is the dorsal slit procedure. The patient's penis should be thoroughly anesthetized prior to performing this procedure. Consideration should also be given to administering intravenous analgesics, intravenous sedation, or procedural sedation.

Insert the bottom jaw of a straight hemostat between the foreskin and glans at the 12 o'clock position (**Figure 150-3A**). For those individual patients or cultural situations where dorsal incision of the foreskin, much less excision, is cosmetically unacceptable, a ventral approach may be substituted which will yield an apparently uncircumcised penis without obstructive symptoms.[12] Advance the hemostat until the tip of the jaw is at the coronal sulcus (**Figure 150-3A**). The coronal sulcus is where the foreskin attaches to the penis. Depending on the cause of the phimosis, adhesions may be encountered. These should be gently broken as the hemostat is advanced. The skin of the prepuce is relatively thin and the jaw of the hemostat should be easily palpated. The tip of the jaw should be seen to tent the skin at the coronal sulcus when properly placed (**Figure 150-3B**). **It cannot be overemphasized that the physician must be confident that the instrument has not been inadvertently placed in the urethra. If the jaw of the hemostat cannot be felt and cannot be seen tenting the skin of the foreskin, remove the hemostat and reinsert it.**

Once properly placed, close the hemostat. Allow the hemostat to remain closed for 2 to 3 minutes to crush the skin. Remove the hemostat. Insert a scissors and advance it with the same attention to position the tip at the coronal sulcus. Incise the crushed tissue to the level of the coronal sulcus (**Figure 150-3C**). If straight scissors are not available, a #15 blade may be used to cut the crushed skin after another instrument is placed underneath the foreskin to protect the glans from injury. **This method of using a scalpel blade is dangerous and not recommended because control is reduced and the potential for error is unnecessarily increased.**

Retract the cut foreskin. This will leave an open wound edge on both sides of the midline (**Figure 150-3D**). Cover the penis with gauze and allow the cut edges to ooze for 10 to 15 minutes. Approximate the open wound edges using 3-0 or 4-0 chromic gut suture in an interrupted or running pattern. Begin suturing from the midline to the distal end of the incision (**Figure 150-3E**).[12] Return the foreskin to its "resting" position to guard against a newly acquired iatrogenic paraphimosis. Apply a bandage of petrolatum gauze and gauze squares over the wound. Apply a piece of tape to hold the dressing on the penis. **The tape should not be applied circumferentially as this can cause ischemia to the penis.**

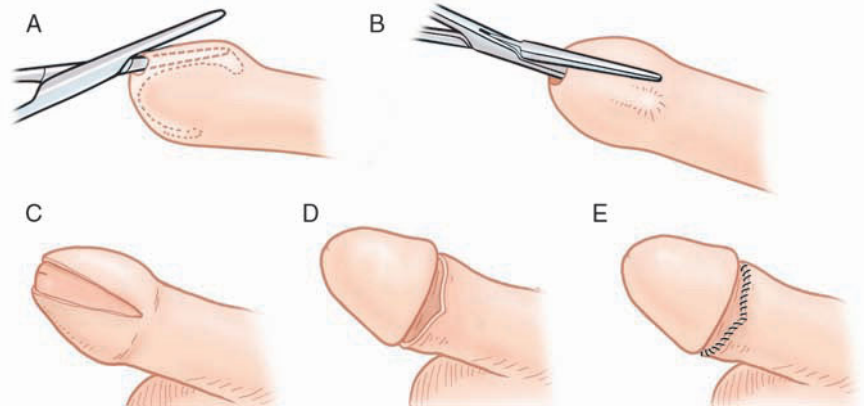


FIGURE 150-3. Dorsal slit of the phimotic foreskin. **A.** A hemostat is inserted under the foreskin and advanced to the coronal sulcus. **B.** The hemostat is elevated to tent the skin and confirm it is properly placed. **C.** The dorsal slit has been made. **D.** The foreskin is retracted. **E.** Interrupted sutures have been placed in the cut edges of the foreskin.

ASSESSMENT

The foreskin should now be retractable to a sufficient degree to allow visualization of the meatus (when performed for a phimosis) or reduced over the glans to relieve pressure (when performed for a paraphimosis). The successfully reduced paraphimosis should have the general appearance of a normal uncircumcised penis. It is normal for residual edema to be present. Reassure the patient that the edema will spontaneously resolve over hours to days. Observe the patient in the Emergency Department for 45 to 60 minutes to confirm hemostasis. Observe the patient for full recovery from any sedation or procedural sedation techniques as per hospital policy.

AFTERCARE

Wound care following a surgical reduction is the same as that for any sutured laceration. Many physicians do not dress the incision site. But if desired, it may be covered with antibiotic ointment or petrolatum gauze and dry sterile gauze.[10] The patient should be counseled on proper wound care. The patient should inspect the glans and foreskin three to four times a day. They should return immediately to the Emergency Department if any signs of infection develop. They should also be advised to avoid intercourse or masturbation for 4 to 6 weeks.[10]

Antibiotics should be prescribed that cover gram-positive organisms. An extended-spectrum penicillin or first-generation cephalosporin is most frequently prescribed. Cephalexin, 500 mg orally four times a day, is usually adequate.

All patients need to follow up with a Urologist in one or two days. The definitive treatment is circumcision, which is typically delayed 7 to 10 days until any edema, inflammation, or ulceration has resolved.[14,15]

COMPLICATIONS

Direct mechanical injury to the glans or urethra by inadvertent placement of instruments into the urethra could be devastating but is easily avoidable by following proper technique. Increased bleeding may result if the skin is not crushed by the hemostat before it is cut with the scissors. It is also important to avoid advancing the clamp, and therefore the incision, beyond the comfortable limitation of the coronal sulcus. Otherwise, the skin on the penile shaft will be cut. This can result in a cosmetic defect and possibly skin sloughing requiring a skin graft. Wound infection and dehiscence are a possibility with any incision and greatly reduced in conscientious patients. Bleeding is a common complication in this very vascular tissue. Venous bleeding can be profuse and it is important to have good control of the tissue edges so that adequate hemostatic stitches can be placed. A compressive dressing may aid in hemostasis. If the penile shaft is lacerated during a surgical reduction, it too should be sutured. And, as with all invasive procedures, infection may be a complication.

SUMMARY

A dorsal slit is an easy and rapid way to relieve strangulation pressure from a paraphimosis or to allow visualization of the urethral meatus from an obstructing phimosis. This procedure is performed primarily in emergency situations as the cosmetic result is usually suboptimal. Patients with a phimosis who are able to void should be referred to a Urologist before performing a dorsal slit. The dorsal slit procedure should only be performed when a phimosis is obstructing and a urethral catheter cannot be placed. A paraphimosis is always an emergency. Often this will reduce with less invasive techniques that should be attempted first. Severe cases will require a dorsal slit.

151 Manual Testicular Detorsion

Steven Go

INTRODUCTION

First described in the English literature by Rigby and Howard in 1907, testicular torsion occurs when the testicle turns around its axis, forcing its blood supply to twist, thereby causing vascular compromise of the testicle (**Figure 151-1**).[1] Testicular torsion is a time-sensitive emergency that demands the Emergency Physician to act swiftly to preserve the testicle. **Testicular torsion is a clinical diagnosis and the primary goal is surgical detorsion in the operating room.** If testicular torsion is strongly suspected clinically, consult a Urologist immediately for a bedside evaluation. Manual detorsion can be attempted while awaiting more definitive surgical intervention.

The incidence of testicular torsion is believed to be approximately 1 in 4000 in males less than 25 years of age.[2] It is primarily a condition that affects the young with a bimodal distribution in the neonatal period and the early teens.[3] Most cases occur in patients less than 21 years of age.[4] Age should not be considered when making the diagnosis, however, as torsion may occur in the antenate, neonate, adult, or geriatric patient.[5–7]

Testicular torsion typically presents with acute or insidious onset of excruciating, usually unilateral testicular and/or scrotal pain. There is a slight predilection for the left testicle.[2] Cases of bilateral torsion can also occur.[8] Torsion may be associated with a history of a recent episode of genital trauma.[9] The patient is often awaken from sleep by the pain. Associated symptoms may include nausea, vomiting, and a low-grade fever.[10] A history of a prior orchiopexy (surgical fastening of the testicle) does not exclude the possibility of torsion.[11]

Physical examination of these patients typically reveals testicular pain to palpation and a painful, edematous scrotum. The testicle may be high-riding with a horizontal lie and anterior rotation of the epididymis.[12] A cremasteric reflex is typically absent but can be present in some cases. Lack of a cremasteric reflex has only a 88.2% sensitivity for torsion.[13–15] Prehn's sign, or the relief of pain with elevation of the scrotum, is classically present in epididymitis and absent in torsion. Unfortunately, Prehn's sign is an imperfect discriminator.[16–18] Bedside Doppler ultrasound stethoscope studies can be misleading, even if flow is heard.[19] Scrotal blood flow can

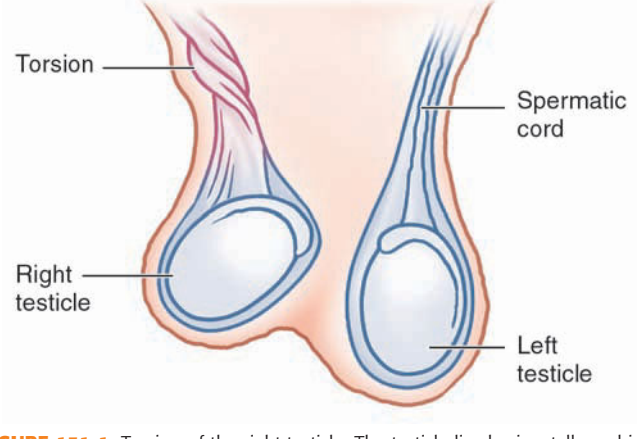


FIGURE 151-1. Torsion of the right testicle. The testicle lies horizontally and in a higher position than the normal testicle.

be erroneously interpreted as testicular blood flow.[19] If flow is not heard, however, one can assume torsion is present.

Color Doppler ultrasonography has largely replaced testicular radionuclide scintigraphy for the confirmation of torsion because of its greater availability, lower cost, and lack of adverse effects. However, two points must be emphasized. **In a patient where torsion is strongly suspected, emergent bedside consultation with a Urologist should not be unduly delayed for the performance of or the results of a radiological study**. This point becomes even more critical the longer the symptoms have been present. Color Doppler ultrasonography has a reported sensitivity for torsion of only 85.7% to 90%.[20–23] **If torsion is suspected and no other competing diagnosis can be definitively confirmed by color Doppler ultrasonography, the patient should still be emergently evaluated by a Urologist.**

The differential diagnosis of the acutely swollen or painful scrotum also includes torsion of the testicular appendage, epididymitis, orchitis, hernia, varicocele, tumor, trauma, idiopathic scrotal edema, fat necrosis, viral inflammation, and Henoch–Schönlein purpura. **As testicular torsion is the diagnosis requiring the most urgent action, it should be first on the differential diagnosis list.** Testicular torsion may result in irreversible damage to the involved testis. It may also affect the contralateral testicle. Recent studies have examined the possible immunologic mechanism for this global effect on fertility but the exact pathophysiology has not been established.[24,25]

ANATOMY AND PATHOPHYSIOLOGY

The testicle is covered by the tunica albuginea, followed by the visceral layer of the tunica vaginalis. The parietal layer of the tunical vaginalis partially encloses both the testicle and the epididymis. The testicular (spermatic) artery acts as the primary blood supply to the testicle and traverses the spermatic cord. Venous drainage is supplied by the pampiniform plexus within the spermatic cord. The above structures, as well as the vas deferens, are enveloped by the cremaster muscle and fascia.

Testicular torsion may be classified as extravaginal or intravaginal.[26] Extravaginal torsion occurs primarily in neonates. The testis, epididymis, and tunica vaginalis twist together on their vertical axis because the gubernaculum has not yet become attached to the scrotal wall. It is thought to be caused by the free rotation of the testicle around the spermatic cord at a level above the tunica vaginalis.[15,27] Intravaginal torsion occurs in peri- or postpubertal males and has been associated with the so-called bell-clapper deformity. In the normal scrotum, the tunica vaginalis only partially covers the epididymis and does not cover the spermatic cord. In the bell-clapper deformity, the tunica vaginalis encases the entire testicle, epididymis, and base of the spermatic cord. This allows the contents to twist and move within the tunica vaginalis as a bell-clapper does within a bell.[26] Both intravaginal and extravaginal torsion usually occur in a medial or inward fashion.

Testicular torsion results in the obstruction of the blood supply to the testis. The venous obstruction leads to edema. This is followed by arterial obstruction that leads to testicular ischemia. Because the degree of torsion or vascular compromise cannot be quantified by current methods, the time for torsion to result in irreversible testicular damage cannot be determined.[26] A complete vascular occlusion will cause a testicle to develop permanent and irreversible damage earlier than a testicle with partial vascular occlusion. The literature is variable and cites a range of 6 to 24 hours of vascular occlusion required to cause irreversible ischemic damage to a testicle. Most authors agree that the best outcomes are obtained with detorsion within 6 hours of symptom onset.[26] Incomplete torsions exist and some blood flow to the testicle may be preserved. **Therefore, a testicle should not be assumed to be nonviable based upon the time of suspected onset alone.**

The definitive therapy for a torsed testicle is surgery. There is agreement that, at the time of surgery, a necrotic testicle should be removed and a pink, healthy appearing testicle should be left in place. The question remains of what to do with those testicles whose viability is not clear at the time of surgery. Current recommendations are to remove an obviously necrotic testicle or a testicle that stays cyanotic after detorsion; but leave in place any testicle which appears viable.[28,29]

Research has addressed the issue of immunology and future fertility post-torsion. The blood-testicle barrier has been well established. The theory exists that ischemic damage to the torsed testicle breaks down the blood-testicle barrier allowing the body to produce autoantibodies that attack the contralateral testicle.[25] Another theory has proposed that abnormal or subfertile testicles are more likely to torse and that these differences in fertility may have predated the torsion.[30,31] These subfertile changes may resolve within several months after orchiectomy of the torsed testicle.[24] Studies in sperm-producing rodents have found evidence of immunologic damage to the contralateral testicle after torsion, especially if the torsed testicle is allowed to remain torsed for more than 24 hours.[24,25] These studies and others seem to support the theory of immunologic damage after ischemia.

INDICATIONS

The Emergency Physician should attempt manual reduction of a torsed testicle while awaiting the arrival of the Urologist.[32] **An attempt should be made to manually reduce all suspected testicular torsions while awaiting the arrival of the Urologist.[32]** If reduced within 6 to 8 hours of the start of symptoms, the survival rate of the testicle after manual detorsion is near 100%.[32] After 8 hours, the risk of testicular atrophy increases but the testis may still be salvageable; especially if the vascular obstruction is incomplete. Successful manual detorsion after longer periods of time becomes difficult due to edema formation. **However, due to the lack of significant complications, manual detorsion should be attempted regardless of the length of symptoms as long as it does not delay definitive surgical management.**

CONTRAINDICATIONS

There are no absolute contraindications to attempt to manually reduce a testicle that is torsed. There are, however, some situations in which it might not be warranted. If the testis has become fixed to the scrotal wall, it may be necrotic and detorsion outside of the Operating Room is not possible.[32] If the Operating Room and Surgeon are available, an attempt at manual detorsion might delay definitive repair. If the degree of swelling and/or pain preclude the examiner from applying firm pressure on the testicle, detorsion might not be possible. If the clinical picture suggests another cause for the patient's symptoms and the suspicion for a testicular torsion is very low, a radiologic study (i.e., testicular scan or Doppler ultrasound) might be warranted prior to an attempt at detorsion. If the testicle has been torsed for more than 24 hours, orchiectomy without detorsion might help to preserve fertility in the contralateral testicle.[25] However, this has not been sufficiently confirmed and is not currently recommended.

EQUIPMENT

No equipment is required to manually detorse a testicle. However, as the testicle is tender and the procedure is bound to be painful, consider the judicious administration of parenteral analgesia, sedation,

or procedural sedation (Chapter 129). The use of a Doppler stethoscope or color Doppler ultrasound to assist with the diagnosis and determination of a successful detorsion is helpful but not required.

PATIENT PREPARATION

Explain the procedure to the patient and/or their representative. Explain that the procedure will be quick but painful. Explain that giving medicine to relieve the pain may interfere with the determination of success. Inform the patient that there are no risks to attempting to manually reduce the torsed testicle. Potential complications include continued pain, increased pain, and the inability to detorse the testicle. No matter what result is obtained with manual detorsion, an operation will be necessary prior to discharge to prevent future episodes of torsion.[10] If manual detorsion is unsuccessful, emergent operative intervention may be required. Therefore, the patient should be kept *non per os* (NPO).

The use of anesthesia is not absolutely contraindicated. It may be required depending on the patient's age, ability to cooperate, and the examiner's preference. The use of a spermatic cord block should be avoided as it interferes with the patient's ability to assess pain and the determination of a successful detorsion.[30] The injection of local anesthetic solution into the spermatic cord may further compromise testicular blood flow.[31] Options for pain relief, when required, include procedural sedation (Chapter 129), intravenous analgesics, and/or intravenous sedatives.

TECHNIQUE

The direction of most torsions has been described as inward or medial, but they can also be outward or lateral.[10] This rotational predilection explains why the initial detorsion attempt should be in an outward or lateral direction (**Figure 151-2**). This has also been described as "detorse as you would open a book" or "supinate the hand as the testicle is rotated."[30] Another way to think of it is if you are looking at the patient from the foot of the bed. Rotate the patient's right testicle counter clockwise and the patient's left testicle clockwise (**Figure 151-2**).

Place the patient semirecumbent or supine. Stand next to the patient. Place the dominant hand on the patient's torsed testicle. Grasp the spermatic cord with the other hand to stabilize it from moving. Grasp the testicle gently but firmly. Rotate the testicle within the scrotum 180° outward (**Figure 151-2**). **There should be no resistance to the rotation.** While some authors have maintained the need to rotate the torsed testicle in two planes[33] (caudal to cranial and medial to lateral), others have reported success with single plane rotation.[26]

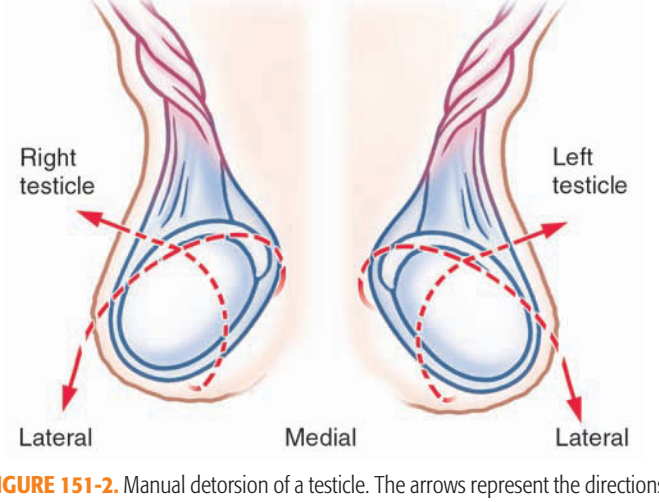


FIGURE 151-2. Manual detorsion of a testicle. The arrows represent the directions to initially attempt to rotate the testicle.

The average degree of torsion has been cited as 720°. It can range from 180° to 1080°.[10] **Continue to detorse the testicle until the patient experiences pain relief and the normal scrotal anatomy is restored.**[26] If at any point in the procedure the patient experiences an increase in pain or there is resistance to rotating the testicle, stop and attempt to detorse the testicle in the opposite direction.[32] Occasionally, a testicle may be torsed outward or laterally.

ASSESSMENT

Successful detorsion is marked by both the sudden relief of pain and the restoration of the normal scrotal anatomy. The normal anatomy is indicated by a lengthening of the spermatic cord and a vertical lie of the testicle.[33] If available, a Doppler stethoscope or color Doppler ultrasound may be used to monitor the effects of the detorsion. The resolution of edema will depend on the degree and duration of ischemia, but will not be as immediate as the pain relief. If the patient has relief of pain but the testicle is still high riding or horizontal, continue to detorse the testicle in the same direction until there is complete pain relief and a return of the normal scrotal anatomy.

AFTERCARE

All patients with a diagnosis of testicular torsion should be admitted to the hospital with an emergent Urological consultation. This is true despite a successful manual detorsion. The timing of the operative intervention will be changed from emergent to urgent if the testicle is detorsed in the Emergency Department.[32,34,35] Urgent surgery is still required because, even with pain relief, the torsion may not have been completely reduced. One study found evidence of continued torsion with venous congestion even after successful manual detorsion. Following testicular torsion, the patient must undergo bilateral orchiopexy. **The bell-clapper deformity that is implicated in many testicular torsions is almost always bilateral.[15] Therefore, the contralateral testicle is at increased risk for torsion.**

COMPLICATIONS

There are few complications to manual detorsion and none that should deter the Emergency Physician from an attempt at detorsion should it be indicated. The procedure is painful and detorsion in the wrong direction will initially increase the patient's discomfort. There is also the possibility that, despite proper technique, the Emergency Physician will be unable to detorse the testicle and emergent surgery will be required. If it turns out that testicular torsion is not the correct diagnosis, the patient will have endured an uncomfortable procedure without gain. While detorsion in the wrong direction may temporarily increase the degree of vascular compromise, it should cause no increase in ischemia if detorsed in the opposite direction. Complications may also arise from a delay in notification of the Urologist.[30]

A more serious potential complication stems from the false sense of security obtained when the patient has pain relief. Manual detorsion may only partially restore blood flow and rapid surgical intervention may still be required. Delaying the trip to the Operating Room due to lack of pain may cause "castration by procrastination."[30]

Due to the risk of impaired fertility after torsion, all efforts must be undertaken to preserve the contralateral testicle and future fertility. Animal studies suggest that detorsion of an ischemic testicle

can cause neurohormonal-mediated damage to the contralateral testicle.[36,37] However, these theories remain controversial and should not be used to justify not attempting a manual detorsion.[15,38]

SUMMARY

Emergency Physicians must be aware of the possibility and urgency of a testicular torsion. They should be prepared to rapidly attempt manual detorsion since "time is testicle." Early notification of the Urologist is essential as the ischemia time and testicular salvage are inversely proportional. Manual detorsion should be attempted on all patients as it may successfully relieve or reduce the ischemia, increasing testicular survival and future fertility. All patients with testicular torsion should receive definitive therapy and repair in the operating room to prevent future episodes of torsion.

152 Zipper Injury Management

Zach Kassutto

INTRODUCTION

Zipper injuries frequently occur to the foreskin, the skin of the penis, and the scrotum. Zipper injuries result in skin and soft tissue entrapment when the zipper is opened or closed. It primarily occurs in uncircumcised young boys, intoxicated adults, the mentally handicapped, males not wearing underwear, and elderly men suffering from movement or cognitive disorders. The most common type of zipper entrapment compresses the skin between the sliding piece (fastener mechanism) and the teeth of the zipper. Another type of entrapment involves the skin between the teeth of the zipper after the sliding piece has moved beyond the area.[1,2] Multiple methods to extract the entrapped skin have been reported.[1–15] These methods range from manipulation to tooth-by-tooth extraction to circumcision. Treatment should be guided by the type of entrapment.[1] Removal of the zipper can be performed quickly using basic tools to extract the entrapped tissue and thus prevent or limit secondary injury.

ANATOMY AND PATHOPHYSIOLOGY

The zipper is a simple device that is used daily by millions of people (**Figure 152-1**). It consists of a sliding piece that moves in two directions. The sliding piece is composed of a front and back plate connected by the median bar.[5] The median bar is usually located at the top of the sliding piece. A finger grip is attached to the front plate of the sliding piece and functions as a handle to move the sliding piece. The teeth are two opposing sets of rectangular metal or plastic pieces attached to fabric to keep them aligned. Moving the sliding piece across an open zipper will interlock the teeth and close the zipper. Reversing the sliding piece direction will unlock the teeth and open the zipper.

Although any area of skin can become entrapped in a zipper, it primarily occurs to the foreskin, penis, and scrotum. Entrapment often occurs in those who are in a rush to get dressed, not wearing underwear, or intoxicated, or in a rush to zip up their pants. Zipper injuries can be extremely painful. Patients are often unable to undo the entrapment themselves and present to the Emergency Department for help. Because this is an embarrassing injury, patients often present after attempts at self-extraction and a few hours after the injury. Delays in seeking medical care may result in significant edema that can complicate the removal of the entrapped tissue.

INDICATIONS

Skin entrapped between the sliding piece and teeth or between the teeth of the zipper must be extricated. The skin should be released as soon as possible to minimize edema and prevent necrosis.

CONTRAINDICATIONS

There are no absolute contraindications to the removal of a zipper, the slider, or the teeth from an entrapped piece of skin. Consult a Urologist after releasing the entrapment in cases of significant edema, skin necrosis, urethral involvement, or infection.

EQUIPMENT

- Heavy-duty wire cutter or bone cutter
- Scissors, bandage or Mayo
- Scissors, small or iris
- Topical anesthetic, e.g., EMLA cream
- Local anesthetic solution without epinephrine
- Mineral oil
- Miniature hacksaw
- 27 gauge needle
- 5 mL syringe

PATIENT PREPARATION

Explain the procedure and aftercare required to the patient and/or their representative. Obtain appropriate consent to perform the procedure. Assess the patient's level of anxiety and pain as

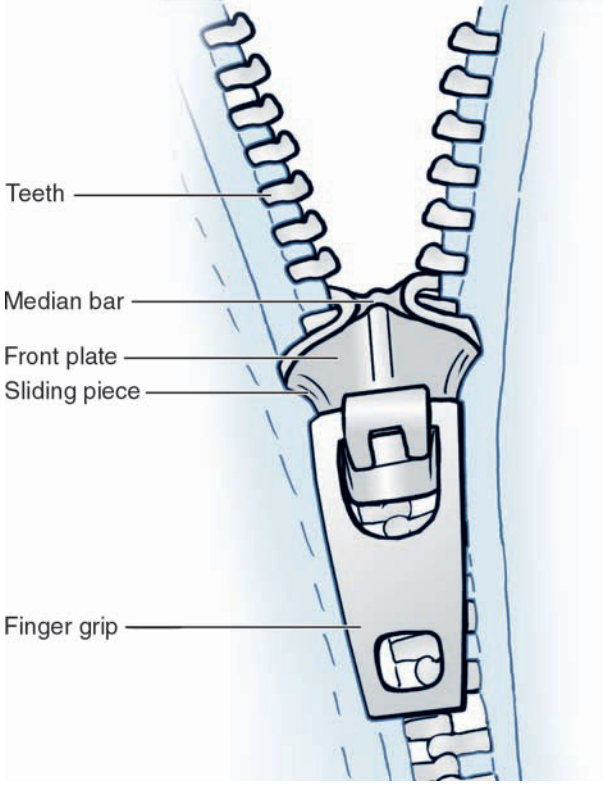


FIGURE 152-1. Anatomy of a zipper.

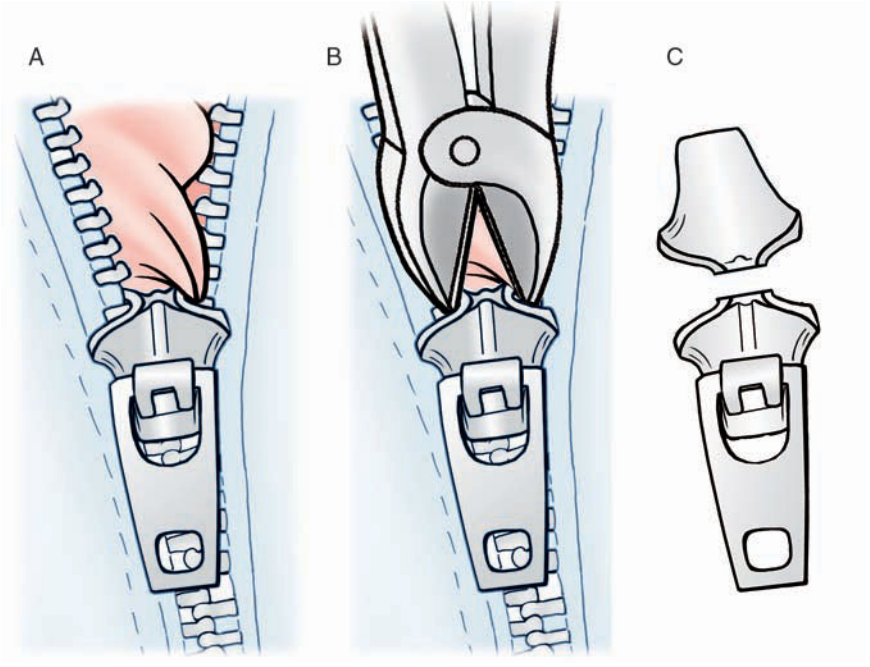


FIGURE 152-2. Cutting the median bar of the zipper. **A.** Skin entrapped between the sliding piece and the teeth. **B.** The median bar is cut. **C.** The front and back plates separate after the median bar is cut and the skin is released.

they must remain calm during the procedure to avoid secondary injury. The application of a topical anesthetic such as EMLA cream may be helpful but delays extraction of the entrapped skin. If the patient has significant pain, local anesthetic solution can be subcutaneously infiltrated around the entrapped skin or a penile block (Chapter 146) can be performed. The application of parenteral analgesia, sedation, or procedural sedation may be required in rare instances.

TECHNIQUES

MANUAL REMOVAL

Apply mineral oil liberally to the zipper and entrapped skin. Allow the mineral oil to soak the skin and zipper for approximately 10 minutes. Apply gentle but steady traction on the zipper, away from the entrapped tissue with special care to avoid further injury.[9,14,15] Attempt to dislodge the zipper manually. **Do not forcefully try to unzip it. Excessive force is unnecessary and can result in avulsions and lacerations to the skin.** If this fails to release the tissue, perform one of the zipper disassembly techniques listed below.

CUTTING OF THE MEDIAN BAR

The median bar can be cut with a heavy-duty wire cutter or bone cutter.[6,7] If the skin is entrapped between the sliding piece and the teeth (**Figure 152-2A**), carefully cut the median bar (**Figure 152-2B**). The front and back plates of the zipper will separate and release the entrapped skin (**Figure 152-2C**). Occasionally, the skin is entrapped between the teeth of the zipper (**Figure 152-3**). Cut the median bar of the sliding piece to remove the zipper. Manually pull the two rows of teeth apart to release the entrapped skin.

CUTTING OF THE CLOTH SURROUNDING ZIPPER TEETH

Occasionally, the skin is trapped between the teeth of the zipper and a wire cutter or bone cutter is not available.[8] Cut the cloth holding the zipper to the clothes with a bandage or Mayo scissors (**Figure 152-4**, long dashed lines). Using a small or iris scissors, cut the cloth between the individual teeth that are entrapping the skin (**Figure 152-4**, small dashed lines). Separate the teeth and free the entrapped skin.

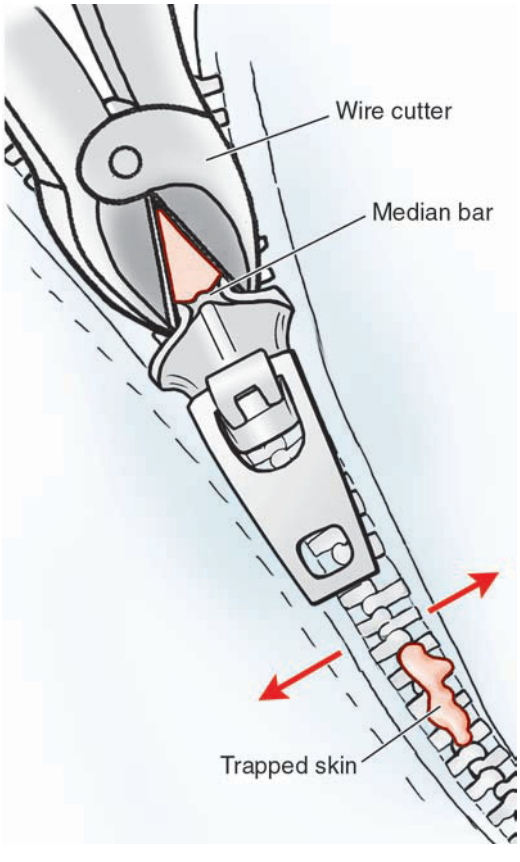


FIGURE 152-3. Skin entrapped in the zipper teeth. Cut the median bar to remove the zipper and manually separate (*arrows*) the two rows of teeth to release the entrapped skin.

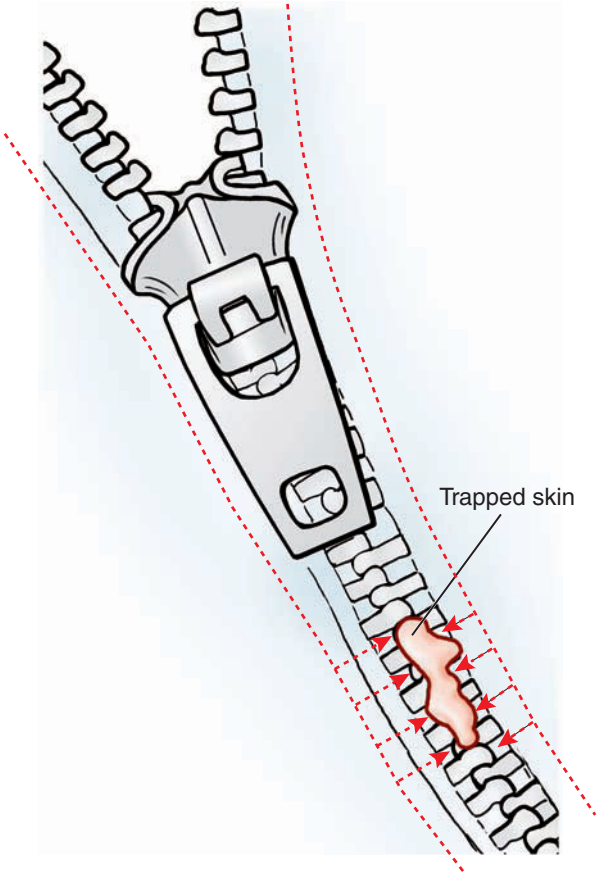


FIGURE 152-4. Skin entrapped in the zipper teeth. Cut the cloth holding the zipper to the clothes (*long dashed lines*) then cut the cloth between the teeth (*short dashed lines*).

This technique is less than ideal. Cutting the cloth between the teeth of the zipper may cause lacerations to the entrapped skin. It is very painful for the patient when the skin is cut. Exercise great caution when cutting the zipper. Given this risk, some prefer cutting the median bar of the fastener mechanism as described above. It is worth the additional time to locate and borrow a heavy-duty wire cutter from the Maintenance Department to cut the median bar.

CUTTING THE ZIPPER TEETH

Cutting the median bar requires the proper equipment and significant strength. Skin trapped between the teeth of the zipper can be released by cutting across the zipper teeth. Cut across the closed zipper teeth using a heavy duty scissors or wire cutter. Pull both halves of the zipper apart to release the entrapped skin. This method is faster and easier than cutting the median bar if the skin is trapped only in the zipper teeth.[12]

ALTERNATIVE TECHNIQUES

If an appropriate wire cutter or bone cutter is not available, or the median bar cannot be accessed with a cutter, the previously mentioned techniques for zipper removal cannot be performed. Alternative techniques do exist but are less than ideal. Each has its own risks and contraindications. The first option is to excise the entrapped skin. This should be considered only if the excised tissue is superficial or redundant and allows for easy removal. A second alternative is to cut the median bar with a miniature hacksaw blade to divide it.[10] This technique carries the risk for significant injury to the skin and soft tissues. A method using a screwdriver has been described to release skin trapped within the sliding piece.[13] Insert the flat blade between the inner and outer faceplates of the slider. Twist the screwdriver clockwise and counterclockwise to widen the gap between the faceplates and release the entrapped skin. If the aforementioned alternatives are not effective to remove a zipper, consult a Urologist for consideration of more aggressive surgical interventions such as an elliptical skin excision or a circumcision.[6,15]

ASSESSMENT

Assess the tissue for any signs of injury after the zipper has been removed from the skin. Any open wounds should be cleaned. Apply an antibiotic ointment and gauze bandage over the wound. A Urologist should be consulted for injuries to deeper penile or scrotal structures, if the entrapped tissue is not viable, if the tissue appears infected, or if the laceration is extensive.[11]

AFTERCARE

Patients with zipper injuries are usually discharged home from the Emergency Department. Their tetanus immune status should be checked and updated if necessary. The patient should be instructed on local wound care and signs of infection. They should return immediately to the Emergency Department if they develop redness, swelling, pus in the wound, or a fever. Otherwise, routine follow-up within 48 hours to evaluate any wounds or injured tissue is satisfactory for most patients. Although no guidelines or evidence exists, some physicians often prescribe oral antibiotics if there are any abrasions or lacerations to the skin. Nonsteroidal anti-inflammatory drugs can be used to provide analgesia.

COMPLICATIONS

Very few complications are associated with the removal of a zipper. Lacerations to the skin and deeper structures may occur. Superficial lacerations are commonly associated with cutting of the median bar. Deep lacerations are due to improper positioning of the wire cutter and can be prevented. Superficial lacerations will heal and require no special care. Large superficial lacerations and deep lacerations will require suturing. Hemorrhage from any laceration can be controlled with the application of manual pressure. Local infections may occur from zipper abrasions, abrasions and lacerations from removal of the zipper, or due to nonviable and crushed skin.

SUMMARY

Zipper injuries may occur when opening or closing a zipper. The foreskin, skin of the penis, and the scrotum are the structures most commonly entrapped and injured by zippers. Injuries are most common in uncircumcised young boys, but can occur in adults with some cognitive or physical impairment. After assessing the degree of injury and the type of entrapment, the zipper should be disengaged from the entrapped tissue. Zipper removal is quick, simple, and very satisfying to the patient.

SECTION 12

Ophthalmologic Procedures

153 Eye Examination

Shari Schabowski

INTRODUCTION

Emergency Physicians often approach the eye examination with some degree of apprehension. Eye complaints comprise up to 10% of Emergency Department visits. A systematic approach to the eye examination can alleviate any discomfort and provide the basis for an accurate diagnosis and treatment.[1–14] The most common ophthalmologic problems that present to an Emergency Department are injuries, inflammation, infections, and visual disturbances.

A careful history will help to guide the differential diagnosis and the physical examination. It must include a history of the presenting complaint, the mechanism of any injury, exposures to chemicals or infectious agents, baseline visual acuity, known ophthalmologic problems, baseline medical problems, current medications, and any known allergies. The eye examination progresses from the outside and works inward, beginning with the visual acuity to assess the function of the eye. **It is important to routinely inspect all anatomic structures of the eye regardless of the presenting eye complaint.** Secondary problems, such as corneal lesions associated with conjunctivitis, may be missed if a complete examination is not performed on all patients.

EYE ANATOMY

The bony orbit is pyramidal in shape and surrounds the eyeball and its associated neurovascular structures. The blood supply to the structures of the orbit originates from the ophthalmic artery. The anatomy of the eyeball and its surrounding soft tissue structures is demonstrated in **Figure 153-1**. A detailed discussion of the complex anatomy of the eye is beyond the scope of this chapter. The anatomy relevant to the eye examination will be discussed throughout this chapter.

VISUAL ACUITY

Visual acuity is referred to as the vital sign of the eyes. It provides a means for the functional assessment of this delicate sensory apparatus. **Documentation of the visual acuity is essential when approaching a patient with eye complaints.** Assess the patient's visual acuity as soon as possible, preferably as part of the triage assessment. Test and document the patient's visual acuity before the physical examination begins. There are few exceptions to this rule. Chemical exposures to the eye require immediate irrigation to avoid potentially irreversible visual loss. **In these cases, irrigation should not be delayed for visual acuity testing.** In all other cases, visual acuity testing should be the primary component of the ophthalmologic exam. **Failure to document visual acuity is a common omission and may have medicolegal ramifications.**

Always test each eye individually and then both simultaneously. Test and document the visual acuity with the respective annotation to the right eye (OD), the left eye (OS), and both eyes (OU). Test the problematic eye first. Completely cover the eye not being tested. Light shining into the opposite eye may adversely affect the results of visual acuity testing. A list of commonly used abbreviations in the measurement of visual acuity is presented in **Table 153-1**. Inquire as to the patient's baseline visual acuity and whether they wear corrective lenses for reference. Test the visual acuity using corrective lenses whenever possible. When corrective lens are unavailable, use of the pinhole device will help to correct any refractory errors. The abbreviations for the documentation of with and without correction are cc and sc, respectively.

Use caution when allowing contact lenses to be used as a visual aid in patients with eye pain, an eye injury, or an eye discharge. Their application may worsen the ocular condition. **Remove all contact lenses before the slit lamp examination and fluorescein staining. Fluorescein will permanently stain soft contact lenses and may stain hard contact lenses.**

An accurate assessment of visual acuity is essential and this cannot be overemphasized. It is not uncommon for a Physician to miss a secondary ophthalmologic diagnosis when they do not recognize a change in visual acuity. **As a rule of thumb, a patient with previously normal (20/20) vision with or without correction that has an acute deterioration to 20/50 or less suggests a serious ophthalmologic condition.** These cases require emergent consultation and prompt referral to an Ophthalmologist.

VISUAL ACUITY CHARTS

The Snellen eye chart is the most commonly used tool for assessing visual acuity (**Figure 153-2**). Place the Snellen chart on a flat wall in a well-lit room without obstructions. Place the patient standing 20 feet from the chart. With one eye completely covered, instruct the patient to read each line of the chart beginning at the top and proceeding to the bottom or until they are unable to correctly and consistently read the letters. The visual acuity is the fraction corresponding to the last line that the patient identifies at least half of the letters correctly (i.e., 20/40). The numerator corresponds to what the patient is able to see at 20 feet. The denominator corresponds to the distance where a patient with normal vision would be able to read the same line accurately. For example, a patient with a visual acuity of 20/40 sees at 20 feet what a patient with normal vision would see at 40 feet. Document the fraction corresponding to the line minus the number of letters missed if the patient is able to accurately identify more than half of the letters on that line (i.e., 20/40 −3).

When a patient is unable to read the Snellen chart at 20 feet, move the patient closer and reevaluate the visual acuity. Test the patient 10 feet from the chart. The test is the same at 10 feet as it is at 20 feet only the documentation changes. Recall that the numerator corresponds to the patient's distance from the chart. If starting at the 10 foot mark and the patient is able to read the letter at the line designated 20/200 then document 10/200. The test can also be performed at 5 feet or closer if necessary, with the appropriate change in the numerator.

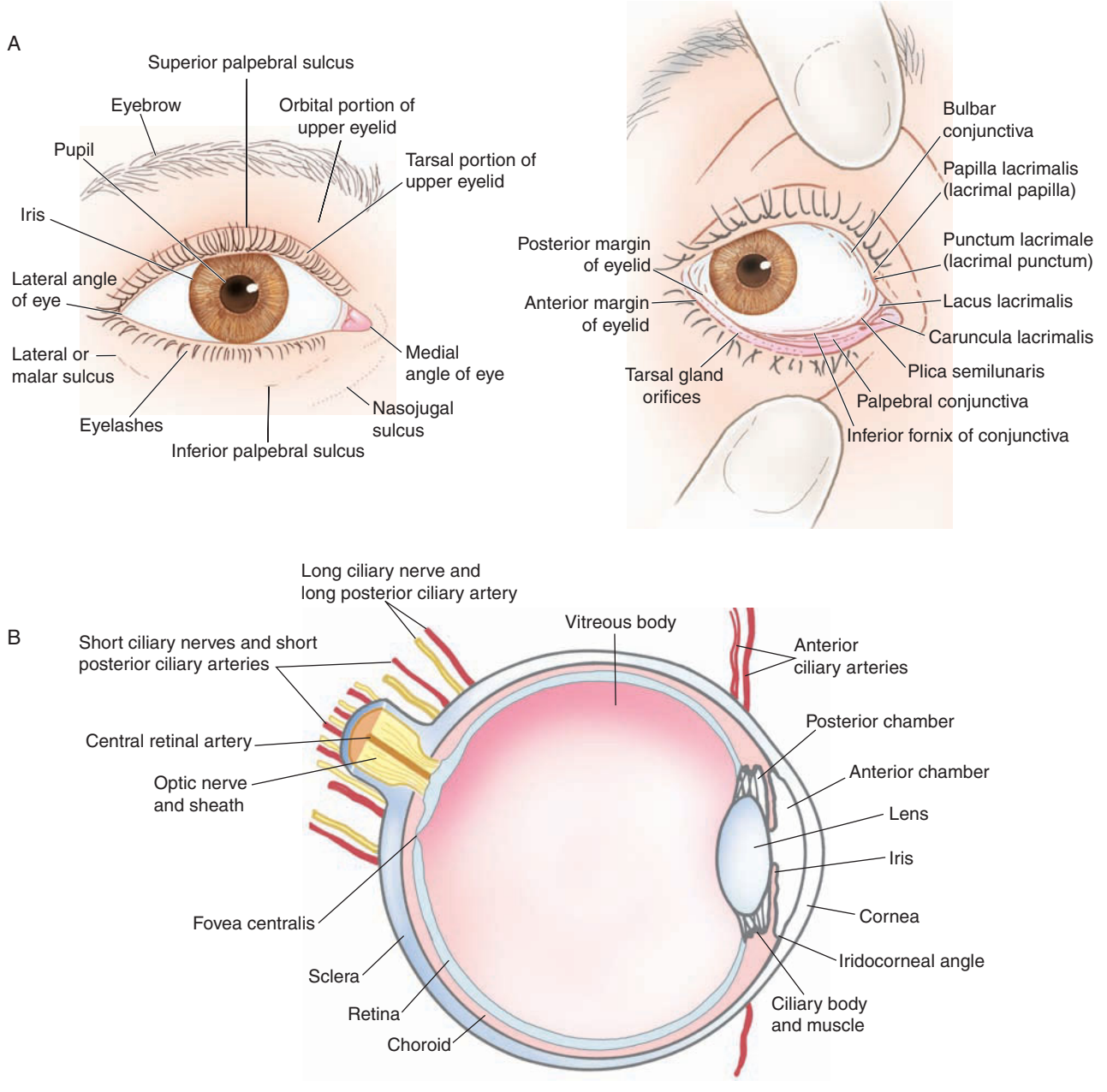


FIGURE 153-1. Anatomy of the eye and its surrounding soft tissues. **A.** Surface anatomy. **B.** Midsagittal section through the eyeball.

TABLE 153-1 Commonly Used Abbreviations for the Documentation of Visual Acuity

OD = right eye
OS = left eye
OU = both eyes
cc = with correction
sc = without correction
CF = counts fingers
HM = hand movement
LP = light perception
NLP = no light perception
+ = positive
– = negative

The Snellen chart is the most effective tool for documenting an accurate and reproducible visual acuity. There are circumstances that render this tool less effective and inaccurate. The chart utilizes the English alphabet and effective use requires that the patient can identify all letters. This is difficult, if not impossible, in patients who are illiterate or do not speak and/or read English. The illiterate E chart is an alternative (**Figure 153-3**). Instruct the patient to identify the direction that each "E" is facing. An alternative is to use a pediatric visual acuity chart (**Figure 153-4**). Instruct the patient to identify the objects on each line. Both of these visual acuity charts are assessed and documented like that of the Snellen chart.

There are a few circumstances where the standard eye chart may give falsely low and inaccurate readings. Patients with eye pain or photophobia may have difficulty reading the chart in bright light secondary to excessive lacrimation, blepharospasm, or pain. There

are several options to provide a more optimal assessment of visual acuity. A Rosenbaum card is the handheld equivalent of the Snellen chart (**Figure 153-5**). It is viewed at a distance of 14 inches. Its advantages are that it can be used in the patient's room with less-offensive lighting and it can adjust for refractory errors in near-sighted patients who present without correction. A clever idea that some use is to attach a 14 inch string to the Rosenbaum card so that it can be accurately tested at the exact distance each time. A near vision test for children may also be used to assess visual acuity (**Figure 153-6**).

Photophobia or eye pain, particularly that which results from corneal injuries or lesions, may prevent the patient from complying with the visual examination. They may often have difficulty opening the eye at all. The instillation of a topical ophthalmic anesthetic agent may be remarkably helpful as an adjunct to the visual acuity evaluation as well as for the remainder of the eye examination.

PINHOLE DEVICE

The pinhole device can filter out excessive light (**Figure 153-7**). It allows direct light rays to pass through the holes while blocking divergent light rays. This results in a sharper, but dimmer, image on the retina. The pinhole device may correct refractory errors to 20/30. An index card punctured multiple times with an 18 gauge needle can substitute if the pinhole device is not available. The pinhole device should be used in a well-lit room because it results in a dimmer image on the retina. Instruct the patient to place the pinhole device over the eye being tested and close the other eye. Instruct the patient to read the visual acuity chart. Record the patient's visual acuity in each eye. Make a notation in the record that the pinhole device (PH) was used in the measurement of the visual acuity.

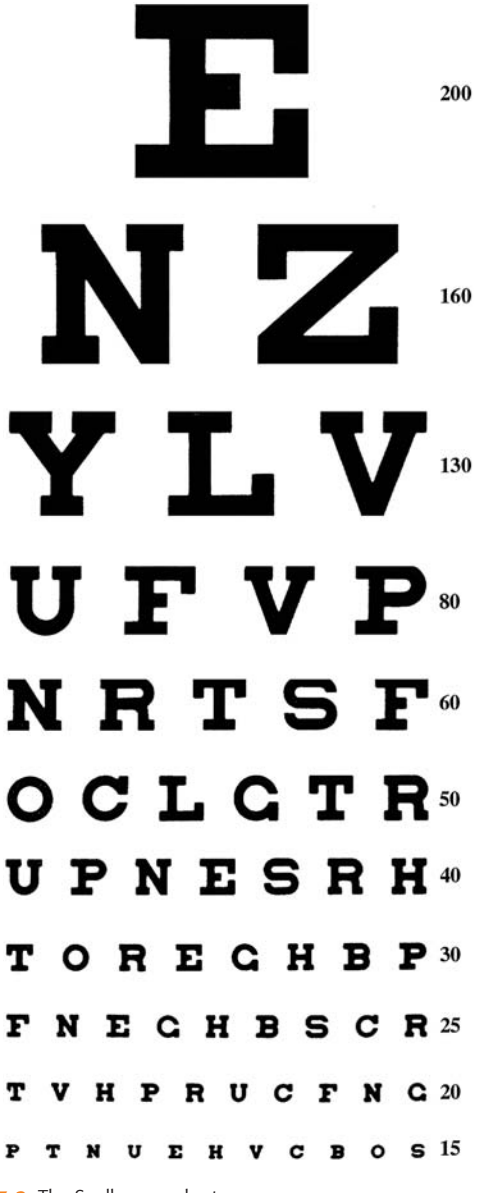


FIGURE 153-2. The Snellen eye chart.

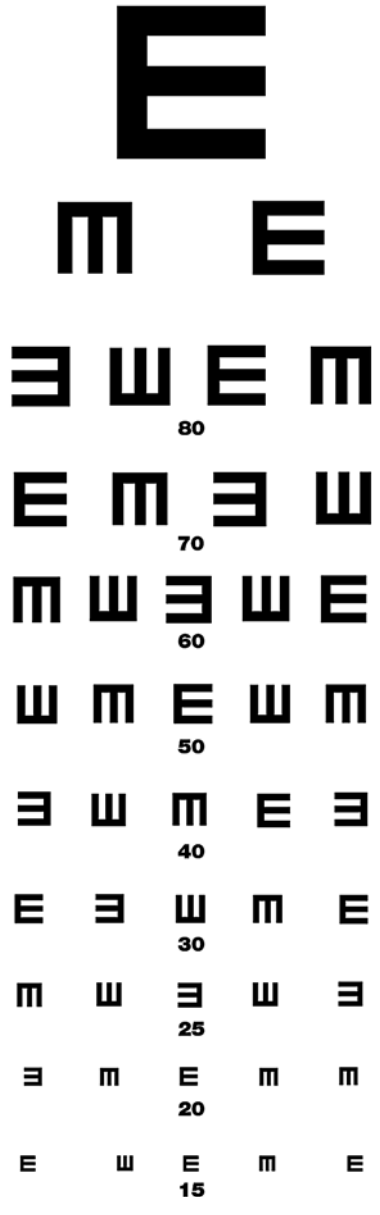


FIGURE 153-3. The illiterate E chart.

FINGER COUNTING

Another means of visual acuity assessment must be utilized if the patient is unable to identify the letter or object in the 20/200 position, the first and largest letter in the visual acuity chart. The next level of visual acuity that is traditionally accepted is the ability to count fingers (CF). It is important for documentation that the

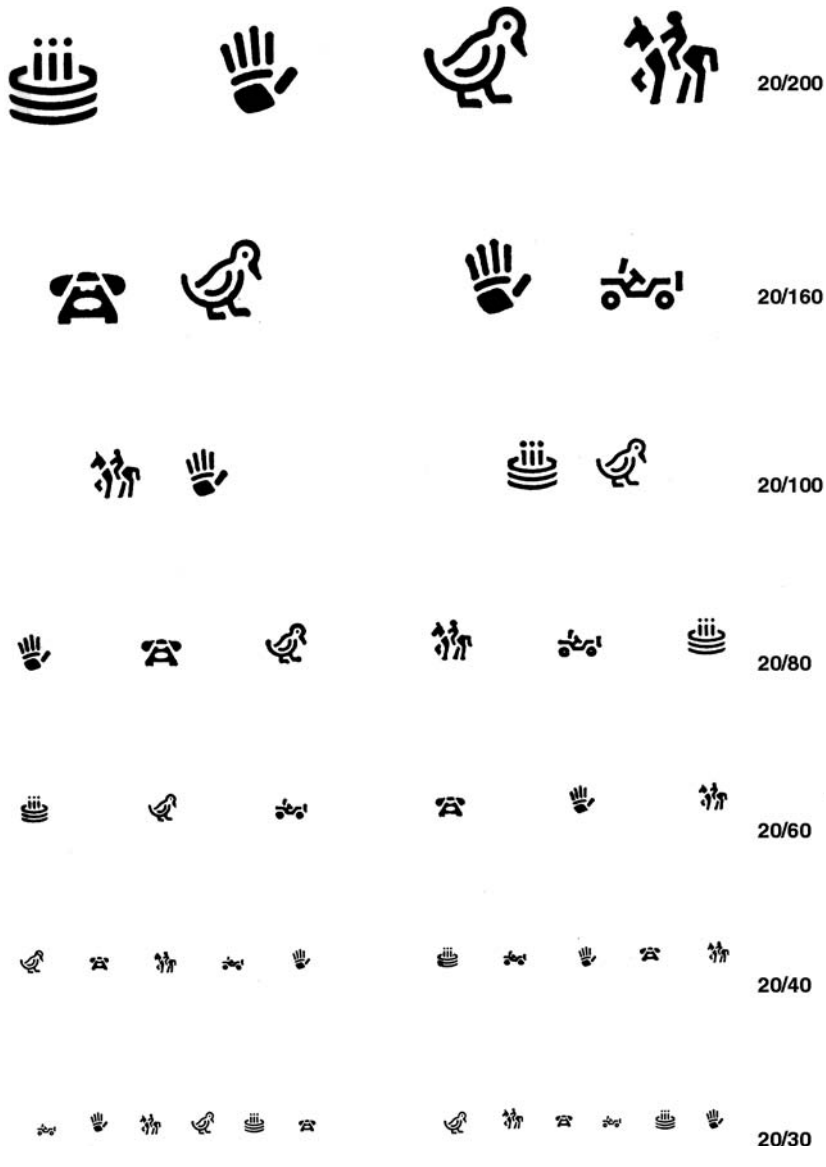


FIGURE 153-4. The pediatric visual acuity chart.

examiner note at what distance from the eye the patient is able to consistently count the examiner's fingers (e.g., OD CF at 12 inches). **The distance used for counting fingers is the distance where the patient is first able to accurately complete the test.** Test one eye at a time and then both eyes simultaneously.

Documentation of "CF at 2 feet" means that the patient can accurately count fingers starting at 2 feet. This implies that the patient cannot accurately count fingers if they were held at a distance greater than 2 feet. **It is thus very important to determine the distance where the patient can accurately count fingers and measure this distance with a tape measure and not estimate.**

HAND MOVEMENTS

The next test of visual acuity to perform is hand movements if the patient cannot count fingers. Move or wave a hand back and forth in front of the eye being examined. Document hand movement positive (HM+) or hand movement negative (HM–). Note the distance from the eye that hand movement is first visible (i.e., how close to the eye must the hand be positioned) in the medical record (e.g., HM+ at 12 inches). Test one eye at a time and then both eyes simultaneously.

LIGHT PERCEPTION

If the patient is unable to perceive hand movement, the next determination of visual acuity is light perception. Use a penlight or ophthalmoscope to determine the presence or absence of light perception. Shine the light directly into one eye while the opposite eye is covered. Document the patient's ability to correctly identify when the light is on and off. This is noted as light perception positive (LP+) or light perception negative (LP–). Test one eye at a time and then both eyes simultaneously. **True blindness is present when the patient has no light perception.**

UNCOOPERATIVE OR UNRESPONSIVE PATIENTS

Unresponsive patients are a challenge for the evaluation of visual acuity. First shine a light into each of the patient's eyes to test for pupillary reactivity. Move the light slowly through all of the cardinal positions to identify if the patient is able to track the light movement. Refer to the evaluation of extraocular movements section below. Perform the doll's eyes maneuver if the patient is unable to track the light.

A difficult situation occurs in the patient whose visual acuity is "no light perception or LP–" but has normal pupillary

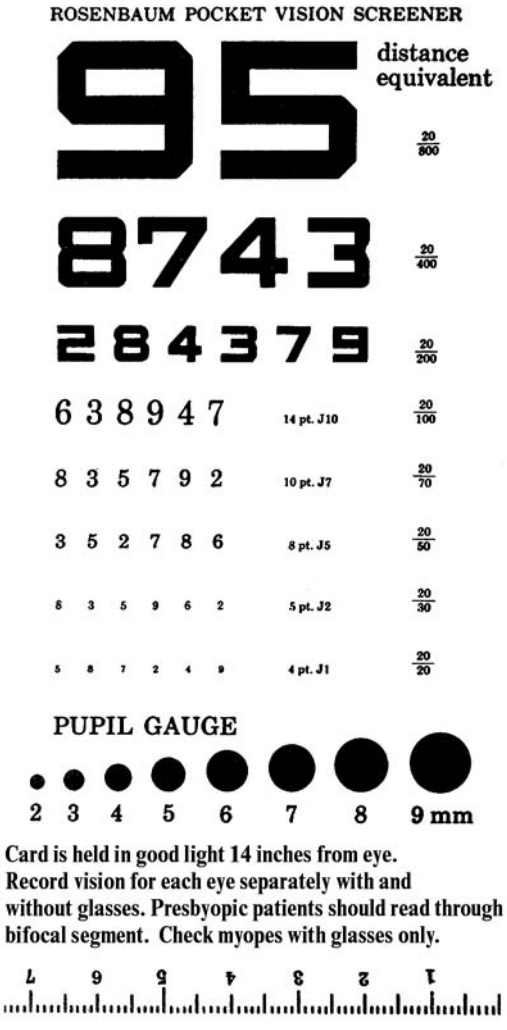


FIGURE 153-5. The Rosenbaum pocket vision screener.

responses and normal responses to the doll's eyes maneuver. This suggests that the visual loss is not anatomic or physiologic, but rather has a psychologic component. Test the optokinetic reflex using either a spinning device or a scintoscope in order to narrow the differential diagnosis. A patient who can see movement will not be able to resist the normal tracking response to the rotating cylinder. A positive response will appear as nystagmus upon examination.

PEDIATRIC VISUAL ACUITY TESTING

It is important to evaluate the vision of infants. There is a critical time during which visual problems must be corrected to avoid permanent visual disturbances. This is optimally before 4 months of age. The eyes continue to develop quickly up to 2 years of age. Refer any questionable visual disturbances to a Pediatric Ophthalmologist.

Infants from term delivery to 3 to 4 months of age are not able to consistently follow and track objects. An infant's eyes may not move in perfect alignment until the age of approximately 3 to 4 months. Infants begin to focus on faces and follow them at approximately 6 weeks of age. They should consistently focus on and follow objects at 4 months of age.

Testing an infant's vision can be quite difficult. Place the infant with their parent holding them in the feeding position. Cover one of the infant's eyes. Ask the parent to move their head from side to side. Note whether the infant's uncovered eye tracks the parent's face. Repeat this with the opposite eye covered. The inability to track objects suggests that the visual acuity is 20/200 or less.

Children who cannot yet read or identify the letters of the alphabet are at a disadvantage when using the Snellen chart (**Figure 153-2**). Use the illiterate E chart (**Figure 153-3**), the pediatric visual acuity chart (**Figure 153-4**), the pediatric near vision test (**Figure 153-6**), or the Allen chart (**Figure 153-8**) to test their visual acuity. The illiterate E chart requires the patient to identify the direction that each variably rotated letter E faces (i.e., up, down, right, and left). Some clinicians find it helpful to describe the E as a table and ask which way the legs are facing. The procedure and documentation is otherwise the same as with the Snellen chart. The pediatric charts use shapes of common objects in the place of letters and apply the same corresponding fractions for determining visual acuity. Have the child identify each of the pictures before beginning the examination to ensure that the child knows what the picture represents. Children may use unexpected words to identify the objects, which may complicate the interpretation of the exam.

GENERAL INSPECTION OF THE EYE

The examination of the eye proceeds from the outside and works inward. Begin with inspecting the external structures. Note the presence of any enophthalmos or exophthalmos. This is best accomplished by viewing the eyes from above and behind the patient. The normal globe position is just within the orbital rim. Enophthalmos is a recession of the globe within the bony orbit. It is an important clue for the presence of a blow-out or orbital floor fracture. Exophthalmos is a protrusion of the globe from the bony orbit. It may be an important clue to the presence of a retrobulbar hemorrhage or an orbital cellulitis. Esotropia refers to an inward or nasal deviation of the globe. Exotropia refers to an outward or temporal deviation of the globe.

Evaluate the eyes and eyelids for symmetry, lid position, obvious injuries, lesions, discoloration, and/or swelling. Ptosis suggests a Horner's syndrome or a third cranial nerve abnormality. **Any evidence of facial trauma or eye trauma raises the possibility of a ruptured globe. Avoid placing pressure directly on the globe if there is any possibility of a ruptured globe. Inadvertent tactile pressure placed on a ruptured globe may result in extrusion of intraocular structures.** This can result in an otherwise avoidable visual loss that is typically not reparable. Manipulate the eyelids by applying pressure over the bony orbit instead of directly on the globe (**Figure 153-9**).

EVALUATION OF EXTRAOCULAR MOVEMENTS

Extraocular movements are easily assessed in the cooperative patient. Instruct the patient to keep their head still and directed toward the examiner. Instruct the patient to follow the motions of a finger with only their eyes as it follows the pattern of an H (**Figure 153-10**). This is referred to as the six cardinal positions for testing extraocular muscle movements. It may be helpful to retract the patient's eyelids to better visualize the eye movements. Observe the eyes for symmetric or conjugate gaze as each position is reached. Note whether the patient sees one finger clearly at each position. Ask the patient to describe the orientation of the images (i.e., side to side) if more than one image is noted. Assess the far lateral positions by paying careful attention for evidence of nystagmus. A few beats of nystagmus that quickly extinguishes is within normal limits.

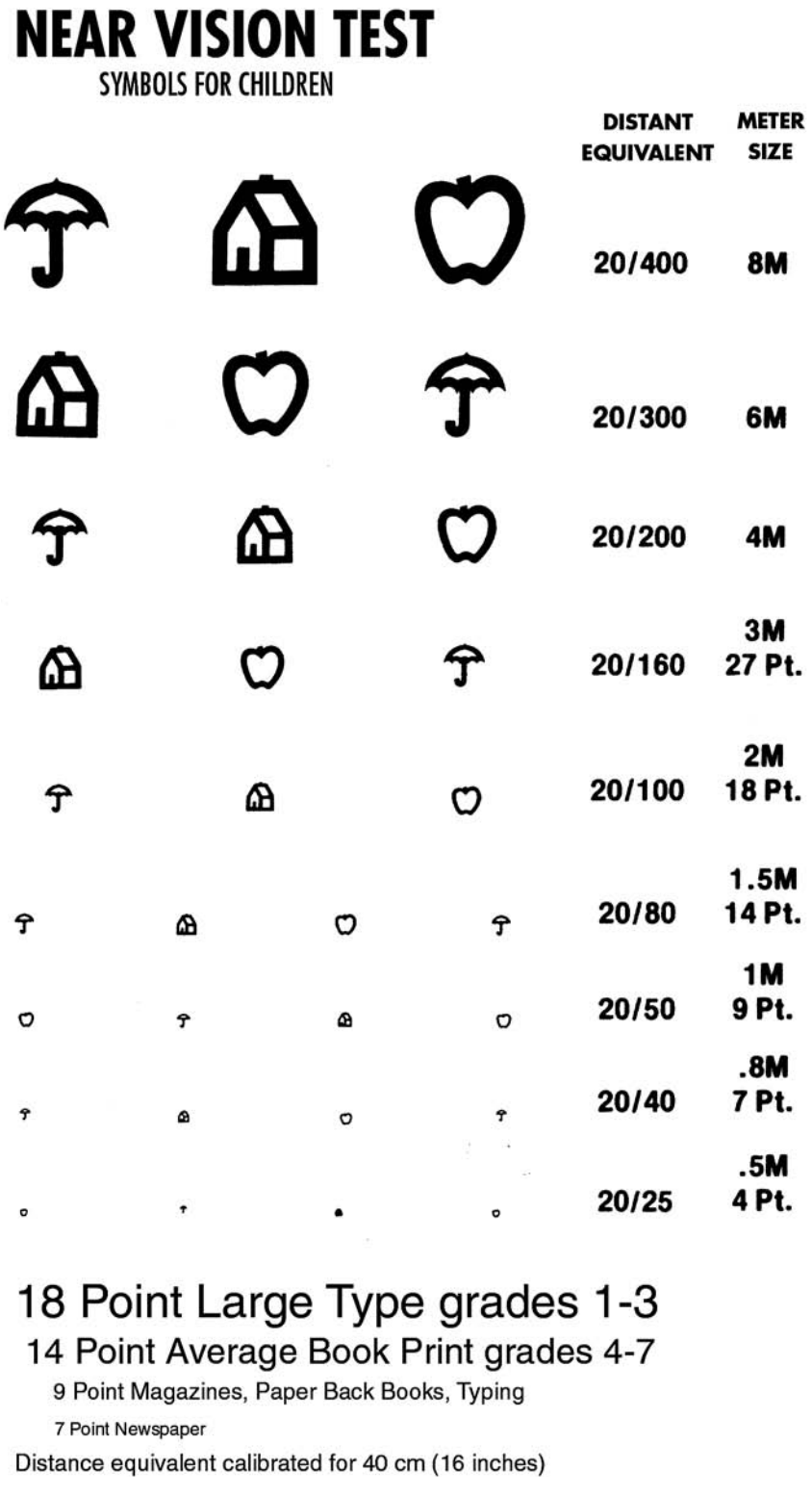


FIGURE 153-6. The near vision visual acuity test uses symbols for children.

Keep in mind that the nose may obstruct the view at extreme points. Move the examining hand into a plane that is a few inches closer to the examiner if this occurs (i.e., a few inches away from the patient), and repeat the testing.

It is helpful to use a penlight directed toward the patient's eyes during the examination when a question of subtle disconjugate gaze is entertained, particularly in the position where the patient complains of diplopia. Look into the patient's pupils to see the reflection of the light (**Figure 153-11**). The reflection of the light is symmetrical, located in the same position in each pupil, if the gaze is conjugate (**Figure 153-11A**). Asymmetrical light reflection is noted in cases of disconjugate gaze (**Figure 153-11B**).

Consider the innervation of the extraocular muscles in order to narrow the differential diagnosis when abnormal extraocular movements are identified. The lateral rectus muscle is innervated by the sixth cranial nerve (CN VI). The superior oblique muscle is innervated by the fourth cranial nerve (CN IV). The remaining extraocular muscles are innervated by the third cranial nerve (CN III). An

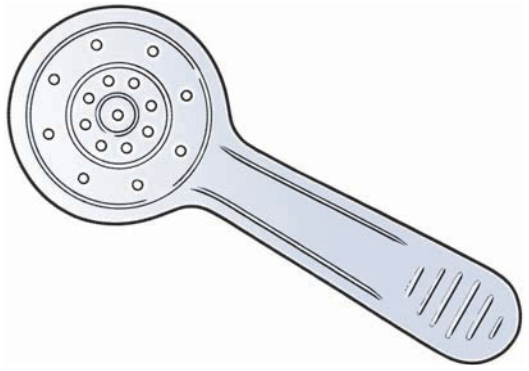


FIGURE 153-7. The pinhole device.

isolated sixth cranial nerve palsy, particularly in a child, strongly suggests an intracranial neoplasm. A complete third cranial nerve palsy suggests an intracranial aneurysm pressing on the oculomotor nerve, particularly when the pupil is involved. A physical obstruction originating in the retrobulbar region manifests as restricted extraocular movements in one eye. Consider the presence of an orbital cellulitis or a retrobulbar hemorrhage in the appropriate clinical setting.

Consider the presence of an orbital floor or blow-out fracture if the patient is unable to elevate one of the eyes. The etiology of the restricted movement may be physical entrapment of the inferior rectus and/or inferior oblique muscles within the orbital floor fracture or a contusion of the nerve innervating the inferior oblique muscle. The two must be distinguished by an Ophthalmologist as the management, treatment, and follow-up are different. Place two drops of a topical ophthalmic anesthetic agent into the affected eye. Grasp the bulbar conjunctiva with forceps and attempt to gently elevate the eye. A physical cause is ruled out if the eye is able to be elevated and a nerve contusion is likely.

EXAMINATION OF THE PUPILS

Place the patient with their head looking directly forward while retracting the upper eyelid. Complete the pupillary examination and a cursory evaluation of the cornea and anterior chamber simultaneously. Clinicians commonly use the abbreviation "PERRLA" as documentation for the pupillary examination. "PERRLA" means the pupils are equal, round, and reactive to light with normal accommodation. **Be sure that you assess accommodation if you use this acronym. In any case, this abbreviation is typically inadequate when a patient has emergent eye complaints.**

When dealing with emergent eye complaints it is important to document a detailed pupillary exam. Darken the room as much

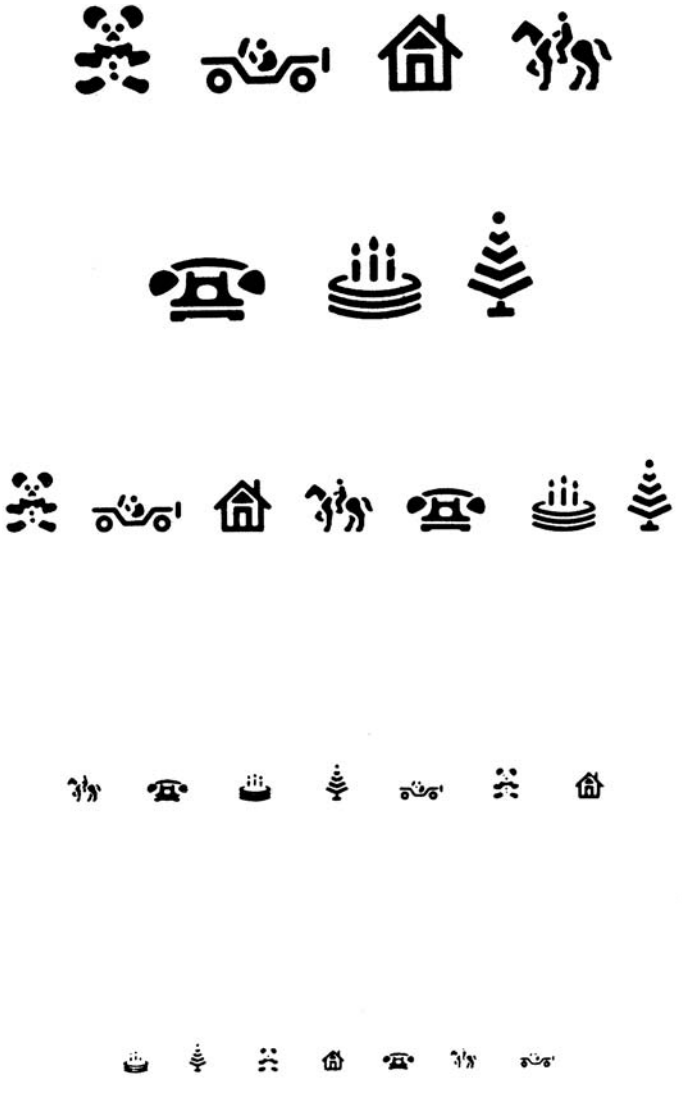


FIGURE 153-8. The Allen chart to measure pediatric visual acuity.

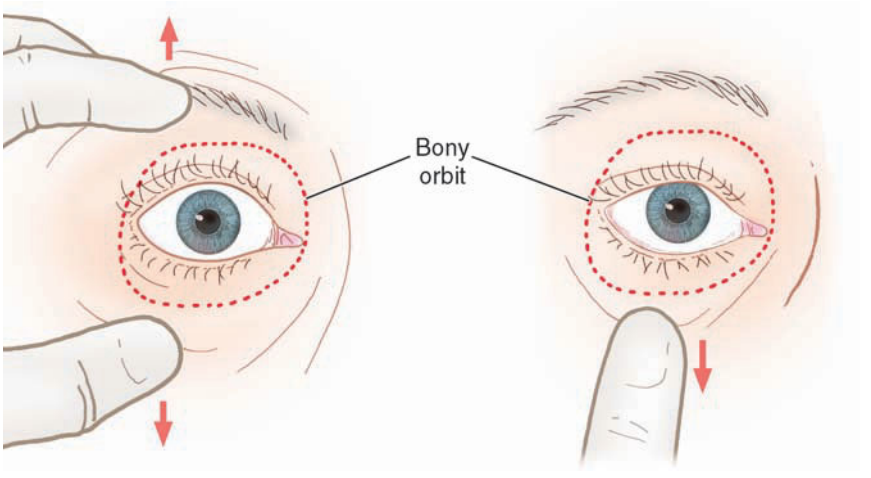


FIGURE 153-9. Open and close the eyelids by applying pressure over the bony orbit in suspected cases of a ruptured globe.

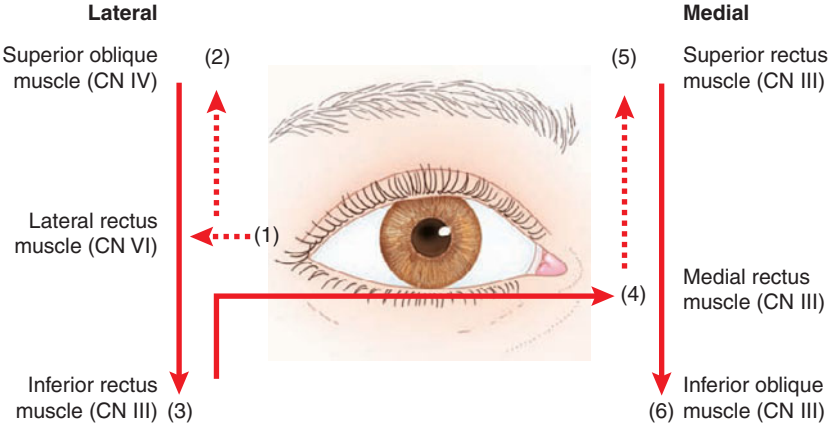


FIGURE 153-10. The six cardinal positions for testing extraocular muscle movements. Start with the eye facing forward and follow the order of the numbers, also known as the six cardinal positions. Note that the testing follows an H-shape.

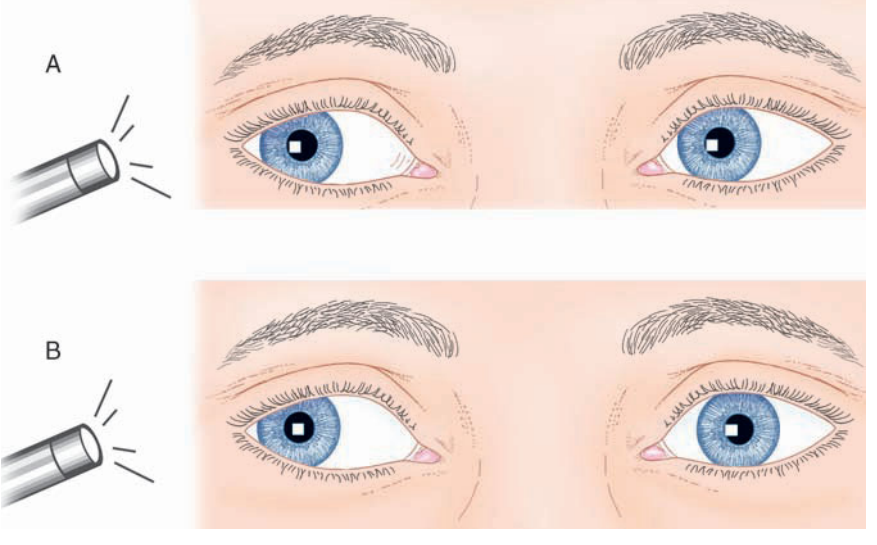


FIGURE 153-11. Shine a penlight into the eyes in the position that the patient complains of diplopia. Observe the light reflection in the pupils. **A.** Conjugate gaze. **B.** Disconjugate gaze.

as possible. Instruct the patient to focus on a distant object. The normal response is symmetric dilation of the pupils. Note the size, in millimeters, of each pupil. Shine a focused beam of light into one eye to test reactivity, or the direct pupillary response to light. The normal pupil will constrict immediately and briskly. Document the direct response to light in millimeters at maximal constriction (e.g., OD = 4 mm → 2 mm). Note if the pupil is not briskly reactive (e.g., OS = 5 mm → 3 mm, sluggish) or if it dilates (e.g., OS = 3 mm → 6 mm). Repeat this test with the contralateral eye.

The consensual pupillary response is the reaction of the contralateral eye to light shined into the opposite eye. The normal consensual pupillary response is constriction of the contralateral pupil when light is shined into the opposite eye. This occurs because some of the efferent optic nerve fibers cross the midbrain to the contralateral optic tract and result in constriction of the contralateral pupil. Be careful to document a normal consensual response if it is present.

When assessing an inflamed eye, the consensual pupillary response can be used as a diagnostic tool. Close and cover the affected eye and shine the light in the opposite eye. With the cornea protected by the lid on the affected side, if the consensual pupillary response causes pain in the affected eye it suggests deep inflammation or a uveitis.

A common example of an abnormal pupillary examination illustrates the importance of paying specific attention to the consensual pupillary response. The relative afferent pupillary defect (RAPD) results from the tested eye not perceiving the light. There is no perception of light (LP–) transmitted to the optic tracts. The tested pupil will not constrict to direct light. The pupil may, in fact, inappropriately dilate in response to direct light. There will be no consensual response in the contralateral pupil. The contralateral pupil will constrict appropriately to direct light and the previously unresponsive pupil will demonstrate a normal consensual response. The "swinging flashlight test" is used to test for a RAPD. Shine the light into one eye. Note the direct and consensual responses. Swing the light over to test the opposite eye. Note the direct and consensual responses.

A common problem for the Emergency Physician is the patient with unequal pupils. In the appropriate context, the primary consideration is typically a "blown pupil" suggesting an uncal brain herniation from a mass lesion. This would be very unusual in a patient who is awake, alert, and cooperating with the eye examination. In this case, physiologic anisocoria is the most common cause. Patients with physiologic anisocoria will have a normal response to light and typically the difference in pupillary size will be no more than 2 to 3 mm. **If the response is abnormal, the Emergency Physician must determine which of the two pupils is problematic.** The normal response to a darkened room is dilation. The pupil that does not dilate is abnormally miotic. The appropriate response to bright light is constriction. The pupil that does not constrict is abnormally mydriatic.

It is important to note and document the shape of each pupil. They should be round and regular. Irregularly shaped pupils may give important clues to otherwise undiagnosed injuries. A "D-shaped" pupil suggests a disruption of the ciliary muscles in the region adjacent to the flat part of the "D". A teardrop-shaped pupil suggests a ruptured globe, with the point of the teardrop directed toward the point of penetration. A quivering and dilated pupil that does not react appropriately to light suggests a lens dislocation partially obstructing the visual axis. An irregularly shaped pupil may be an important diagnostic clue, but do not be misled. The most common cause of an irregularly shaped pupil is a postoperative change. **Always inquire about previous eye surgery or old injuries, especially if an abnormality is noted.**

A new device, the NeurOptics® NPi™-100 pupillometer, has been developed to accurately measure pupil size and reactivity (NeurOptics, Irvine, CA). This handheld device is easy to use, takes over 30 pictures a second, analyzes the pictures, and prints via infrared to a portable printer. It can display values over time numerically or graphically. While not for routine daily use, it has a role in the evaluation of critically ill or injured patients.

EXAMINATION OF THE EXTERNAL STRUCTURES

The examination should proceed from the outside and work inward following an anatomic checklist. Examine the eyelids, lash line, and tarsal plates. Examine them for symmetry, normal position of the eyelashes, injury, infection, or inflammation. Examine the puncta of the lacrimal apparatus for signs of inflammation and obstruction. Examine the bulbar conjunctiva and vasculature for injection, ciliary flush, chemosis, discharge, and foreign bodies. Examine the cornea for clarity, evidence of injury, lesions, or foreign bodies. Examine the palpebral conjunctiva and cul-de-sac for injection, foreign bodies, discharge, and lymphatic (follicular) enlargement. Examine the anterior chamber for clarity, depth, and particulate matter.

Expose the structures of the inner aspect of the upper eyelid. Evert the eyelids (**Figures 153-12 & 153-13**) or retract the eyelids (**Figures 153-14 & 153-15**). Place the patient facing forward

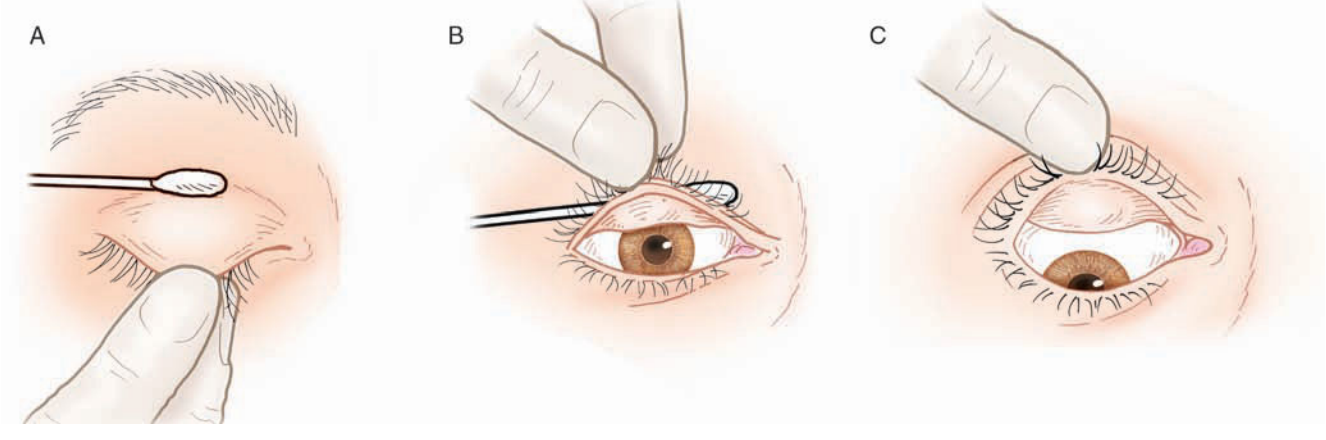


FIGURE 153-12. Eversion of the upper eyelid. **A.** Grasp and pull down the upper eyelashes while simultaneously placing a cotton-tipped applicator at the base of the upper eyelid. **B.** Flip the upper eyelid over the cotton-tipped applicator. **C.** Hold the everted eyelid in place and gently remove the cotton-tipped applicator.

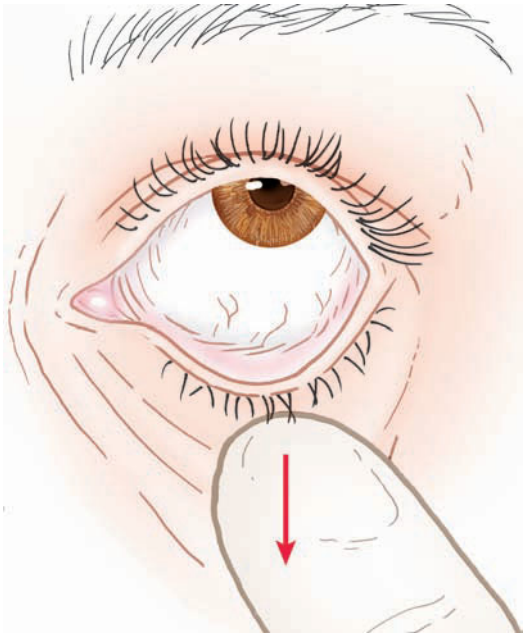


FIGURE 153-13. Eversion of the lower eyelid.

with their eyes focused downward to evert the upper eyelid (**Figure 153-12**). **The patient's eyes must remain directed downward during the entirety of the exam as looking up or forward will cause the eyelids to return to their natural position.** This process requires the use of a cotton-tipped applicator. An assistant may be required to aim and focus a light source during the examination as it may require two hands to evert and hold the eyelids in position.

Grasp the midpoint of the upper eyelash line or the tarsal plate between the index finger and thumb (**Figure 153-12A**). Place a cotton-tipped applicator 0.5 to 1.0 cm superior to the tarsal plate, with the cotton tip in the midplane of the upper eyelid (**Figure 153-12A**). Apply gentle pressure directed slightly downward against the upper eyelid with the cotton-tipped applicator. Use the other hand to pull the eyelid upward and evert it (**Figure 153-12B**). The upper eyelid may not completely evert. Sweep the cotton-tipped applicator from left to right while still holding the lash line in one hand and simultaneously applying gentle downward pressure with the applicator within the false pocket to completely evert the upper eyelid (**Figure 153-12C**). Gently and slowly remove the cotton-tipped applicator.

Eversion of the lower eyelid is much simpler (**Figure 153-13**). Instruct the patient to look upward. Place the index finger on the patient's lower eyelid. Apply downward traction to evert the lower eyelid.

The use of a Desmarres eyelid retractor is an alternative option, if available, to retract the eyelids. It is very difficult to manually evert the eyelids when they are swollen. Manual eyelid eversion can result in excessive pressure being placed on the potentially injured globe. An eyelid retractor can be used to avoid placing pressure on the globe (**Figure 153-14**). Place the patient facing forward with their eyes directed downward. Place the eyelid retractor approximately 5 mm above the tarsal plate on the outer surface of the eyelid (**Figure 153-14A**). Grasp the midpoint of the upper eyelash line or the tarsal plate between the index finger and thumb. Slightly retract the upper eyelid away from the globe. Elevate and retract the tarsal plate upward to evert the eyelid onto the retractor (**Figure 153-14B**). Lift the retractor upward to fully expose the undersurface of the eyelid (**Figure 153-14C**).

This technique allows the eyelid to be retracted with one hand while directing the light with the other hand. It also prevents any pressure from being placed on the globe if a rupture is suspected. It may be necessary to slide the retractor 0.5 cm to the left and to the right of midline to fully visualize the ocular structures. Use the same technique to retract the lower eyelids. Instruct the patient to direct their gaze and focus upward when retracting the lower eyelid.

A simple method to retract, but not evert, the eyelid with the Desmarres retractor is shown in **Figure 153-15**. Place the eyelid retractor in front of the upper eyelid (**Figure 153-15A**). Gently insert the retractor under the upper eyelid (**Figure 153-15B**). Apply slight outward traction on the retractor to securely grasp the tarsal plate. Rotate the retractor upward to retract the upper eyelid (**Figure 153-15B**). Elevate the retractor upward to open the eyelid (**Figure 153-15C**). Use the same technique to retract the lower eyelid. **Never use this technique if a foreign body or ruptured globe is suspected.** It may cause secondary injury by embedding a foreign body, perforating the globe with the foreign body, or expressing the ocular contents if the globe is ruptured.

Eyelid retractors are not uniformly available in all Emergency Departments. They should be part of an "eye kit" (**Table 153-2**). An alternative used by some is to unfold a paper clip and bend it into shape with a hemostat (**Figure 153-16**). **This is not recommended by the editor as the metal coating on the paper clip flakes off and can result in corneal abrasions and foreign bodies.** Plastic-coated paper clips, if available, might be a safer alternative to metal paper clips.

SLIT LAMP EXAMINATION

The slit lamp is an essential piece of machinery for a thorough eye examination (**Figure 153-17**). It is an invaluable resource that can be used to identify and aid in the treatment of ophthalmologic problems that might otherwise go unrecognized. It provides an adjustable light source with variable magnification. The eyes remain in a fixed position while the light and microscope are

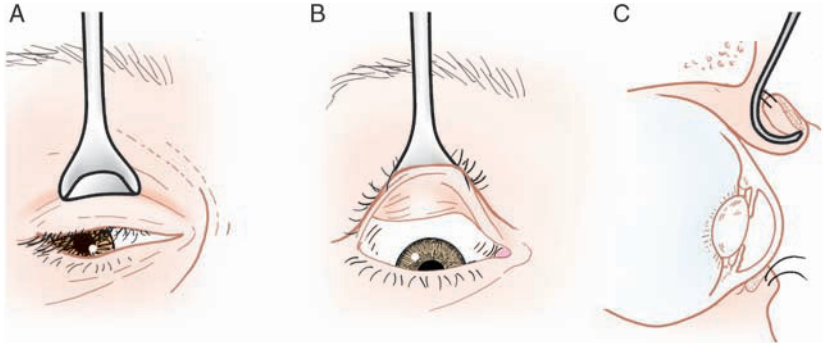


FIGURE 153-14. Eversion of the upper eyelid with a Desmarres retractor. **A.** Place the retractor 5 mm above the tarsal plate. **B.** Grasp the eyelashes and evert the upper eyelid over the retractor. **C.** Elevate the retractor to fully expose the under surface of the eyelid.

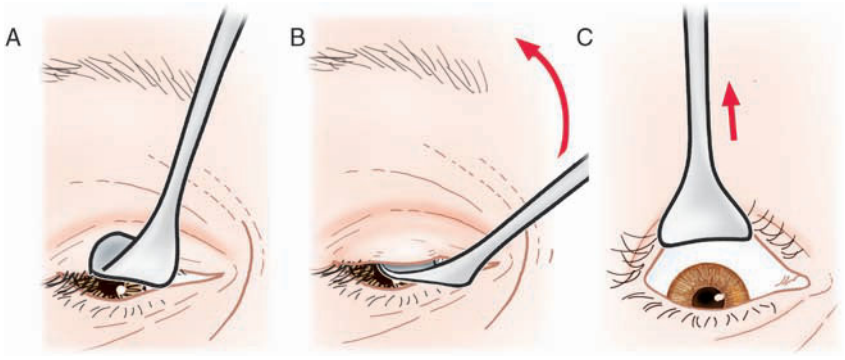


FIGURE 153-15. Retraction of the upper eyelid with a Desmarres retractor. **A.** Place the retractor in front of the eyelid. **B.** Insert the retractor and rotate it toward the forehead. **C.** Elevate the retractor to expose the globe.

independently adjusted. The result of these attributes is that it can focus precisely on the structures of the eye and provide a three-dimensional image. The slit lamp provides valuable information, particularly when examining the cornea and the anterior chamber. The three-dimensional microscopic capability is best demonstrated when examining the intricate topography of the iris.

It may be helpful to set up the slit lamp before the patient is in the room until one feels comfortable using the slit lamp. Place one hand against the middle of the forehead bar in the examination plane to help become familiar with the capabilities of the machine and the joystick. Practice focusing the slit lamp on the details of the skin on your hand. Adjust the focus and depth of vision by sliding the joystick to move the entire slit lamp apparatus forward and backward. Slide the joystick side to side to scan across and examine the entire width of the hand. Rotate the joystick clockwise and counterclockwise to move the line of vision up and down.

Place the slit lamp in the standard position. **It takes very few adjustments of the slit lamp to complete the entire examination.** The slit lamp can be focused and locked in position with the knob located on the table base for procedures that require the Emergency Physician's hands to be free (e.g., foreign bodies embedded within the cornea). This allows one hand to hold the eyelids open while using the appropriate tool in the other hand.

SETTING UP THE SLIT LAMP

The slit lamp has many parts, most of which are capable of movement. The slit lamp components are often moved into a complete disarray by previous users. The position should be checked when the Emergency Physician sits down to use the slit lamp. **It is important to start by readjusting the slit lamp to a "standard operating position."**

TABLE 153-2 Recommendations for a Complete Emergency Department Eye Examination Kit

Snellen chart
Rosenbaum card
"E" chart
Pinhole device
Lid retractor
Fluorescein strips (individually packaged)
Slit lamp
Alcohol swabs
Ophthalmoscope
Topical anesthetic agent, e.g., proparacaine or tetracaine
Topical mydriatic agent, e.g., phenylephrine
Topical cycloplegic agents, e.g., homatropine or cyclopentolate
Topical pupillary constrictors, e.g., pilocarpine and timolol

The body of the slit lamp has three rotating arms. The examiner's neutral position is designated as 0° and the center of the chin rest is designated 180°. The lower arm rotates the binocular microscope. It is rarely, if ever, necessary to move the rotating binocular microscope from the 0° position for the purposes of an Emergency Department examination. The next two arms are moved as a unit. The lower arm rotates the light 90° in either direction. The light source remains directed toward the structure that is being focused upon. The angle of the light is changed when the arm is rotated up to 90° in either direction. The standard position for the light is to rotate it 45° to the examiner's left to examine the patient's right eye and 45° to the examiner's right to examine the patient's left eye. Rotation of the upper arm independently rotates the slit of light in the coronal plane. It is unnecessary to rotate the two upper arms independently during the Emergency Department examination.

The eyepieces of the binocular microscope can be adjusted and focused independently in accordance to the Emergency Physician's needs. The standard starting position is in the 0 and 0 position. The eyepieces can be adjusted to compensate for refractory errors and to correct for the interpupillary distance of the Emergency Physician.

Two levels of magnification are typically available (10× and 16×). The switch to change magnification is located just below the eyepieces. The standard beginning position is low magnification. The

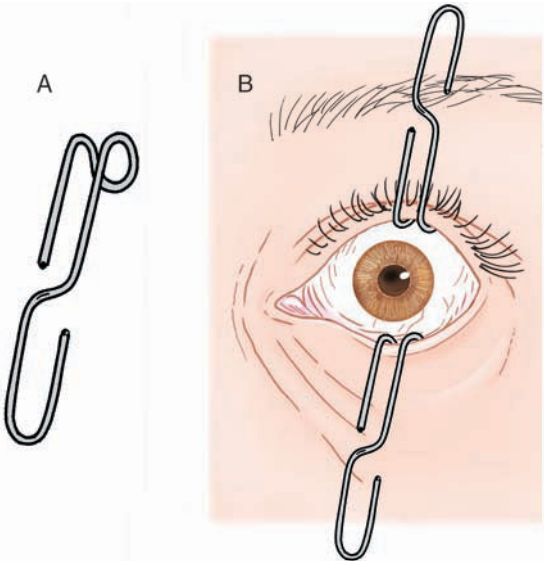


FIGURE 153-16. An alternative to an eyelid retractor. **A.** Unfold a paper clip and bend it into shape with a hemostat. **B.** Paper clips used to retract the eyelids.

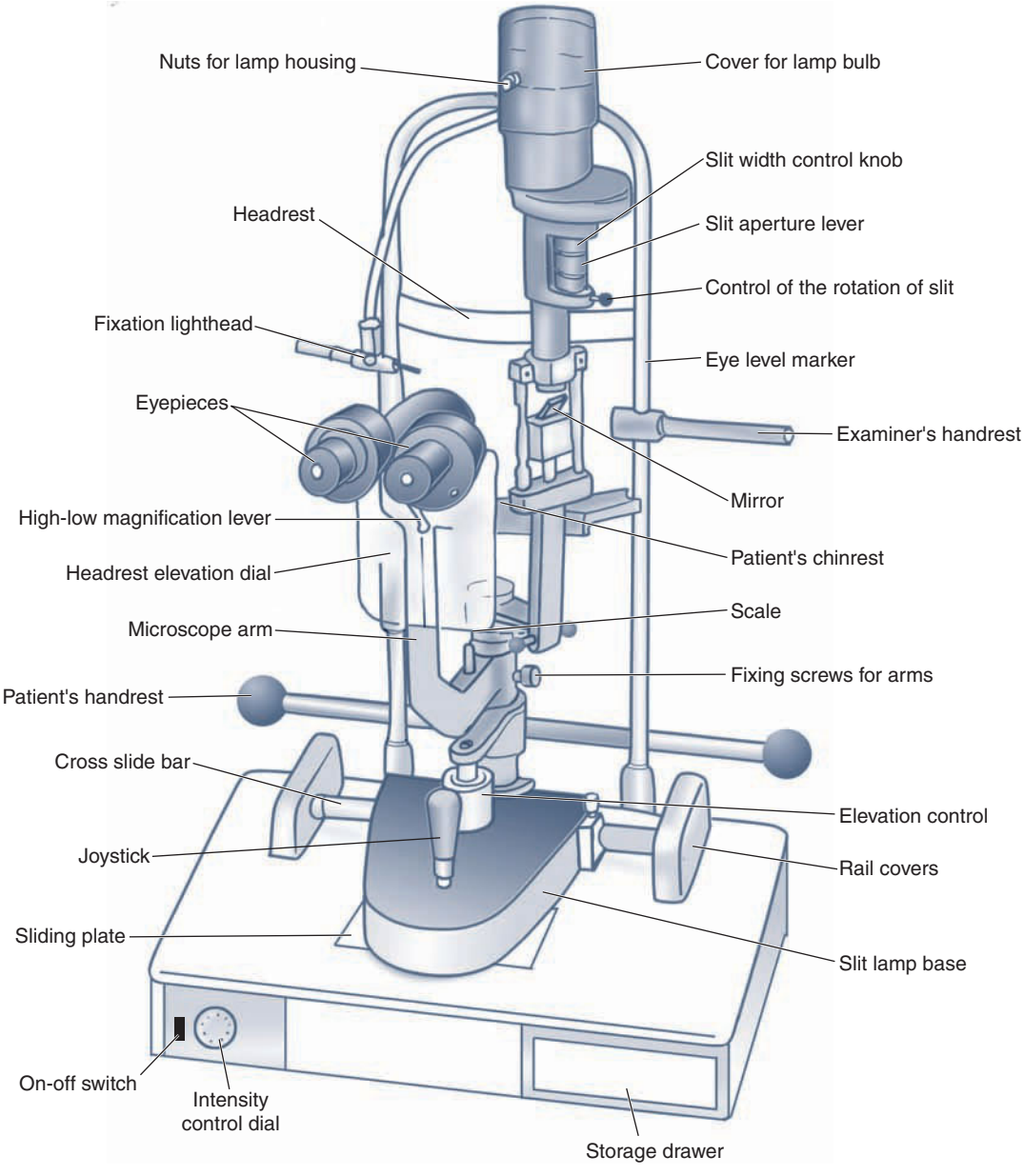


FIGURE 153-17. The slit lamp.

higher power may be helpful when examining the details of the cornea or looking for cellular or inflammatory material within the anterior chamber.

The next step is to find the on–off switch. It is typically located just under the table base and on the left. Place one hand in the examination plane against the headband where it should pick up a focused beam of light to ensure that the light source is functional. Observe the top of the slit lamp to determine whether light shines through the casing that houses the light source. The bulb will periodically need to be replaced. Remove the casing and replace the bulb as needed. The correct position for the bulb is obvious as it has a notch that fits into a corresponding notch in the housing.

The focused light can be adjusted in intensity, color, vertical width, and horizontal width. The standard position is for the light to be at its maximum size with a circular beam of white light at a moderate intensity. This position is used for scanning the eye and examining the external structures. Three independent adjustment mechanisms interact to create the most appropriate illumination to meet examination needs.

The color of the light and the intensity of the light originate from the same mechanism. Most of the positions represent variations in intensity of a white light. There are two other options for color. The cobalt blue light is used for emphasizing corneal lesions that pick up fluorescein stain. The green light or red filter is helpful for patients who cannot tolerate the white light secondary to photophobia. This green light will cause red structures to appear darker or black.

The horizontal width of the light can be adjusted with the knob located at the base of the middle arm. The light can be narrowed to 1 to 2 mm or a "slit" for evaluating the depth of corneal lesions (**Figure 153-18A**). The vertical control is used in conjunction with the horizontal control. Narrow the horizontal width to 2 to 3 mm and the vertical width to 2 mm when examining the anterior chamber. This creates a small focused beam. Rotate the light 30° to 60° in order to illuminate the depth of the anterior chamber (**Figure 153-18B**). This orientation is most beneficial when attempting to identify cellular or inflammatory material within the anterior chamber.

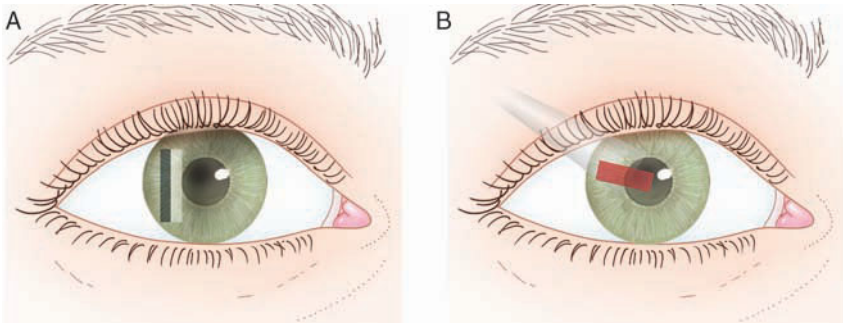


FIGURE 153-18. The light of the slit lamp. **A.** A narrow slit to focus on the cornea. **B.** A focused beam of light directed from a 45° angle illuminates the anterior chamber.

PATIENT POSITIONING

Cleanse the chin rest and the forehead bar before the slit lamp is used to examine a patient. The patient must be able to tolerate a seated position, leaning slightly forward with their head placed in the chin rest and their forehead pressed against the bar to use the slit lamp (**Figure 153-19**). The slit lamp examination cannot be completed in a patient who cannot remain in a seated position. **Patients will often need to be reminded to keep their head in the chin rest and their forehead against the bar.** Subtle movements from this position will change the viewing plane and disrupt the focus on the structures of the eye. **Always check the patient's position if you are having difficulty focusing the slit lamp.**

A motorized chair with the ability to move up and down is optimal for this examination. The slit lamp can be adjusted to match the height of a chair or stretcher if necessary by pressing the release bar located below the slit lamp table to move the entire table up and down. When the table height is properly positioned, release the bar to lock the table at this new height. The level of the chin bar can be adjusted to account for the subtle differences in the length of individual patient faces. Rotate the knob located at the base of the chin rest apparatus to move it up and down. Raise or lower the chin bar so that the reference mark located below the forehead bar is at the patient's eye level.

Use the joystick to move the slit lamp and scan the patient's eye. The patient must keep their eye in a fixed position while the Emergency Physician uses the joystick to move the slit lamp and scan the eye. Instruct the patient to focus their eye on your shoulder or earlobe. It is very difficult for the Emergency Physician to focus and complete a thorough examination if the patient's eyes wander.

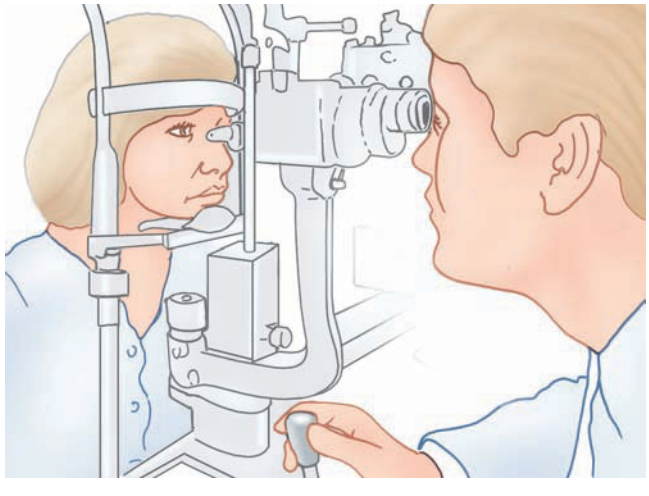


FIGURE 153-19. Patient positioning in the slit lamp.

THE SLIT LAMP EXAMINATION

The slit lamp examination begins with an overall microscope-enhanced evaluation of the external structures of the eye including the lash line, the bulbar conjunctiva, the palpebral conjunctiva, and the lacrimal puncta. The cornea is best evaluated primarily with a wide beam and the fine details are evaluated with the slit. **Do not focus the light into the pupil for an extended period of time.** It is very uncomfortable for the patient and may result in injury. The normal cornea is perfectly clear and homogeneous. Note any deviation from this if applicable. Specific abnormalities are best documented in writing in addition to a basic schematic diagram.

The anterior chamber should be clear and without particulate matter. It may be difficult initially to identify cells floating in the anterior chamber. They appear like "dust in a sunbeam." The cells, if not clumped, are barely visible with the microscope at the lowest magnification. They do, however, often reflect the light slightly, and this may catch the Emergency Physician's eye. Take care to pay special attention to the lower one-fourth of the anterior chamber because, in an upright position, cells and inflammatory products tend to settle and may form a meniscus. Flare is the noncellular inflammatory material in the anterior chamber that makes the aqueous humor appear hazy, or gelatinous, and obscure the details of the iris. Use the high-power magnification to identify particulate matter after scanning the anterior chamber with the low-power magnification.

ADMINISTRATION OF FLUORESCEIN

Repeat the corneal examination with the aid of fluorescein stain after the slit lamp examination is completed without stain. Fluorescein is a hydrophilic substance that stains and illuminates any portion of the cornea where there is a breech in the epithelium. The addition of fluorescein helps to illuminate corneal lesions that might otherwise go unrecognized. This includes corneal abrasions or keratopathy associated with viral infections. Fluorescein is most commonly packaged as individual single-use strips. There is the potential for infectious agents to be transmitted when one fluorescein strip is used for both eyes or when a multidose vial of fluorescein solution is used. Take care to avoid iatrogenically transmitted infections.

Remove all contact lenses before the slit lamp examination and fluorescein staining. Accidental application of fluorescein without their removal will permanently stain contact lenses. Place a small drop of saline or topical ophthalmic anesthetic solution onto the tip of the fluorescein strip. Retract the lower eyelid by placing pressure on the skin overlying the inferior orbital rim and distracting it downward. Ask the patient to look upward to facilitate the administration of the stain and to avoid inadvertent corneal injuries caused by the strip itself. Touch the fluorescein strip lightly against the palpebral conjunctiva of the inferior eyelid (**Figure 153-20A**).

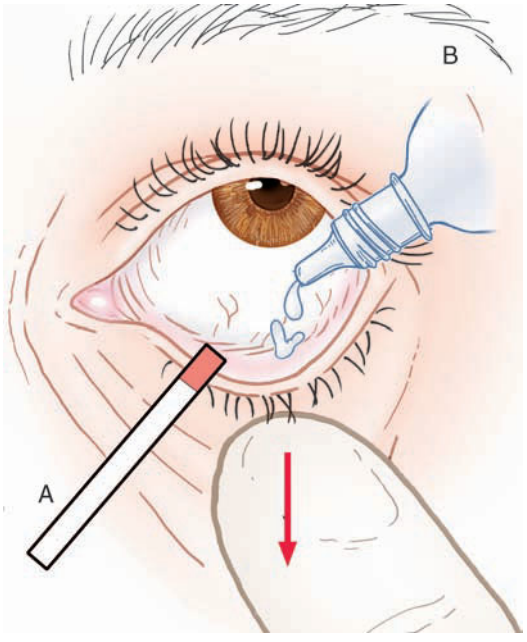


FIGURE 153-20. Instillation of fluorescein stain. **A.** Fluorescein-tipped strips. **B.** Aqueous fluorescein solution.

Remove the fluorescein strip. Ask the patient to gently open and close their eyelids to distribute the fluorescein across the entire eye.

Aqueous fluorescein solution can be used as an alternative to the paper strips. Retract the lower eyelid and instill two drops of fluorescein into the cul-de-sac of the lower eyelid (**Figure 153-20B**). **Take special care when using fluorescein to avoid accidentally staining the patient's skin, clothing, or contact lenses.** Most Emergency Departments use fluorescein strips rather than liquid solution. The liquid solution, or the tip of the applicator, can become contaminated and transmit infection.

A small amount of fluorescein is required to adequately stain the cornea. A common mistake is to apply an excessive amount of fluorescein stain. This illuminates the entire tear film and makes it difficult to evaluate subtle lesions on the cornea. Ask the patient to blink several times to remove the excess fluorescein from the cornea. This maneuver will not remove the fluorescein adhering to any corneal defects. If blinking does not remove the excess fluorescein, place one or two drops of sterile saline or eyewash onto the eye. Avoid the use of excessive fluorescein as it is likely to obscure exam and potentially stain the patient's skin.

The underlying cell layers of the cornea will hold the fluorescein stain if the corneal epithelium is injured. This allows corneal lesions to be visualized. Use the cobalt blue light, preferably in conjunction with the slit lamp, to identify and evaluate any corneal lesions that become apparent. The regions that stain with fluorescein and are visible with the cobalt blue light will appear bright yellow to yellow-green. **The green light on the ophthalmoscope and the slit lamp are not intended to be used to illuminate the fluorescein stain.** The green light will enhance the stain in some circumstances but is not as reliable as the cobalt blue light source.

EYEDROP ADMINISTRATION

TRADITIONAL METHODS

Topical ophthalmologic medications are used for examining and treating the eyes. Eyedrops and ophthalmologic ointments are most effectively and accurately instilled within the lower eyelid (**Figure 153-21**). Instruct the patient to direct their head toward the examiner with their eyes looking upward (**Figure 153-21A**). Patients often close their eyes at this point. Retract the lower eyelid, without placing pressure on the globe, and expose the inferior cul-de-sac (**Figure 153-21B**). Apply the drops, or ointment, in the cul-de-sac (**Figure 153-21C**). Close the eyelid and apply thumb pressure over the lacrimal duct (**Figure 153-21D**). This prevents the liquid medicine from immediately draining through the nasolacrimal duct and

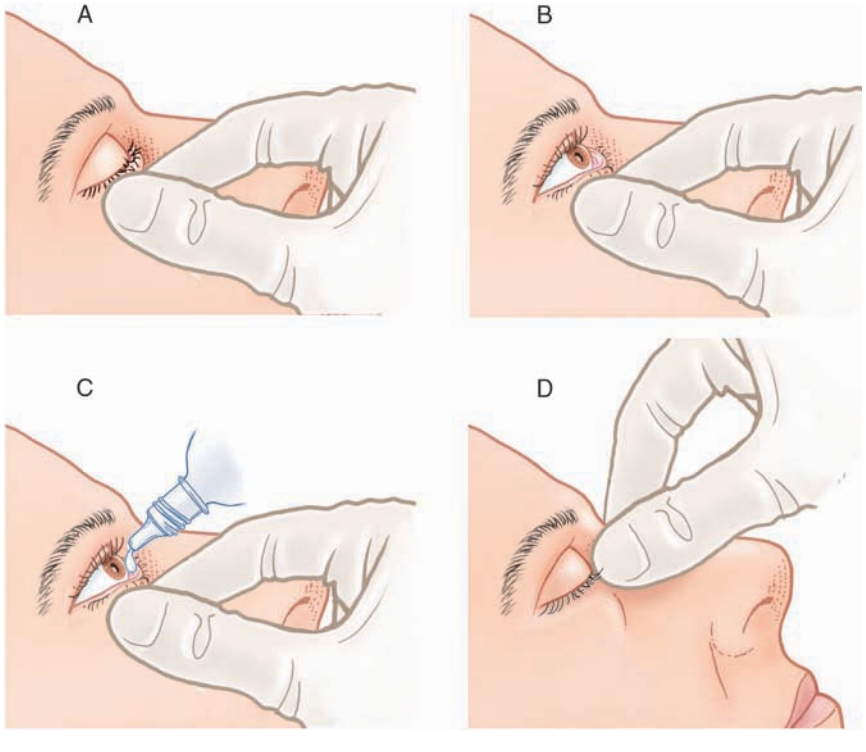


FIGURE 153-21. The instillation of eyedrops. **A.** Grasp the lower eyelid. **B.** Pull the lower eyelid downward and outward to expose the cul-de-sac. **C.** Place the drops into the cul-de-sac. **D.** Apply thumb pressure over the lacrimal duct to prevent drainage of the drops into the nose.



FIGURE 153-22. The instillation of eyedrops in an uncooperative patient.

into the nose. Instruct the patient to blink once or twice to quickly distribute the medication across the globe. This last step, applying pressure on the lacrimal duct, is unnecessary if instilling an ophthalmic ointment.

UNCOOPERATIVE PATIENTS

Some patients require but do not want medication in their eyes. The best examples of these challenging patients are infants, small children, and patients with altered mental status. Prying the eyes of these patients open and applying the drops is difficult for both the physician and the patient. **Forcefully opening the eyelids is potentially dangerous because secondary injuries may occur.** The majority of medication is typically applied to the physician's hand or the stretcher, as anyone who has tried this approach knows. An alternative approach in this situation is advisable.

The problem is that the uncooperative patient squeezes their eyes closed tightly. Place the patient supine with an assistant holding the head in a fixed upright position with the eyes facing the ceiling in order to overcome this challenge (**Figure 153-22**). Note the small anatomic depression created over the medial canthus of each eye when they are closed tightly. Place the eyedrops in this anatomic depression to create a shallow pool (**Figure 153-22**). Firmly maintain the patient's head in this position until they spontaneously open their eyes and allow the medication to spread across the globe.

OPHTHALMIC ANESTHETIC AGENTS

Two types of eye medications are required in drop form for most routine ophthalmologic examinations, a topical ophthalmic anesthetic agent, and a dilating agent. Topical ophthalmic anesthetic agents provide relief from eye pain and photophobia. This may help the patient to cooperate with the necessary examination. Topical ophthalmic anesthetic agents may be used as adjuncts to fluorescein application and to facilitate the placement of eyelid retractors. They may at times be used as an adjunctive diagnostic tool. There are several possible causes of eye pain and photophobia that must be differentiated, some of which may coexist. Complete symptom relief with a topical ophthalmic anesthetic agent suggests that the etiology of the pain is the conjunctiva or cornea.

Tetracaine hydrochloride and proparacaine hydrochloride are the most commonly available agents. Their onset of action and duration of action are similar. The onset is within 1 minute and lasts approximately 10 to 20 minutes. Tetracaine hydrochloride (Pontocaine) instillation often results in a transient stinging sensation that lasts 3 to 10 seconds before dissipating. Proparacaine hydrochloride (Ophthetic or Ophthaine) does not result in the stinging sensation.

Topical ophthalmic anesthetic agents are toxic to corneal epithelial cells and can delay corneal healing.[15] **They are currently used in the Emergency Department only to aid in the diagnosis and evaluation of an eye problem. They should not be prescribed for treatment outside the Emergency Department except by an Ophthalmologist.** These agents are currently being used for up to 4 days on an outpatient basis after photorefractive keratectomy surgery.[16] Several small studies suggest these agents are safe to use for a few days without adverse effects.[17,18] With additional studies, the Emergency Department practice of not prescribing topical ophthalmic anesthetic agents for outpatient use may change.

PUPILLARY DILATING AGENTS

Dilating agents are used as an adjunct to the fundoscopic examination. **Always perform and document a complete pupillary examination before instilling dilating agents.** It is important to document the use of dilating agents and the time of administration. **Avoid using dilating agents in patients who require serial pupillary examinations to follow their neurologic status. Dilating agents are contraindicated in patients with a known or suspected narrow iridocorneal angle.** Dilating the pupil may result in acute angle-closure glaucoma. Some intraocular lens implants may become dislodged if the pupils are pharmacologically dilated. **Inquire about ocular surgery, known narrow angles, and glaucoma prior to dilating any pupils.**

Dilating agents are categorized as mydriatics and cycloplegics. **All dilating agents are stocked with red caps**. **Mydriatic agents directly dilate the pupil while cycloplegics paralyze the ciliary muscles. Cycloplegic agents should not be used in patients who require serial neurologic examinations.** Choose a noncycloplegic mydriatic agent such as phenylephrine to dilate the pupils of a patient requiring serial examinations. The duration of action is significantly shorter than that of a cycloplegic agent. **Phenylephrine is systemically absorbed and may be inappropriate for patients with hypertension or cardiac conditions.** A combination of a mydriatic agent (e.g., phenylephrine) and a shorter-acting cycloplegic agent (e.g., cyclopentolate) is optimal when maximal dilation is necessary or when a single agent is ineffective.

Most Emergency Departments stock or have access to five dilating agents. The choice of agents depends upon the length of time required for dilation, the need for a cycloplegic agent, and the need for a mydriatic agent. Atropine (Isopto Atropine) produces cycloplegia lasting 5 to 10 days and mydriasis lasting 7 to 14 days. Cyclopentolate (Cyclogyl, AK-Pentolate, Pentolair) produces cycloplegia lasting 6 to 24 hours and mydriasis lasting 24 hours. Homatropine (Isopto Homatropine) produces cycloplegia and mydriasis lasting 1 to 3 days. Phenylephrine (Neo-Synephrine, Mydrin, Relief) produces mydriasis lasting 5 hours. Tropicamide (Mydriacyl) produces mydriasis lasting 4 to 6 hours.

THE FUNDOSCOPIC EXAMINATION

A fundoscopic examination is an essential part of every eye evaluation. It is particularly helpful when the patient complains of visual disturbances or visual loss. Examine the patient's right eye first. Hold the ophthalmoscope in the right hand and use the right eye to examine the patient's right eye. Remember "right eye to right eye and left eye to left eye" or the Emergency Physician may otherwise find themself in an awkward nose-to-nose position with the patient.

Instruct the patient to focus the eye not being examined on a fixed object over the Emergency Physician's shoulder and approximately 6 to 8 feet away. It is important that the patient maintain their focus on the object throughout the complete examination of the eye.

Set the ophthalmoscope initially at 0. Adjust the dial as the examination begins to adjust for refractory errors. Moving the dial into the red numbers moves the point of focus forward toward the red retina. Moving the dial into the black numbers moves the point of focus closer to you. Approach the eye from a slightly lateral position to quickly identify the medial position of the optic disk. Position the ophthalmoscope as close as possible to the patient's eye without making contact. Imagine looking at the fundus through a peephole. The closer you get, the wider the view on the other side. By the same analogy, the larger the peephole the better the view on the other side. Thus, dilate the patient's pupils to obtain the best results from the ophthalmoscope examination.

Adjust the diameter of the light down to the size of the patient's pupil in order to avoid the bright reflection off of the iris if dilation is not possible. This bright reflection is a common reason for inadequate visualization of the fundus. The patient's eyes are often moving if the structures seem to move in and out of focus. Remind the patient to focus on one point in the distance.

Inspect the eye grounds for uniformity. The normal color of the fundus is creamy peach to pink, but may be pigmented in darker skinned people. A pale fundus with a small cherry-red spot in the region of the macula suggests an infarction generally associated with a retinal artery occlusion. The optic disk is located on the nasal aspect of the fundus. If the optic disk does not come into view, follow the blood vessels that extend from the disk to the periphery of the retina. The disk margin should be sharp with the exception of the nasal aspect that may appear slightly blurred in a normal eye. Papilledema appears as diffusely blurred disk margins. Papilledema may be the result of localized inflammation of the optic nerve or may be the result of elevated intracranial pressure.

The veins will appear darker and wider than the arteries. Evaluate the blood vessels for evidence of hemorrhages and irregularities. Acute hemorrhages may be helpful in the diagnosis of a variety of problems such as a hypertensive emergency or the shaken baby syndrome. Give careful consideration to the clinical setting. A helpful finding in the patient suspected of having increased intracranial pressure is the presence or absence of venous pulsations. Venous pulsations are best seen as the veins cross into the optic cup. The presence of venous pulsations is a normal finding. The first sign as the intracranial pressure rises is a loss of venous pulsations followed later by papilledema. The green light or red filter helps to provide a sharper image when evaluating the retinal vessels in detail.

Examine the fovea and the surrounding macula. This area is located approximately two to three disk diameters (DD) lateral to the optic disk. Instruct the patient to look directly into the light to bring the fovea and macula into view. The target setting on the ophthalmoscope is helpful for this purpose. Look into the patient's eye with the ophthalmoscope turned to the target. Instruct the patient to look directly into the center of the target. The fovea will be found at the center of the target in your view as well.

Examine the vitreous chamber for evidence of a vitreous hemorrhage when a retinal detachment is suspected or when the patient complains of floaters. The fluid within the vitreous chamber is gelatinous so blood within it does not dissipate quickly. Blood within this chamber appears as clouds, spots, or veils to the patient and the examiner. Their color is typically described as black or red. Set the ophthalmoscope to +10 to move the point of focus anteriorly toward the examiner's eye to evaluate the vitreous. Dial the ophthalmoscope down as the examination proceeds. Each click results in focusing a little deeper within the vitreous chamber until the point of focus is upon the retina at the posterior aspect of the chamber.

INTRAOCULAR PRESSURE MEASUREMENT

The measurement of intraocular pressure should be included in the eye examination. It is particularly important in patients with eye pain and visual loss. Refer to Chapter 156 regarding the complete details of ocular tonometry.

SUMMARY

Approach all eye complaints with a detailed history that includes a chief complaint, the duration of symptoms, and the natural history of their evolution. It is important to inquire about exposures and trauma. The past medical history must include the patient's baseline visual acuity and any history of eye problems. Perform a complete examination on all patients with eye complaints. Always document an accurate visual acuity and carefully inspect all of the eye structures. A thorough approach in all patients with eye complaints improves diagnostic accuracy. The end result is decreased morbidity and long-term complications in this vital sensory apparatus.

154 Contact Lens Removal

Dino P. Rumoro

INTRODUCTION

The Emergency Physician must be familiar with the proper technique of removing both soft and hard contact lenses from patients who are unable to do so on their own for various reasons. Patients with altered mental status are at particular risk of corneal damage if contact lenses are allowed to remain in place. Healthy individuals who wear contact lenses overnight experience a 4- to 15-fold increase in the risk of corneal injury over those who remove their contact lenses daily.[1] The explanation for this increased risk of injury is based on the development of corneal hypoxia and an immune response to antigens present on the lens surface, both of which lead to an inflammatory response and susceptibility to infectious organisms.[1] This results in an increased incidence of ulcerative keratitis, *Pseudomonas aeruginosa* infection, and corneal neovascularization.[2,3]

ANATOMY AND PATHOPHYSIOLOGY

Contact lenses rest on a three-layer tear film (outer lipid, middle aqueous, and inner mucus layer) that covers the corneal and conjunctival epithelium. This tear layer provides oxygen and nutrients to the avascular cornea. The cornea also receives nutrition from blood vessels at the limbus and the aqueous humor. It is believed that contact lenses increase tear evaporation and disrupt the three-layer tear film, leading to the lack of corneal oxygenation and the symptoms of dry eye.[4] A dry eye causes discomfort and corneal edema with resultant hazy vision. The normal blinking action initiates contact lens movement and a "fresh" flow of oxygenated tears over the cornea in an awake patient. This blinking action is not present in the sleeping or comatose patient.

The normal resting position of the contact lens is over the cornea. It may occasionally drift from the center of the eye and

relocate over the sclera or in various parts of the eye, including under the upper eyelid. Thorough exploration of all aspects of the eye is essential when evaluating an individual for the presence of contact lenses prior to their removal. This evaluation should include inspection under the lower eyelid margin as well as eversion of the upper eyelid. Failure to adequately perform this examination can lead to the mistaken belief that a contact lens does not exist. In turn, a contact lens that remains in place acts as a foreign body and can lead to chronic irritation, inflammation, and development of a mass. Mass development from a retained contact lens typically occurs in the upper fornix of the eyelid and requires double eversion of the eyelid for identification and retrieval.[5]

INDICATIONS

Contact lenses must be removed from any patient who is unconscious or suffers an ocular injury. Contact lenses should not be left in place if fluorescein stain is to be used to examine the eye. Fluorescein can permanently stain the contact lens material. Give patients the opportunity to remove their own contact lenses if there are no contraindications (i.e., immobilization or ocular trauma). Patients are usually quite adept at removing their own contact lenses. Remove the contact lenses if the patient is unable to remove them or cannot remove them.

CONTRAINDICATIONS

The only absolute contraindication to removing a contact lens would be in the case of a ruptured globe. Leave the contact lens in place for the Ophthalmologist to remove at the time of their examination and/or surgical repair. Extreme caution must be exercised to avoid unnecessary pressure on the eye itself so as not to complicate the injury when severe ocular damage has occurred. Place an eye shield and not an eye patch to avoid pressure on the globe with resultant exacerbation of the injury (Chapter 161).

EQUIPMENT

- Normal saline
- Two cups, labeled "left" and "right"
- Hard lens remover suction cup device, optional
- Soft lens remover device, optional
- Cotton-tipped applicators

PATIENT PREPARATION

Explain to the patient, if they are awake, that their contact lenses must be removed. A signed consent is not required to remove a contact lens. Place the patient sitting or supine, whichever is most appropriate for the current clinical situation. Place several drops of a saline solution onto the eye and wait 5 to 10 minutes to allow the saline to penetrate the lenses. This maximally moistens the contact lenses to the point where they can be seen to slide easily over the surface of the eye when the patient blinks.

All contact lenses should be centered over the cornea for ease of removal by gentle manipulation of the eyelids. The lenses may often become displaced from the cornea. Care must be taken to search for the lens in other parts of the eye. Shine a penlight at an angle to the eye to aid in the search. A common location for a displaced contact lens to migrate is under the upper eyelid. **Evert the upper eyelid if a contact lens cannot be found elsewhere to complete the search before assuming either that the lens fell out or the patient is not wearing contact lenses.** Instill fluorescein into the eye if the patient still insists that it is present. The fluorescein will pool around the edges of the contact lens and make it easy to locate. **Warn the patient that fluorescein may permanently stain their contact lens.**

Prepare the equipment. Locate the equipment required to remove the contact lenses. Label two cups, "left" and "right," to place the lenses in after they are removed. Fill the cups with enough saline to cover the contact lenses. The person performing the procedure should wear powderless gloves to prevent the powder from irritating the eye. Wipe powdered gloves clean with a saline or a water-moistened towel to remove the powder. Powdered gloves can also be placed under running water to flush away the powder.

HARD CONTACT LENS REMOVAL TECHNIQUES

A hard contact lens can be identified by its small size (6 to 10 mm). It is smaller than the cornea. Center the hard contact lens on the cornea. Place the index finger (or thumb) of one hand at the base of the eyelashes of the upper eyelid and the index finger (or thumb) of the opposite hand at the base of the eyelashes of the lower eyelid (**Figure 154-1A**). Gently, but firmly, approximate the eyelids by moving them toward the center of the cornea until the margins of the eyelids touch the edges of the hard contact lens (**Figure 154-1B**). Press slightly harder on the lower eyelid until the bottom edge of the

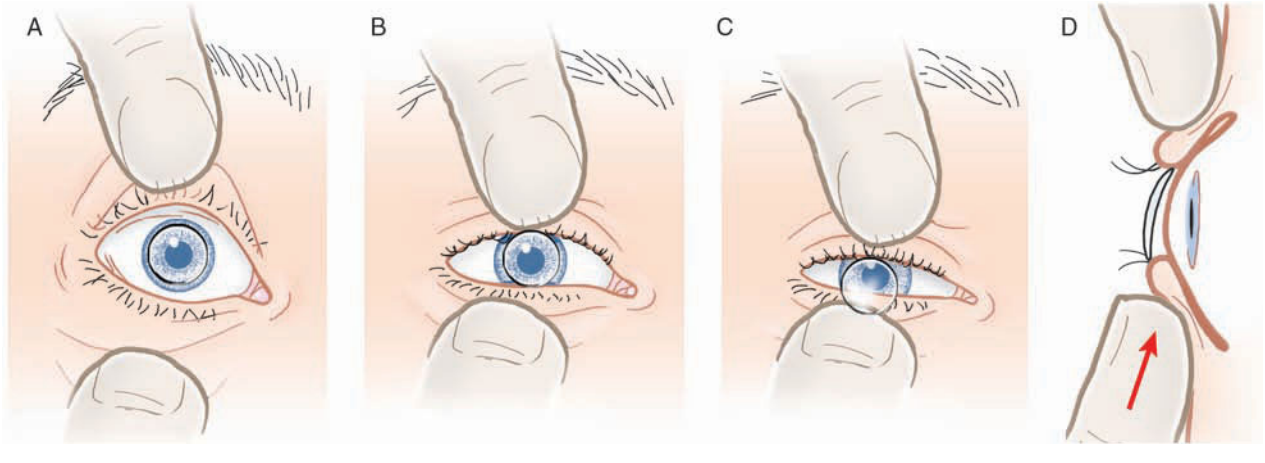


FIGURE 154-1. Hard contact lens removal. **A.** Use both thumbs to open the eyelids. **B.** Close the eyelids until the edges of the eyelids just contact the lens. **C.** Push the edge of the lower eyelid under the edge of the contact lens to pop it off the eye. **D.** Lateral view of the lower eyelid pushing the contact lens off the eye.

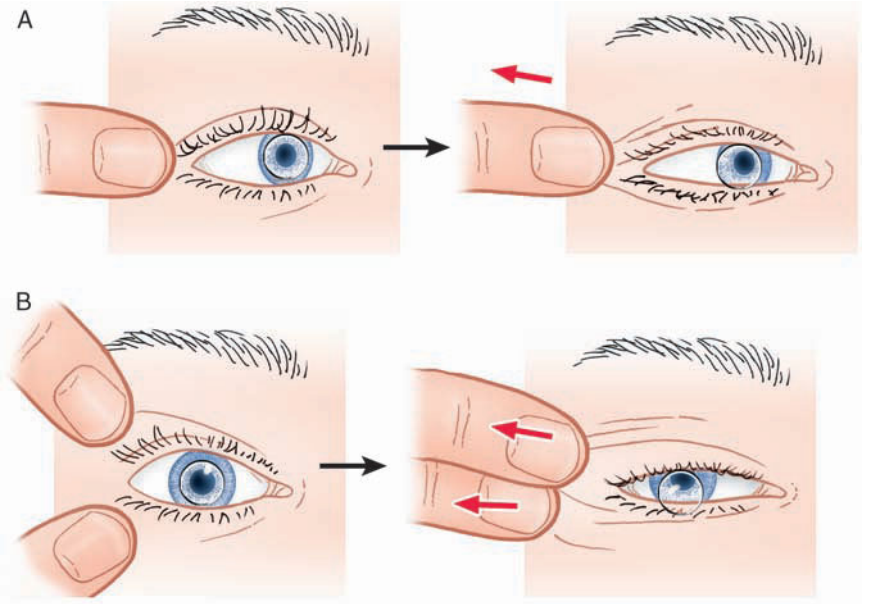


FIGURE 154-2. Alternative hard contact lens removal techniques. These methods do not apply pressure onto the globe. Apply laterally directed pressure to the skin lateral to the eyelids (**A**) or to the eyelids (**B**) to "catch" the contact lens and pop it off the eye.

hard contact lens lifts off the cornea utilizing the edge of the lower eyelid as a fulcrum (**Figures 154-1C & D**). Continue to push the eyelids together until the hard contact lens is lifted completely off the cornea and can be easily grasped.[6,7]

The patient who is awake and alert may not like the Emergency Physician's fingers near their eyes. Pull the skin of the lateral margin of the eyelids laterally with an index finger (**Figure 154-2A**). Alternatively, place one finger on the lateral edge of the upper eyelid and one finger on the lateral edge of the lower eyelid and pull laterally (**Figure 154-2B**). Instruct the patient to look downward and inward toward their nose. The hard contact lens will pop off the cornea. Grasp and remove the contact lens. This technique does not put as much pressure on the globe as the previous technique, an advantage if the patient has ocular trauma.

A commercially produced suction cup-like rubber device, resembling a golf tee, can be used to remove hard contact lenses if available (**Figure 154-3**). Moisten the surface of the device with a drop of saline. Gently touch the suction cup to the center of the hard contact lens. Suction will form and result in the hard contact lens adhering to the device. Lift the device and the attached contact lens from the cornea. **Slide the hard contact lens sideways to remove it from the suction cup. Do not attempt to pull the hard contact lens off the suction cup as this may damage the contact lens.**

A final technique involves the use of a cotton-tipped applicator (**Figure 154-4**). Moisten the cotton with saline. Place the cotton-tipped applicator over the lower edge of the hard contact lens (**Figure 154-4A**). Carefully and gently slide the hard contact lens off the cornea and onto the sclera with the moistened cotton-tipped applicator. Gently press the cotton-tipped applicator into the sclera and under the edge of the hard contact lens (**Figure 154-4B**). Lift the hard contact lens from the sclera. **Do not use the cotton-tipped applicator to elevate the hard contact lens from the cornea as this can result in a corneal abrasion.**[8]

SOFT CONTACT LENS REMOVAL TECHNIQUES

Soft contact lenses can be identified by their larger sizes (12 to 14 mm). They usually extend to, or just beyond, the corneal-scleral junction. There are numerous techniques to remove a soft contact lens (**Figures 154-5** to **154-7**). The easiest and simplest method is to remove it manually (**Figure 154-5**). To remove the contact manually, retract the lower eyelid with the nondominant index finger

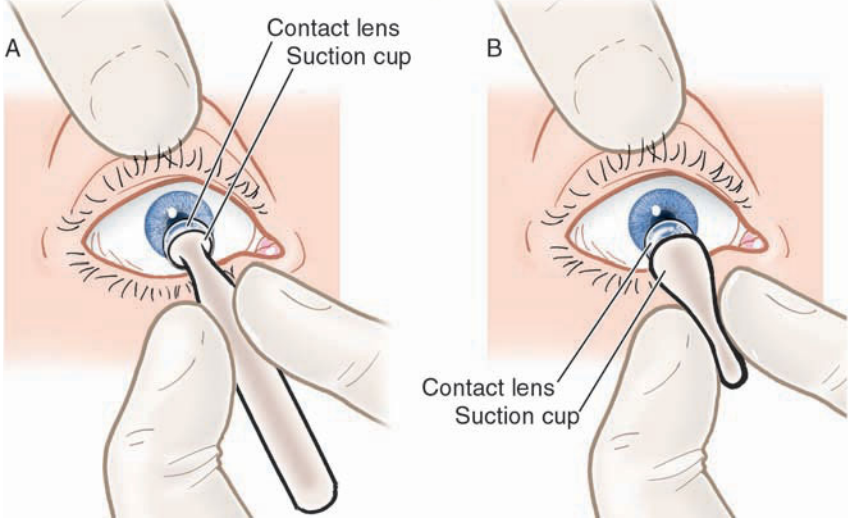


FIGURE 154-3. Suction cup removal of hard contact lenses. **A.** Suction cup on a plastic handle. **B.** Fingertip held suction cup.

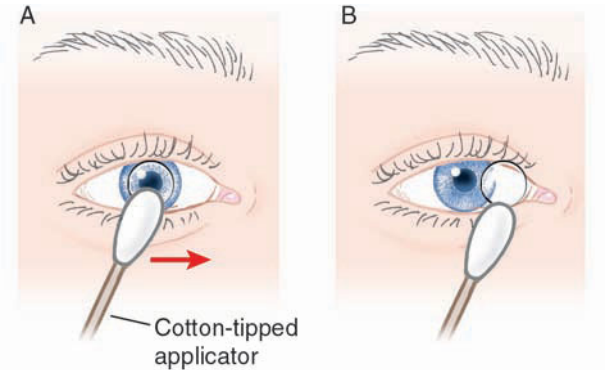


FIGURE 154-4. A cotton-tipped applicator to remove a hard contact lens. **A.** Place a cotton-tipped applicator against the lower edge of the hard contact lens. Push the hard contact lens onto the sclera. **B.** Push the cotton-tipped applicator under the edge of the contact lens to lift it off the eye.

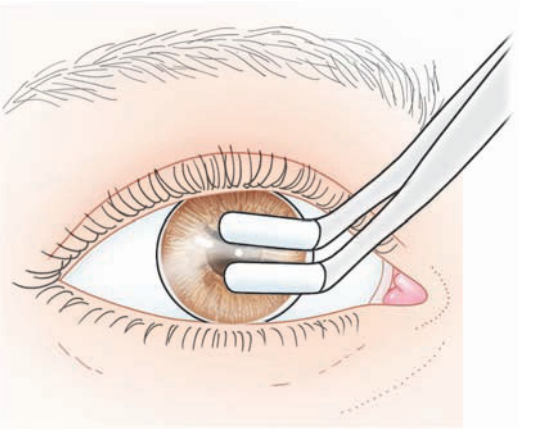


FIGURE 154-6. A tweezer-like device to grasp and remove the soft contact lens.

(**Figure 154-5A**). The soft contact lens will slide partially onto the conjunctival surface of the lower sclera. Gently grasp the soft contact lens between the thumb and index finger of the dominant hand. Pinch the fingers together and remove the soft contact lens.

A second technique to remove soft contact lenses is illustrated in **Figure 154-5B**. Gently place the index finger and thumb of the non-dominant hand on the upper and lower eyelids, respectively. Retract the eyelids. Gently grasp the soft contact lens between the thumb and index finger of the dominant hand. Slide the soft contact lens inferiorly. Gently pinch the fingers together to pull the soft contact lens from the eye.[6]

A third technique to manually remove a contact lens uses the patient's eyelids (**Figure 154-5C**). Place the thumb of the non-dominant hand and dominant hand on the upper and lower eyelid, respectively. Retract the eyelids until the edges of the contact lens are fully visible. Close both eyelids against the superior and inferior edges of the soft contact lens. Continue to close the eyelids until the contact lens pops off the eye. Grasp and remove the soft contact lens with the dominant hand.

A commercially available rubber tweezer-like device can be used to remove soft contact lenses. Place the rubber tips of the device onto the center of the soft contact lenses (**Figure 154-6**). Gently

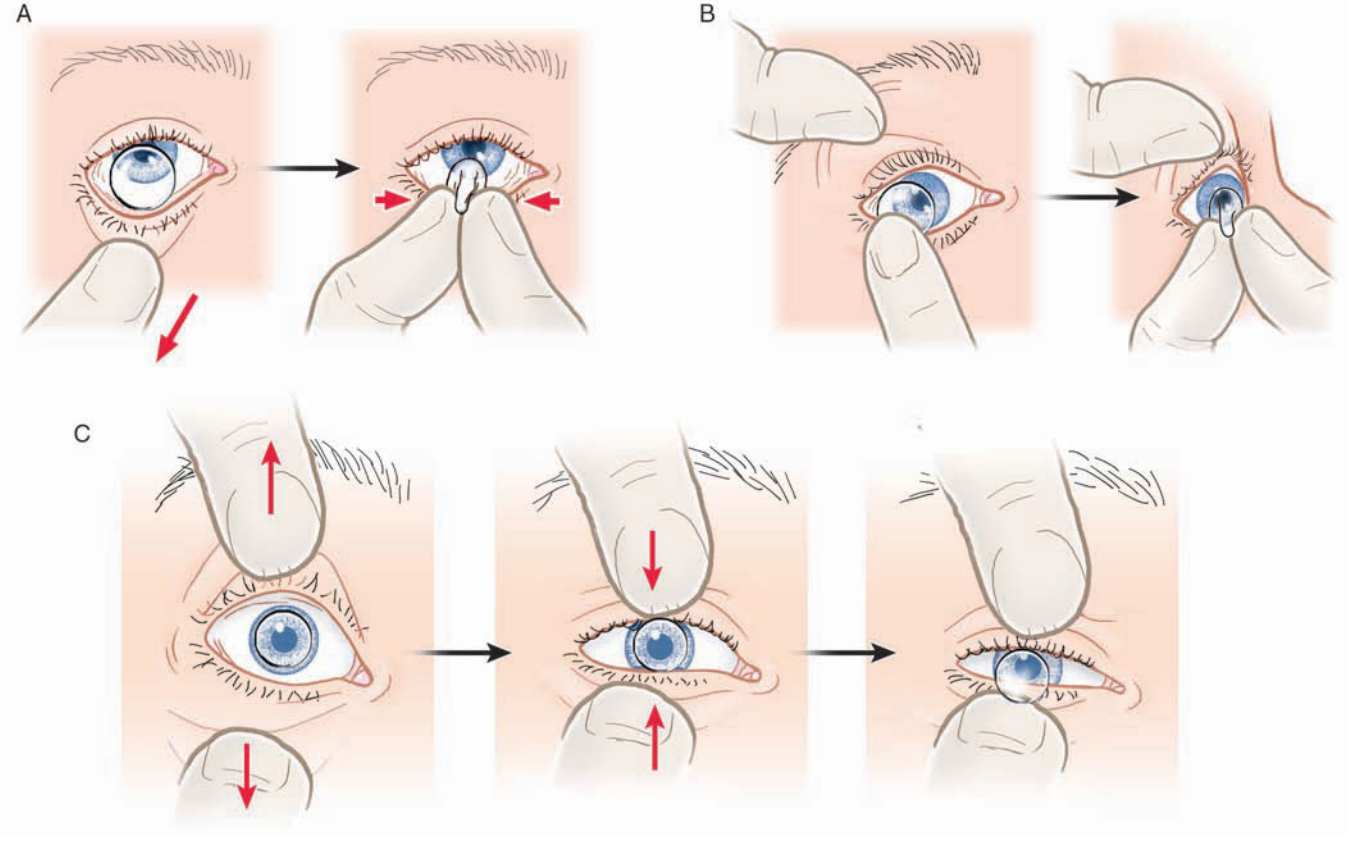


FIGURE 154-5. Manual soft contact lens removal techniques. **A.** Pull the lower eyelid downward and grasp the contact lens. **B.** Retract the eyelids. Slide the soft contact lens off the cornea and onto the sclera. Grasp and remove the contact lens. **C.** Use the patient's eyelids to pop the contact lens off the eye.

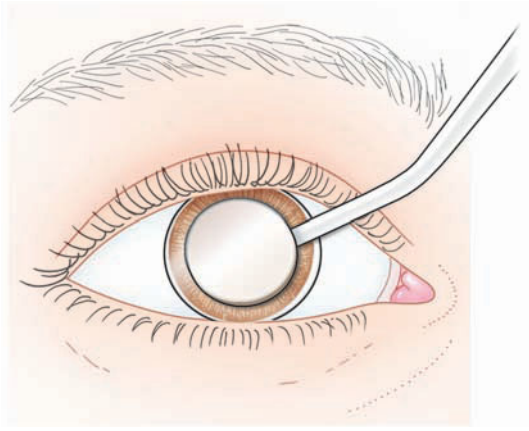


FIGURE 154-7. A rubber pad to remove a soft contact lens.

squeeze the tweezers closed using minimal pressure. The soft contact lens will fold and lift off the eye. Remove the soft contact lens from the eye.

A commercially available rubber disc on a stick can be used to remove soft contact lenses. Place the rubber disc over the center of the soft contact lens (**Figure 154-7**). Apply gentle pressure to slide the soft contact lens onto the sclera. Lift the stick to remove the attached soft contact lens. The rubber disc may occasionally not stick to the soft contact lens. Apply a drop of saline to the rubber disc and repeat the procedure. The drop of liquid will form a seal between the rubber disc and the soft contact lens.

SCLERAL LENS REMOVAL TECHNIQUES

The scleral lens is essentially a very large, soft contact lens. It is approximately the size of a quarter and covers the cornea and sclera. Remove the scleral lens using the same techniques described to remove a soft contact lens.

AFTERCARE

Place removed contact lenses in the appropriately marked container. Ensure that the contact lenses are covered completely with saline solution. Perform an eye examination using fluorescein eye drops if the patient complains of eye pain after contact lens removal. The procedure may have resulted in a corneal abrasion.

COMPLICATIONS

Any attempt to remove contact lenses with fingernails or other solid objects not approved for the removal of contact lenses can cause corneal abrasions. Their use must be avoided. Proper contact lens removal techniques can also result in corneal abrasions. Do not patch corneal abrasions resulting from contact lens removal in order to prevent an infectious process.[8] The suction cup of the hard contact lens remover may occasionally be inadvertently placed on the cornea. **Do not pull it off the cornea.** Slide it to the lateral corner of the sclera and remove it with a twisting motion.

Never remove a contact lens if there is concern for a potential globe perforation. The techniques described in this chapter are gentle yet put pressure on the globe while removing a contact lens. This pressure on the globe may result in extrusion of the intraocular contents (i.e., lens or vitreous) and cause permanent blindness. Use a suction cup device (hard contact lens) or a rubber disc (soft contact lens) if the contact lens must be removed before the Ophthalmologist arrives.

Additional complications include the inability to remove the lens and damage to the contact lens itself.[8] Consult an Ophthalmologist or Optometrist if a contact lens cannot be removed from the cornea. Desiccated lenses that are not properly rehydrated prior to removal can result in the removal of the corneal epithelium and a corneal abrasion.[8] A properly hydrated lens will slide easily over the surface of the eye. Apply saline drops onto the eye to hydrate the contact lens prior to removal.

SUMMARY

Removal of contact lenses is a procedure that all Emergency Physicians must be able to perform on any patient who is unconscious, who has ocular trauma, or who cannot remove their own lenses. Failure to perform this simple procedure appropriately can result in serious ocular damage. The removal of a contact lens is easy, quick, simple, and straightforward. Never remove a contact lens if a globe perforation is suspected unless absolutely necessary.

155 Ocular Burn Management and Eye Irrigation

Steven J. Socransky

INTRODUCTION

Ocular burns are true emergencies and represent a significant minority (7.2% to 9.9%) of ocular trauma cases.[1,2] Chemical burns account for the large majority of ocular burns, with thermal burns being the second most common cause.[3] Most victims are young males.[2,4] The industrial workplace is the most common setting, although a significant number of cases occur in the home.[4] Assaults are a significant cause of ocular burns in the lower socioeconomic groups of large cities.[4,5]

Caustic agents are primarily responsible for the most severe chemical ocular burns. Most reports indicate that alkali burns are more frequent than acid burns.[1,3,4] Examples of more common alkalis and acids are listed in **Table 155-1**.[4,6–13] Ammonia causes the most serious alkali burns, while calcium hydroxide (lime) is the most common cause of alkali burns.[4] Hydrofluoric acid causes the most serious acid burns, while sulfuric acid is the most common cause of acid burns.[4] Fortunately, caustic agents account for only a minority of chemical ocular exposures.[1] Most chemical

TABLE 155-1 Common Caustic Agents and Their Sources

Substance	Class	Source
Ammonium hydroxide	Alkali	Fertilizers, refrigerants, and sparklers
Calcium hydroxide	Alkali	Mortar, plaster, and cement
Magnesium hydroxide	Alkali	Sparklers and fireworks
Potassium hydroxide	Alkali	Oven and drain cleaners
Sodium hydroxide	Alkali	Lye soaps, airbags, EMLA cream, and hair straightener
Sodium hypochlorite	Alkali	Bleaches and drain cleaners
Acetic acid	Acid	High vinegar concentrations
Chromic acid	Acid	Chrome plating
Hydrochloric acid	Acid	Household and pool cleaners
Hydrofluoric acid	Acid	Rust removers; glass, mineral, gasoline, and silicone industries
Sulfuric acid	Acid	Industrial cleaners and battery acid
Sulfurous acid	Acid	Bleach and refrigerants

ocular exposures are due to relatively innocuous noncaustic substances (e.g., shampoos, hair sprays, and personal defense sprays) and therefore do not cause significant or lasting damage.[1,14,15]

Ocular irrigation is a simple procedure that is commonly employed in the Emergency Department. It is potentially an eye-saving procedure in the setting of significant chemical ocular burns. Physicians, nurses, and emergency medical personnel who deal with ocular emergencies should be trained in ocular irrigation. When possible, first aid personnel in the workplace should be familiar with the use of ocular irrigation.[16] **Most importantly, ocular irrigation must be employed rapidly.[1,17] Delays in irrigation can limit its effectiveness and increase morbidity.[3]**

ANATOMY AND PATHOPHYSIOLOGY

The anterior surface of the globe is the major target of toxins in ocular burns (**Figure 155-1**). The eyelids are the most important protective structure for the eye. The orbicularis oculi muscle is innervated by branches of the facial nerve and closes the eyelids in response to noxious stimuli. The cornea provides little in the way of protection from chemical agents. The cornea is composed of five convex and transparent tissue layers. The cornea's major function is the refraction and transmittance of light. Despite its avascularity, the cornea is exquisitely sensitive to pain. Paradoxically, more extensive burns may be less painful due to destruction of corneal nerve endings and resultant anesthesia.[18] The cornea merges with the sclera to form the limbus at its outer margins. Stem cells at the level of the limbus are responsible for regeneration of the corneal epithelium. The corneal epithelium is unable to regenerate when the limbus is damaged. Although tougher than the cornea, the fibrous sclera is also susceptible to chemical injury.

The sclera is covered by the bulbar conjunctiva, which becomes the palpebral conjunctiva as it reflects onto the inner surface of the eyelids. These areas of reflection are referred to as the superior and inferior fornices of the upper and lower eyelids, respectively. The spaces between the eyelids and the globe are referred to as the superior and inferior conjunctival sacs (also known as palpebral sulci). Posterior to the cornea lies the anterior chamber, which contains the aqueous humor. The anterior and posterior chambers are separated by the iris, ciliary body, trabecular meshwork, and lens.[19]

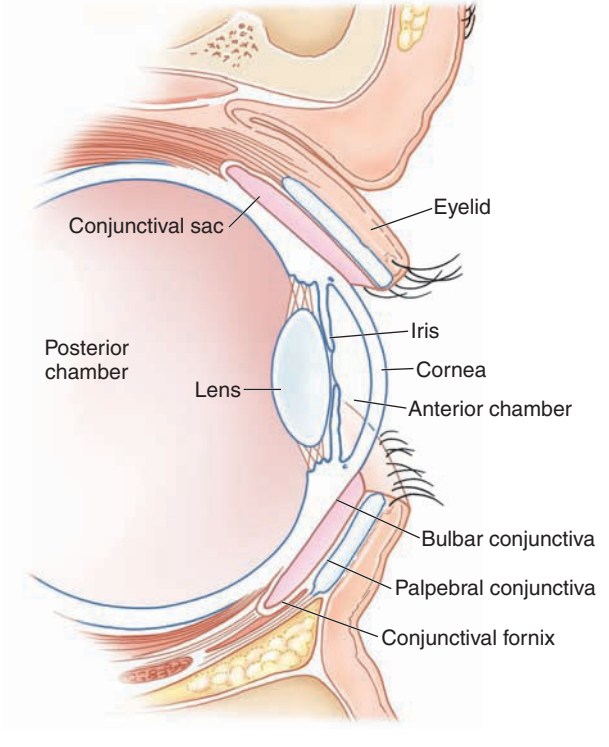


FIGURE 155-1. Cross-sectional anatomy of the eye and surrounding structures.

The damage produced to the eye by toxins depends on several factors: duration of contact; anion or cation concentration; and amount, pH, and inherent toxicity of the chemical.[17,20] **Alkalis generally produce the most damage.** Alkalis release hydroxyl ions that combine with tissue fatty acids and proteins, causing liquefaction necrosis.[11] The resultant degradation of corneal tissue allows for easy passage of the chemical into the anterior chamber. This causes a rapid rise (within a few seconds to a few minutes of contact) in aqueous humor pH and consequent damage to the iris, lens, ciliary body, and other ocular structures.[4,18,21] Damage to these structures and the cornea results in decreased visual acuity, secondary glaucoma, and cataracts. This damage can continue as the anterior chamber pH may remain elevated for hours. **Measurement of tear film pH immediately after irrigation will often yield a normal pH.[7,8] This may be falsely reassuring.** It may either reflect the pH of the irrigant or a transient neutralization of the tear film pH.[18] Alkalis may diffuse from the anterior chamber to the anterior ocular surface several minutes after irrigation has been discontinued, causing the tear film pH to rise again.

In general, acids cause less damage than alkalis. Acids lead to coagulation necrosis and protein precipitation, which usually prevents penetration beyond the cornea.[11] Exceptions include acids in higher concentration (particularly sulfuric acid) and hydrofluoric acid, which behaves more like an alkali.[4,5,18] These acids, like alkalis, can cause damage to deeper structures. Ocular burns caused by weaker acids can progress if treatment is delayed.[18]

Most noncaustic chemical eye exposures involve nontoxic agents that do not penetrate the cornea and cause only mild and self-limited irritation. Notable exceptions include surfactants and high-concentration lacrimators, both of which can cause damage to deeper structures.[10,18] Lacrimators in low concentration (e.g., tear gas) stimulate corneal nerve endings, causing pain and tearing, but they do not cause deeper injury.[18] Surfactants can cause significant damage that is often minimally symptomatic.[10] Although most solvents can cause sizable superficial corneal defects, reepithelialization is the rule and deeper tissues are spared.[10,18] Corneal injuries with capsicum (i.e., pepper spray) usually cause self-limited injuries, but significant corneal defects requiring Ophthalmology follow-up do occur occasionally.[22]

INDICATIONS

The treatment of chemical exposures to the eye is the primary indication for ocular irrigation. In this setting, irrigation has three principal objectives: immediate dilution of the offending agent, removal of the agent, and normalization of anterior chamber pH.[18] Nonembedded foreign bodies that are too small or too numerous to be removed adequately with a forceps or a cotton-tipped applicator can usually be removed with irrigation. Foreign bodies that are suspected but cannot be visualized may be removed with irrigation. Certain ocular infections are treated with antibiotics delivered by eye irrigation, although this is not a usual indication in the Emergency Department.

CONTRAINDICATIONS

There are no true contraindications to ocular irrigation. **An irrigating lens (e.g., Morgan Lens) should not be used if a deep corneal injury or a foreign body is suspected.[23] This lens may cause the foreign body to further injure the cornea or penetrate the globe. It is preferable to carefully employ the traditional method of**

irrigation using intravenous tubing and eyelid retraction rather than commercial devices that contact the globe in the setting of an actual or potential globe penetration or rupture.

EQUIPMENT

- Topical ophthalmic anesthetic agent, 0.5% proparacaine or 0.5% tetracaine
- Towels and a basin to collect fluid runoff
- Bags of crystalloid solution
- Intravenous tubing
- Gauze pads
- Cotton-tipped applicators
- Lid retractors, paper clip or Desmarres
- Commercial irrigation device, Morgan Lens or Eye Irrigator
- Protective eyewear, gloves, and gowns for healthcare personnel

PATIENT PREPARATION

Patients with ocular chemical burns may also have upper respiratory tract injuries, gastrointestinal tract injuries, and facial burns.[1] Nonchemical traumatic injuries are also possible. Airway, breathing, and circulatory problems should take priority. Significant ocular burns will need to be dealt with early and simultaneously with other problems. Initially, irrigation of the periocular skin should be performed with ocular irrigation itself such that residual toxin does not enter the eye causing further chemical injury.

Patients with isolated ocular injuries often have severe pain that requires parenteral narcotics. If this is the case, a monitored setting is appropriate. Intravenous sedatives and analgesics may facilitate ocular irrigation in a patient with severe pain and blepharospasm. Place the patient supine. Place towels and a basin under the patient's head to collect the runoff irrigant solution. Due to the speed with which ocular irrigation must be started, an explanation of the risks and benefits of the irrigation procedure should be offered to the patient while preparing for and initiating irrigation. Healthcare personnel and first-aid workers in the workplace are at risk for injury themselves. Protective equipment is essential and should be easily and rapidly accessible. Contaminated clothes should be removed and bagged in plastic until they can be cleaned or discarded.[15]

TECHNIQUES

A topical ophthalmic anesthetic agent, if immediately available, should first be instilled into the inferior conjunctival sac. Commonly available topical anesthetics include tetracaine and proparacaine. Proparacaine causes less irritation than tetracaine.[24] Each has a duration of action of approximately 10 minutes. Frequent readministration of the topical anesthetic may be necessary every 5 to 10 minutes to ease patient discomfort and facilitate irrigation. An alternative to readministration of local anesthetic would be to add 10 cc of 1% lidocaine to 1 L of crystalloid solution. Compared to an initial instillation of two drops of tetracaine alone, O'Malley et al found that lidocaine added to the irrigant in this way decreased the discomfort of irrigation when the irrigation lasted more than 10 minutes.[25]

OCULAR IRRIGATION

Hang the bag of crystalloid solution at a height of 70 to 200 cm above the patient's head in order to obtain an adequate flow rate.[26,27] The traditional eye irrigation technique involves directing the flow of crystalloid solution over the globe at a wide open rate

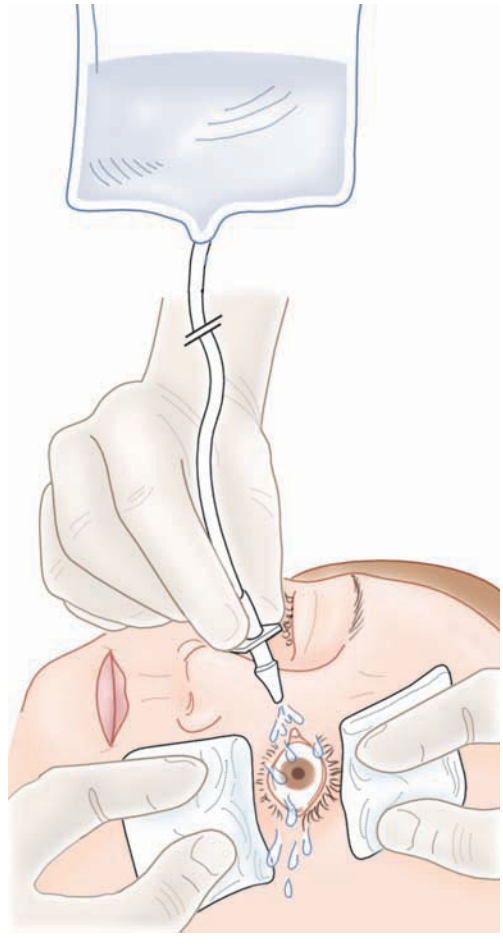


FIGURE 155-2. Standard ocular irrigation setup using intravenous tubing. An assistant retracts the eyelids using gauze pads or lid retractors. Complete irrigation of the conjunctival sacs is crucial.

(**Figure 155-2**). Hold the end of the intravenous tubing 3 to 5 cm above the patient's eye to avoid blunt injury to the ocular surface. An assistant is usually needed to hold the eyelids open. Dry gauze pads will facilitate one's ability to maintain a grip on the slippery eyelids and keep them open. Direct the flow of crystalloid solution at the entire surface of the globe, including into the conjunctival sacs and down to the conjunctival fornices.[18,28] Having the patient look in a direction opposite to where the irrigant is directed helps in this regard.[29] Although one can point the stream directly at the conjunctiva, it is better to direct it across the cornea in order to reduce the potential for further corneal injury.[23]

Manual retraction of the eyelids with gauze pads does not always allow for adequate irrigation of the conjunctival fornices. In these instances, eyelid retractors (Desmarres or bent paper clip) must be employed (**Figure 155-3**). **The eye must be well anesthetized when using eyelid retractors, and care must be taken to avoid further ocular injury.** Desmarres retractors are preferred to paper clips. Many paper clips are coated with nickel or silver that, when the paper clip is bent, can flake off, resulting in iatrogenic foreign bodies.[30] The use of a Water-Pik or handheld drench hose has been described but offers no definite advantages over intravenous tubing.[31,32]

Two commercially available devices exist which are less labor-intensive and facilitate ocular irrigation. The Morgan Lens (MorTan Inc., Missoula, MT) is a scleral contact lens-type device that is designed to fit over the anterior ocular surface (**Figure 155-4A**). Connect the proximal end of the device to intravenous tubing and

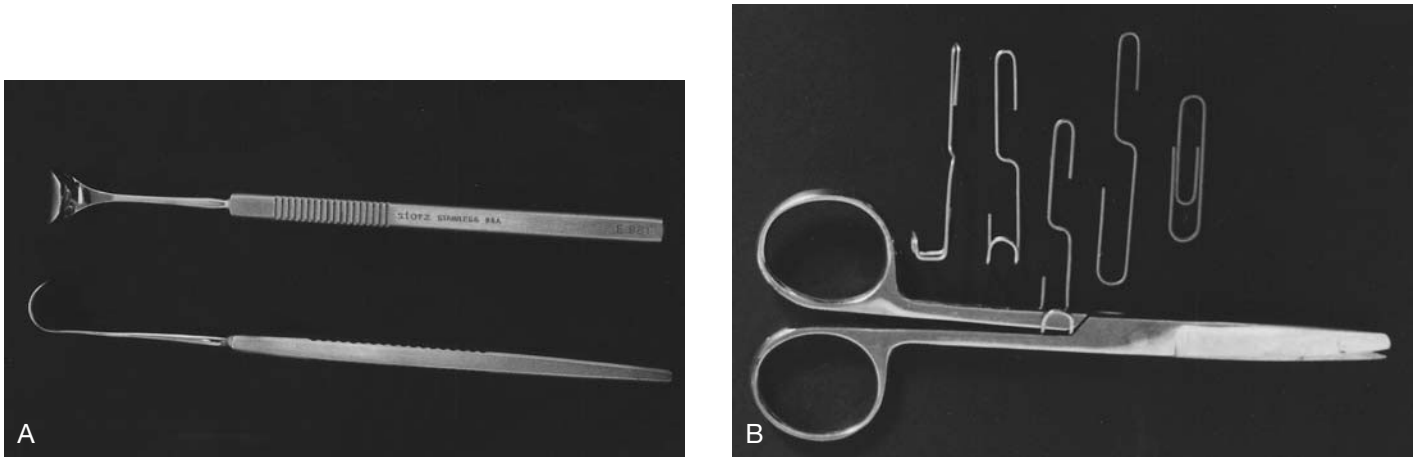


FIGURE 155-3. Eyelid retractors. **A.** The Desmarres eyelid retractor. **B.** An eyelid retractor fashioned from a paper clip.

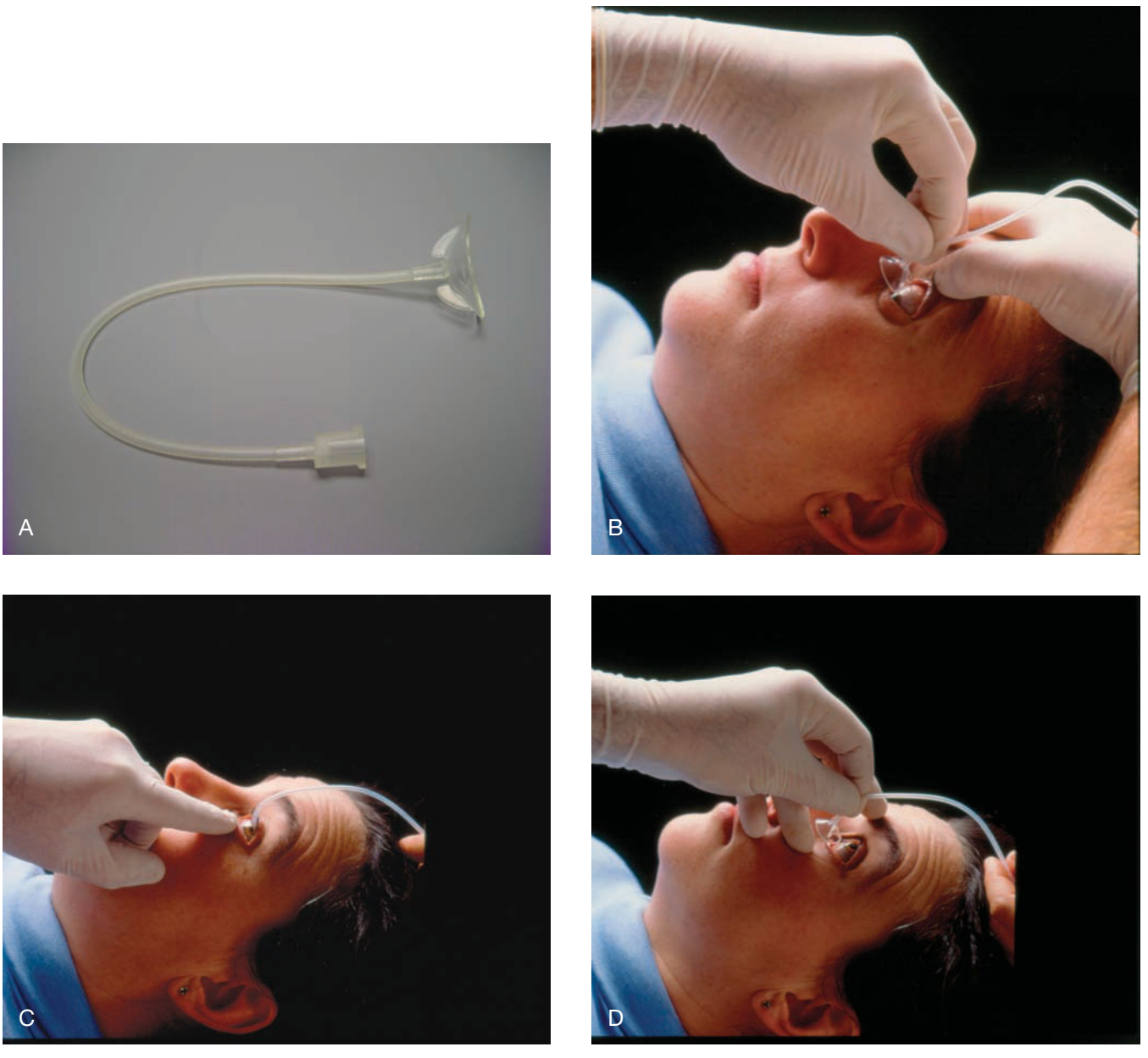


FIGURE 155-4. Eye irrigation with the Morgan Lens. **A.** The Morgan Lens. **B.** Placement of the lens under the upper eyelid. **C.** Placement of the lens under the lower eyelid. **D.** Removal of the lens. (Photos **B–D** courtesy of MorTan Inc., Missoula, MT.)

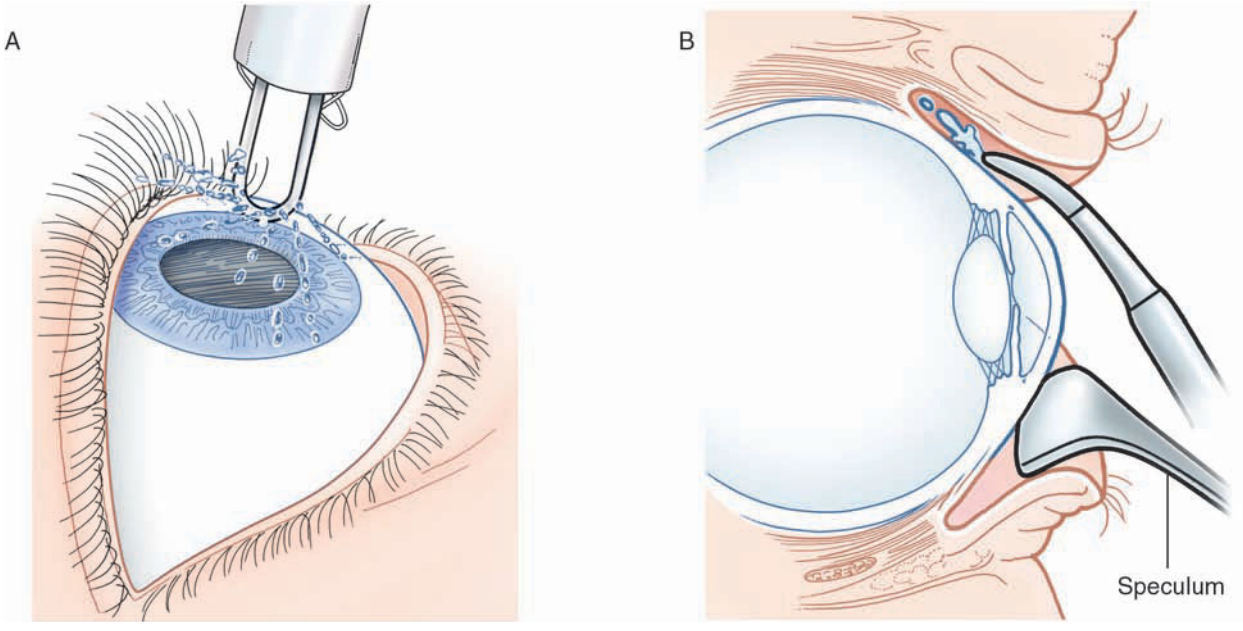


FIGURE 155-5. Eye irrigation with the Eye Irrigator. **A.** The Eye Irrigator. **B.** Cross section of the orbit with the Eye Irrigator under the upper eyelid and a speculum opening the lower eyelid.

start a minimal flow of irrigant solution through the Morgan Lens. Retract the upper eyelid and ask the patient to look down. Insert the lens under the upper eyelid (**Figure 155-4B**). Retract the lower eyelid and ask the patient to look upward. Insert the lower part of the lens under the lower eyelid (**Figure 155-4C**). Increase the flow of the irrigant solution through the lens. Remove the lens by reversing these steps (**Figure 155-4D**).

The Eye Irrigator (American Health & Safety, Madison, WI) delivers the irrigant via a U-shaped cannula with multiple perforations through which the irrigant flows (**Figure 155-5A**). Insert a speculum into the inferior conjunctival sac and retract the lower eyelid (**Figure 155-5B**). Insert the Eye Irrigator under the upper eyelid (**Figure 155-5B**). These steps are reversed for removal of the device. This device is somewhat similar to irrigating systems reported both by Yamabayashi and Terzidou.[26,27]

The EyeCap (Splash Medical Devices LLC, Atlanta, GA) is a simple device to irrigate an eye (**Figure 155-6**). The unit is quick to set up by just screwing it onto a bottle of sterile saline. The base of the unit has universal threads to attach to a bottle of sterile saline (**Figure 155-6**). The other end is wide and contoured to fit over the orbit. The device allows the saline to deflect off its sidewalls and pool over the eye. The patient can open their eye "under water" to gently allow high volume eye irrigation. This device cannot be used for foreign bodies embedded in the cornea, penetrating injuries, or if a ruptured globe is suspected.

SOLID PARTICLES

Ocular burns can be caused by chemicals that are primarily in the solid form (e.g., lime). **Prior to irrigation, attempt to remove as much solid as possible using a moistened cotton-tipped applicator while everting and retracting the eyelids. Quickly proceed to irrigation once most of the solid material has been removed or if removal is limited by blepharospasm.** Copious irrigation is often successful in removing any residual solid material.[17] Proceed directly to irrigation when solid material is not suspected in significant quantity and inspect the conjunctival sac for foreign material once the initial irrigation has been completed.

CONTACT LENSES

Concern that contact lenses may trap chemicals between them and the cornea appears to be unfounded. Contact lenses may, in fact, be protective and act as a shield between the chemical and the cornea.[33,34] **Irrigation should not be delayed in order**



FIGURE 155-6. The EyeCap device attached to a bottle of sterile saline. (Photo courtesy of Joseph Schultz, M.D. and BSN Medical Inc.)

to remove a contact lens unless it appears that a contact lens can be removed easily and quickly. This is the case even when commercial irrigation devices are used. Contact lenses can be removed once an initial period of irrigation has been completed. Refer to Chapter 154 regarding the details of contact lens removal. The contact lenses should be discarded as the chemical may be absorbed by the contact lens, only to be released onto the surface of the cornea if reused.[15,33]

IRRIGATION FLUID

The choice of irrigation fluid is much less important than the speed with which irrigation is started.[18,21] Tap water is perfectly acceptable at the scene of the chemical exposure, although there may be problems with patient discomfort.[17] Normal saline and Ringer's lactate solution are both acceptable during ambulance transport and in hospital. It has been thought that the more neutral pH of Ringer's lactate solution (pH 6.0 to 7.2) should cause less patient discomfort than normal saline (pH 4.5 to 6.0). Similarly, balanced salt solutions (e.g., BSS Plus, Alcon Laboratories, Fort Worth, TX) should theoretically cause less patient discomfort due to its enhanced buffering capacity, physiologic osmolarity, and physiologic pH. These theories have yet to be clearly substantiated.[14,35,36] **Use the irrigant fluid that is most readily available.** Balanced salt solutions should be used only in patients who require prolonged irrigation and for whom other irrigants are unsuitable due to their expense and time-consuming preparation (requiring reconstitution in glass bottles).[14,35]

The use of warmed irrigation fluid appears to increase patient comfort.[37] Ernst et al have reported an optimal irrigant temperature of 32.2 to 37.8 °C (90 to 100 °F). Werwath et al found that 120 seconds were required to heat 1 L bags of normal saline and Ringer's lactate solution to a temperature of 101 °F in a microwave oven set at the highest cooking intensity.[38] **This cannot be routinely recommended, as microwave ovens vary and overheated irrigant fluid will cause secondary injury. Irrigation should not be delayed while an irrigant fluid is being warmed despite the potential value of warmed fluid.** Commence irrigation with room temperature crystalloid solution and switch to a warmed crystalloid solution once prepared. Although not experimentally validated, Rost et al has suggested that cooler liquids at the beginning of irrigation may help reduce the heat of the reaction, thus limiting chemical injury.[21] Saidinejad and Burns has put forward the unproven theory that using a cold irrigant may provide cold anesthesia.[39]

There is probably no chemical ocular burn for which crystalloid irrigants are contraindicated.[18] Metallic sodium, metallic potassium, and white phosphorus may react violently. Remove any visible solid particles with a cotton-tipped applicator prior to irrigation. Irrigation with copious amounts of crystalloid probably dissipates the heat of the initial reaction more than it initiates a thermochemical reaction.[18]

SPECIFIC ANTIDOTES

The mainstay of treatment for chemical ocular burns is early and copious irrigation. Although specific antidotes usually play little role in the treatment of most ocular exposures, there are some instances where antidotes can be helpful once the initial irrigation has been performed. **Consultation with a poison center or Toxicologist should be considered in cases of exposure to unusual agents.**[23]

EDTA may be helpful in removing adherent calcium hydroxide corneal deposits from lime exposures that cannot be removed with a cotton-tipped applicator or toothless forceps.[1,10,23] A 0.05 M neutral solution of EDTA can be prepared by diluting 20 mL of Endrate disodium (150 mg/mL) with 180 mL of normal saline.[10] A cotton-tipped applicator soaked in the EDTA solution can be used to loosen such deposits. EDTA may also be useful in exposures to potassium permanganate and zinc chloride.[10]

Ascorbic acid may be useful in potassium permanganate exposures. A 5% solution can be prepared by dissolving a 500 mg tablet of ascorbic acid in 25 mL of normal saline. The resultant manganese oxide deposits can be dissolved by dripping the solution into the eyes from a moistened piece of gauze.[40]

Numerous other miscellaneous antidotes can be used for specific exposures. Copper sulfate (3% solution) can be used to negate the effects of embedded white phosphorus.[10,23] Polyethylene glycol may be useful in phenol exposures.[41] Mineral oil has been suggested in the removal of cyanoacrylates.[23] Calcium gluconate solutions have no beneficial effect in ocular exposures to hydrofluoric acid.[42]

DURATION OF IRRIGATION

Irrigation should be continued for 20 minutes in the home or workplace prior to patient transport. Emergency medical technicians should continue irrigation during ambulance transport until hospital arrival. The duration of any further irrigation in the Emergency Department depends on the severity of the exposure and the nature of the agent.

Minor exposures with nontoxic substances need not undergo copious irrigation. Irrigation with crystalloid solution using a squeeze-type bottle may be sufficient. In fact, irrigation that had been performed either in the home or in the workplace may be all that is needed. However, treatment should proceed as for caustic agents if the chemical nature of the substance is unknown. **Assume that any previous irrigation was inadequate and that further irrigation is necessary in the Emergency Department.**[4]

Although no definite standard duration for ocular irrigation is available in the literature, most would agree that patients who are significantly symptomatic or who have received a caustic exposure should have their eyes irrigated with a minimum of 1 to 2 L of crystalloid solution over 20 to 30 minutes.[17,43] Exposures to noncaustic agents, milder acid burns, and very mild alkali burns will usually not need further irrigation. Moderate to severe acid burns and anything more than a mild alkali burn will likely require more prolonged irrigation.

The duration of irrigation for caustic exposures is in part governed by pH measurement. After the initial irrigation, measure the pH of the inferior conjunctival sac using wide-range pH paper (i.e., accurate in the pH range of at least 2 to 10) or litmus paper.[10] Litmus paper with a narrower range and urine dipsticks may not be adequate. **If the pH is abnormal, continue irrigation and recheck the pH at 10 to 15 minute intervals until it normalizes.**[10,23] If the pH has reached the near-normal range (i.e., 7 to 8), discontinue irrigation and recheck the pH in 10 to 30 minutes to ensure that it continues to remain normal.[18,23] **In clinically severe caustic burns, regardless of the ocular pH, irrigation should be continued until the patient is evaluated by an Ophthalmologist. Alkali burns are more likely to require prolonged irrigation than acid burns.** In fact, several hours of irrigation may be required for severe alkali burns. In this instance, the Ophthalmologist may opt to perform a regional nerve block to incapacitate the orbicularis oculi muscle, thus limiting blepharospasm and improving patient comfort.[11]

ASSESSMENT

Ocular assessment should be limited to observation of gross injury, assessment of ocular pH, and quick verification of visual acuity until irrigation is complete. These assessments

should not be prolonged and should not delay initial irrigation. A full ophthalmologic assessment is required once irrigation has been discontinued. This should include a recheck of visual acuity, measurement of intraocular pressures, and a slit lamp examination to evaluate for corneal injury, uveitis, and globe perforation.

AFTERCARE

The extent of aftercare required is dependent upon the severity of the injury. Minor exposures to innocuous agents and very mild caustic exposures without corneal changes should be reevaluated in 24 hours if the patient is asymptomatic. Some exposures (e.g., gases, vapors, and fumes) can result in delayed evidence of corneal injury on slit lamp and fluorescein exams.[10] Thus, patients with apparently minor exposures should be cautioned to return to the Emergency Department if their symptoms worsen or do not improve.

Patients with mild exposures that result in corneal defects should be treated with topical antibiotics that have antistaphylococcal and antipseudomonal activity.[10] Ascertain the patient's tetanus immune status and administer prophylaxis as indicated. Analgesics or an eye patch may be offered if patient discomfort is significant.[1,10] Cycloplegics should be prescribed in order to decrease the pain resulting from ciliary spasm and to decrease the risk of the formation of posterior synechiae if anterior chamber involvement is suspected.[10,28] After a chemical burn, patients chronically using phosphate buffer-containing eye drops (e.g., timolol and latanoprost) are at greater risk of corneal calcification.[44] Telephone consultation with an Ophthalmologist is recommended. Ophthalmology follow-up should occur within 24 hours.

Moderate to severe ocular burns require admission and acute evaluation by an Ophthalmologist. Medical treatment of secondary glaucoma may be required. Anterior chamber paracentesis and lavage may be needed early in the course of severe alkali burns in order to decrease the anterior chamber pH as well as intraocular pressure.[1,10,23,41] Necrotic tissue will have to be debrided.[4] The goals of longer-term therapy include the prevention of corneal ulceration, prevention of scarring of the anterior ocular structures, prevention of globe perforation, and the promotion of corneal reepithelialization.[23] Steroids, nonsteroidal anti-inflammatory agents, frequent lubrication, and soft contact lenses may help in this regard.[1,4] Ascorbic acid and collagenase inhibitors are experimental. More severe injuries require surgical intervention due to the loss of stem cells at the limbus and thus the loss of potential corneal reepithelialization.[4]

COMPLICATIONS

Pain and discomfort are common after ocular exposure to chemicals. These can be minimized with topical ophthalmic anesthetic agents, parenteral sedatives, and parenteral narcotics in the Emergency Department. Corneal injury is usually the result of the primary chemical injury. Corneal injury may result from the irrigant or irrigating device, particularly if improper technique is used. Frequent use of topical ophthalmic anesthetic agents can lead to corneal injury. Extrusion of ocular contents is possible in the setting of a globe penetration. The diving reflex is a rare but possibly significant complication. This reflex is mediated by the ophthalmic branch of the trigeminal nerve and the vagus nerve. It is triggered by a cold water stimulus to the face and results in bradycardia without hypotension. The diving reflex is more common in infants and children. Its clinical importance is greatest in patients with significant comorbid disease. Continuous cardiac monitoring is wise in these subsets of patients. Irrigation with warm water may limit this reflex.[45,46]

SUMMARY

Ocular irrigation is an eye-saving procedure in the setting of significant ocular burns. For trained personnel, it is an easy and safe procedure to perform. First-aid workers, emergency medical technicians, and Emergency Department personnel should be trained in its use. Ocular irrigation should be performed rapidly with the most available nontoxic irrigant, as delays of even seconds can limit its effectiveness.

156 Intraocular Pressure Measurement (Tonometry)

Michelle M. Verplanck, Mark A. Rolain, and Aaron D. Cohn

INTRODUCTION

This chapter is designed to help the Emergency Physician know when it is necessary to measure intraocular pressure (IOP) and reviews several reliable methods of tonometry to measure IOP. There are multiple traumatic, pathologic, and postsurgical causes of altered IOP. The clinical signs and symptoms of elevated IOP are similar regardless of the etiology. Digital palpation is the oldest and simplest form of tonometry and remains useful in select situations. Schiøtz indentation tonometry is discussed for historical purposes but is still an accurate method to measure IOP. The nonportable Goldmann or applanation tonometer serves as the standard for measuring accurate IOP. It requires the use of a slit lamp and can be difficult to master. The handheld Perkins and Kowa tonometers are based on the same principle as the Goldmann and require experience to use effectively. The electronic Tono-Pen is best known to most Emergency Physicians and is discussed at length. It is useful to become comfortable with one or more of these techniques because early detection of abnormal IOP can prevent irreversible vision loss.

ANATOMY AND PATHOPHYSIOLOGY

Aqueous humor is produced by the ciliary body in the posterior chamber of the eye, directly behind the iris (**Figure 156-1**). Most of the aqueous humor flows forward, through the pupil, into the anterior chamber. It drains out of the eye through the trabecular meshwork located at the angle where the cornea and iris meet. This is the area referred to in open angle, narrow angle, and angle closure glaucoma. In healthy eyes, aqueous humor production is equivalent to outflow. IOP reflects the pressure of the ocular contents and by convention is expressed in millimeters of mercury or mmHg.[1] The mean IOP in the general population is 16 mmHg with a standard deviation of 3 mmHg.[2] Therefore, normal pressure is considered to range from 10 to 22 mmHg.

Aqueous humor production and outflow can be dramatically affected by disease or injury of the eye. Even small changes in IOP over long time periods can be vision threatening. However, significant increases in pressure can cause rapid and irreversible damage to vision in just a few hours. Nontraumatic conditions that result in an elevation of IOP include primary angle-closure glaucoma and secondary angle-closure glaucoma. Traumatic conditions associated with elevated IOP include retrobulbar hemorrhage, hyphema, and traumatic iritis. Conditions associated with low IOP that threaten vision include penetrating trauma and postsurgical complications.

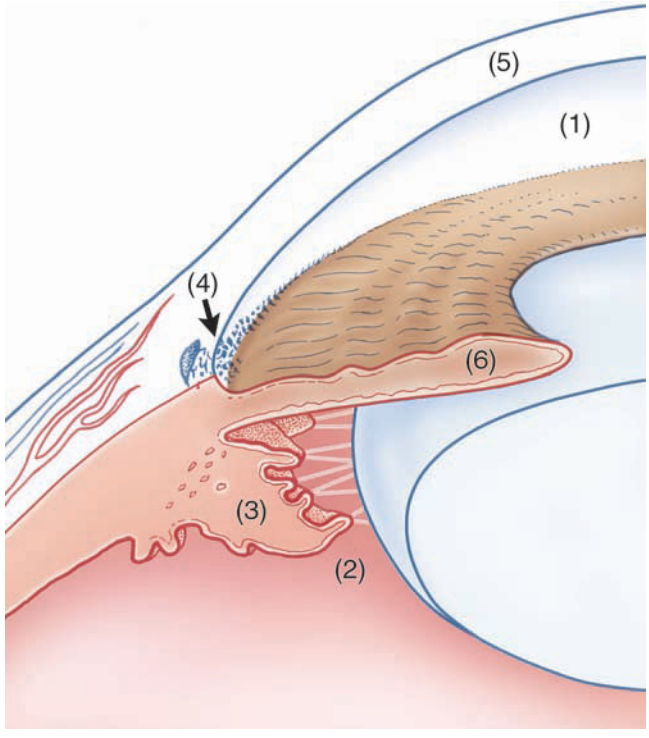


FIGURE 156-1. Anatomy of the anterior segment of the eye: (1) anterior segment; (2) posterior segment; (3) ciliary body; (4) trabecular meshwork; (5) cornea; and (6) iris.

Patients with primary or secondary acute angle-closure glaucoma often present with ocular pain and decreased vision, usually in one eye. They may describe a headache in the brow region, with or without associated nausea and vomiting. External examination frequently reveals that the conjunctiva is erythematous, the cornea appears milky or hazy, and the pupil is slightly dilated with a sluggish response to light (**Figure 156-2**).

Traumatic retrobulbar hemorrhage can result in markedly elevated IOP. Patients will present with a painful proptosis and fullness of the periorbital tissues. There is usually restricted movement of the eye in one or more fields of gaze. Acute onset of retrobulbar inflammation will present the same way, but there is no history of trauma. A spontaneous nontraumatic retrobulbar hemorrhage can occur in patients with a coagulopathy. Refer to Chapter 162 regarding the complete details and management of a retrobulbar hemorrhage.

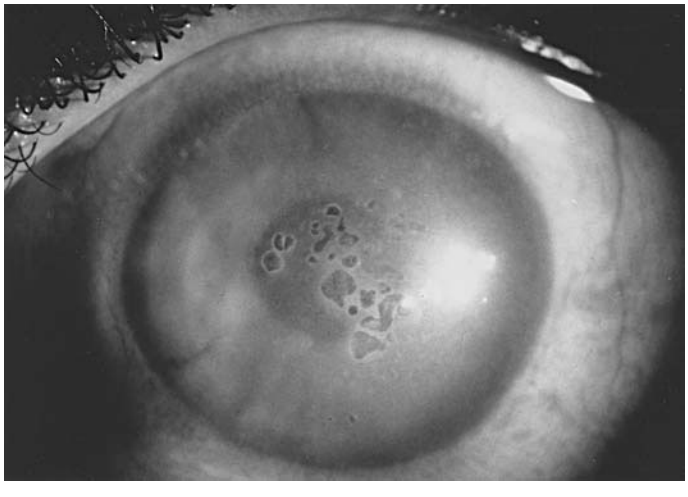


FIGURE 156-2. A high magnification of an eye with angle-closure glaucoma and a markedly elevated IOP. Note the corneal edema and the mid-dilated pupil.

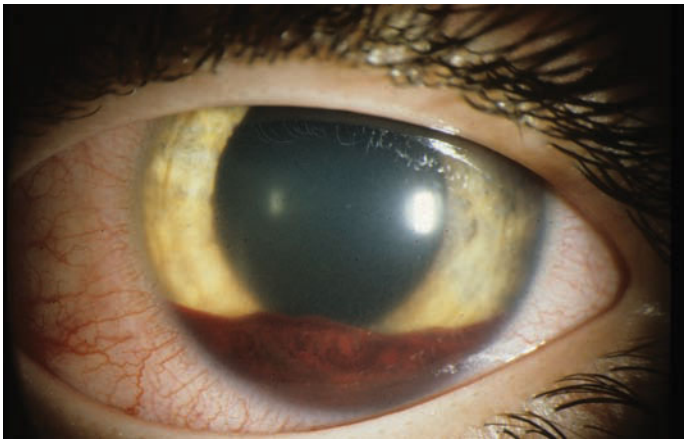


FIGURE 156-3. A traumatic hyphema with 10% to 15% layered blood in the anterior chamber.

Traumatic iritis may result in an elevated or a reduced IOP. Traumatic iritis presents following blunt, nonpenetrating trauma to the eye. Inflammatory cells circulating in the anterior chamber may impede aqueous outflow resulting in high IOP. Iritis may also affect the ciliary body causing a decrease in the production of aqueous humor and a lower IOP. These patients present with eye pain and photophobia. They usually describe their vision as slightly blurred and give a history of trauma within the last 48 hours. The history of recent trauma and light sensitivity is important given that the external examination of the eye may appear normal. The cornea will be clear and a slit lamp examination is usually necessary to identify the inflammatory cells in the anterior chamber.

A hyphema is visible blood that layers out in the anterior chamber between the iris and the cornea (**Figure 156-3**). A microhyphema is diffuse blood circulating in the anterior chamber. These patients present with decreased vision, photophobia, and blood in the anterior chamber. A common cause of blood in the anterior chamber is blunt, nonpenetrating trauma to the eye. A patient with blood in the anterior chamber and a history of sickle cell disease or trait is at a higher risk of elevated IOP.[3] Consult an Ophthalmologist if a sickle cell patient presents with blood in the anterior chamber.

INDICATIONS

Patients presenting with a painful eye and/or decreased vision, and no history of ocular trauma, should have their IOP measured and documented. Do not measure IOP if there is a history of blunt trauma associated with these symptoms. Some of the common presentations that require documentation of the IOP are reviewed in the previous section. This includes confirming the clinical diagnosis of acute angle-closure glaucoma, determining IOP after blunt ocular trauma, and determining IOP in a patient with iritis.

CONTRAINDICATIONS

It is essential to rule out a ruptured globe before tonometry is performed when a patient relays a history of trauma. Tonometry should be strictly avoided if there is evidence of a ruptured globe

or the suspicion of a ruptured globe. A ruptured globe from penetrating trauma to the anterior segment of the eye, including corneal or scleral lacerations, is usually obvious upon clinical examination. However, blunt trauma resulting in a ruptured globe may be very difficult to see on examination. Any blunt force (e.g., closed fist) causing an anteroposterior compression of the globe can result in a scleral rupture posterior to the attachment of the extraocular muscles. This is rarely obvious on external examination or a nondilated slit lamp examination. The clue here is that the patient has dramatically reduced vision and prominent swelling of the periorbital tissues.

Viral conjunctivitis is one of the most common ocular conditions seen in the Emergency Department. Conjunctivitis is so highly infectious that it is a relative contraindication to performing tonometry. These patients may present with ocular pain and decreased vision just like patients with angle-closure glaucoma. Conjunctivitis symptoms are usually binocular and the pain is not as severe. Acute angle-closure glaucoma almost always presents in one eye. It is reasonable to proceed with tonometry to rule out increased IOP as an etiology of a painful red eye if the diagnosis of conjunctivitis is uncertain. **Clean the instrumentation carefully to prevent spreading the infection to the contralateral eye.** The instrument of choice in cases of suspected infection is the Tono-Pen as it uses disposable, single-use, latex covers for the instrument.

EQUIPMENT

Topical Ophthalmic Anesthetic Agents

- Proparacaine hydrochloride 0.5% (Alcaine, Ocu-Caine, Ophthaine, Ophthetic)
- Tetracaine hydrochloride 0.5% (AK-T-Caine, Altacaine, Opticaine, Protocaine)

Topical Stain for Tear Film

- Fluorescein sodium 1 mg strips (Fluorets, Fluor-I-Strip-AT, Ful-Glo)
- Fluorescein ophthalmic solution (Fluress, Fluorescein Sodium)

Tonometers

- Goldmann applanation tonometer
- Handheld applanation tonometer (e.g., Tono-Pen)
- Schiøtz indentation tonometer

Antiseptic

- >70% isopropyl alcohol solution/swabs
- 3% hydrogen peroxide solution

PATIENT PREPARATION

Inform the patient of the need to measure the pressure in their eye. Explain that an instrument will contact their tear film directly over the cornea. Reassure the patient that tonometry is not painful. It is not necessary to have the patient sign a consent form, as tonometry is part of a routine eye examination. One may choose to document the discussion with the patient for completeness.

Remove all contact lenses before the instillation of any topical ocular anesthetic agent or fluorescein. Measuring IOP through a contact lens is unreliable. The fluorescein dye will permanently stain contact lenses and clothing.

Instill one drop of a topical ophthalmic anesthetic agent in both of the patient's eyes. The contralateral eye is used as the control, even if only one eye is of concern. Topical ophthalmic anesthetic agents begin working within 30 seconds and remain effective for 10 to 20 minutes. The drops may burn when applied and may cause a transient drying of the cornea. Instruct the patient not to touch or rub their eyes until the anesthesia wears off.

Instill fluorescein when using any prism applanation tip, such as in Goldmann, Perkins, or Kowa tonometers. Fluorescein is not needed when using the Tono-Pen or the Schiøtz tonometer. Fluorescein is available on strips or in solution. Fluorescein strips are applied to the tear film on the inner layer of each lower eyelid. Dampen the strip with a drop of topical anesthetic before application if the eye is extremely dry. If using fluorescein solution, instill a drop of fluorescein in the cul-de-sac of each lower eyelid.

All plastic prism applanation tonometer heads and the metal plunger of the Schiøtz need to be sterilized to prevent cross contamination. **Do not use sterilization solution on electronic tonometer tips.** Replace the disposable cover over the tip of the tonometer after each use. To sterilize the tip of a tonometer, use a prepackaged 70% alcohol swab or gauze soaked in 70% alcohol. Apply the alcohol to the tip of the prism for 10 seconds and allow it to air dry. Gauze soaked in 3% hydrogen peroxide may also be used. Rinse the tip with sterile saline to wash off the 3% hydrogen peroxide before application to prevent iatrogenic corneal abrasions. These described methods effectively disinfect for common bacteria and viruses, adenovirus, herpes simplex, and HIV.[4,5]

TECHNIQUES

DIGITAL PALPATION

Digital palpation is not as accurate as applanation tonometry. Digital palpation has been an informal means of judging IOP, as there is a built-in comparison with the contralateral eye. Studies examining this technique have shown inexperienced examiners can improve their accuracy with a short training session to within 5 mmHg of the actual IOP 88% of the time.[6] **Digital palpation should not be attempted if there is any potential for a ruptured globe.**

Place the patient supine or in a reclined position. Ask the patient to close their eyes and look straight ahead through the closed eyelids. Stand next to the patient's torso and facing them. Place the right thumb over the patient's left eye and left thumb over the patient's right eye. Place the remaining fingers of both hands on the patients' temples for stability. Apply gentle alternating pressure to each globe. The Emergency Physician should be able to ascertain any difference in pressure between the two eyes using the patient's contralateral eye as a control. The Emergency Physician may also gently palpate their own globe as a normal control. This qualitative measurement is often sufficient to determine a significantly elevated IOP.

SCHIØTZ TONOMETRY

The Schiøtz tonometer estimates IOP by measuring the indentation of the globe caused by a known weight.[7] The Schiøtz tonometer is a sturdy, low maintenance, and affordable instrument. It is gravity dependent and requires the patient to be supine or have their head fully extended to get an accurate reading. The Schiøtz tonometer case contains the Schiøtz tonometer, a calibration scale, weights, and a calibration platform (**Figure 156-4**).

The tonometer consists of a plunger and a hammer device connected to a needle (**Figure 156-5**). The needle is calibrated to a scale, with each unit measuring 0.05 mm on the scale. The plunger, the hammer, and the needle weigh 5.5 g. This can be increased to 7.5, 10, or 15 g by adding known weights to the tonometer. The weighted plunger is heavy and has a large contact area that causes significant indentation of the cornea with each measurement. **The**

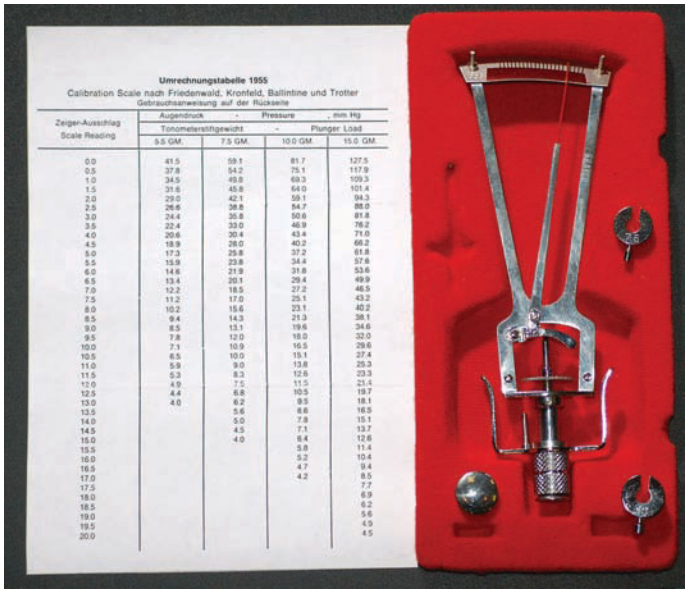


FIGURE 156-4. The contents of the Schiøtz tonometer case.

more weight it takes to move the needle on the scale or indent the cornea, the higher the IOP. The scale reading is converted to IOP in mmHg by a conversion chart supplied with each Schiøtz tonometer (**Figure 156-4**).

Place the patient supine or sitting with their head fully extended. Ensure that the patient is comfortable. A tight collar, flexed neck, breath-holding, squeezed eyelids, looking toward the nose, or accommodation results in a falsely elevated reading. Place two drops of a topical ophthalmic anesthetic agent onto each eye.

Calibrate the tonometer by placing the footplate of the plunger on the platform provided in the case (**Figures 156-4 & 156-5**). **The scale reading must be "0" while the footplate is on the platform. The instrument requires repair if it does not read zero while on the platform.**

Instruct the patient to look at a fixation target directly overhead and to open both eyes as wide as possible. Spread the eyelids with the nondominant index finger and thumb if necessary. Grasp the Schiøtz tonometer by its handle. **Ensure that the fingers holding the eyelids open are pushing on the orbital rim and not the globe, falsely elevating the IOP.** Place the footplate of the Schiøtz tonometer directly over the pupil and gently lower it onto the tear film (**Figure 156-6**). Note the reading on the scale. Add more weight if the scale reading is less than three units. **Do not push down on the cornea with the Schiøtz tonometer. This will cause a false elevation in the IOP reading.** Repeat the measurement several times or until three readings are within 0.5 scale units. Convert the scale reading to IOP with the conversion chart (**Table 156-1**).[8]

Clean the tonometer immediately after each use. Clean the barrel with two pipe cleaners, the first soaked in 70% isopropyl alcohol and the second one dry. Clean the plunger with an alcohol swab. Allow the instrument to air dry 1 to 2 minutes before being used in the contralateral eye so that the alcohol evaporates and is not transferred to the corneal surface.[10]

GOLDMANN (APPLANATION) TONOMETRY

The Goldmann tonometer is considered the clinical standard for measuring IOP. This method of tonometry is based on the Imbert-Fick principle.[4] It states that the pressure inside an ideal dry, thin-walled sphere equals the force necessary to flatten its surface divided by the area of the flattening ($P = F/A$; where P = pressure, F = force,

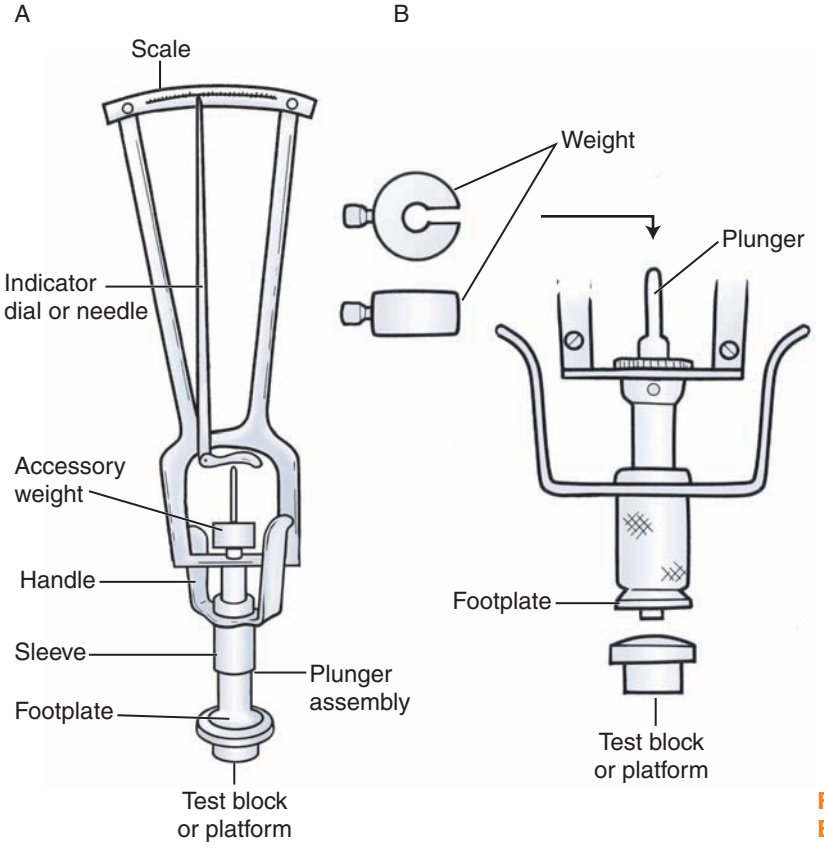


FIGURE 156-5. The Schiøtz tonometer. **A.** Schematic of the tonometer. **B.** Schematic of the plunger assembly.



FIGURE 156-6. The Schiøtz tonometer positioned on the cornea.

TABLE 156-1 The Schiøtz Tonometer Scale

Tonometer reading	5.5 g load	7.5 g load	10 g load	15 g load
0.0	41.5	59.1	81.7	127.5
0.5	37.8	54.2	75.1	117.9
1.0	34.5	49.8	69.3	109.3
1.5	31.6	45.8	64.0	101.4
2.0	29.0	42.1	59.1	94.3
2.5	26.6	38.8	54.7	88.0
3.0	24.4	35.8	50.6	81.8
3.5	22.4	33.0	46.9	76.2
4.0	20.6	30.4	43.4	71.0
4.5	18.9	28.0	40.2	66.2
5.0	17.3	25.8	37.2	61.8
5.5	15.9	23.8	34.4	57.6
6.0	14.6	21.9	31.8	53.6
6.5	13.4	20.1	29.4	49.9
7.0	12.2	18.5	27.2	46.5
7.5	11.2	17.0	25.1	43.2
8.0	10.2	15.6	23.1	40.2
8.5	9.4	14.3	21.3	38.1
9.0	8.5	13.1	19.6	34.6
9.5	7.8	12.0	18.0	32.0
10.0	7.1	10.9	16.5	29.6
10.5	6.5	10.9	15.1	27.4
11.0	5.9	9.0	13.8	25.3
11.5	5.3	8.3	12.6	23.3
12.0	4.9	7.5	11.5	21.4
12.5	4.4	6.8	10.5	19.7
13.0	4.0	6.2	9.5	18.1
13.5		5.6	8.6	16.5
14.0		5.0	7.8	15.1
14.5		4.5	7.1	13.7
15.0		4.0	6.4	12.6
15.5			5.8	11.4
16.0			5.2	10.4
16.5			4.7	9.4
17.0			4.2	8.5
17.5				7.7
18.0				6.9
18.5				6.2
19.0				5.6
19.5				4.9
20.0				4.5

Use the tonometer scale reading and the weight applied to the plunger (gram load) to determine the IOP reading in mmHg.

and A = area). The Goldmann tonometer determines the force necessary to flatten or applanate an area of the cornea 3.06 mm in diameter. The degree of flattening is determined while viewing the cornea through a split prism device in the tonometer head. Fluorescein is used to stain the tear film in order to distinguish the cornea from the tear film. The eye is viewed through the cobalt blue filter causing the fluorescein-stained tear film to appear yellow-green. The technique is described below.[5]

The Goldmann tonometer is not portable. It requires the patient to be cooperative, the patient to sit upright, and a working knowledge of the slit lamp. The Goldmann tonometer in combination with a slit lamp examination provides the clinician with the most detailed information about the patient's ocular condition.

Place two drops of a topical ophthalmic anesthetic agent onto each eye. Place fluorescein dye in the eye. Position the tonometer head and cobalt filter on the slit lamp. Set the tension knob at 10 mmHg. It is more accurate to measure IOP by increasing rather than decreasing the force of applanation. Seat the patient in front of the slit lamp. Support the patient's chin in the chin rest and place their forehead firmly against the strap (**Figure 156-7**).

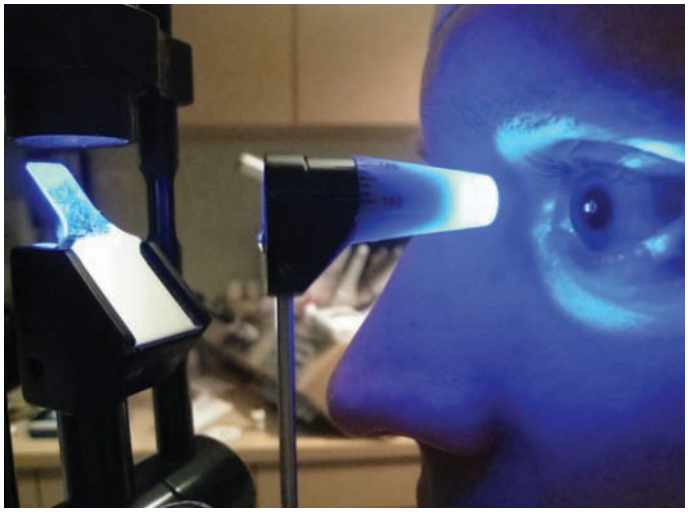


FIGURE 156-7. A patient positioned in the slit lamp with a Goldmann tonometer in position to be advanced onto the cornea.

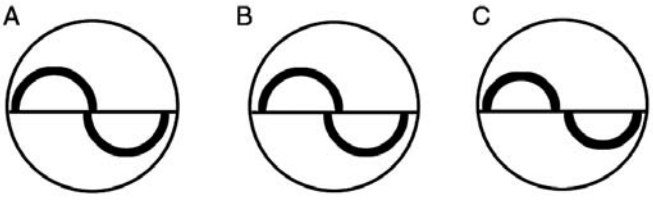


FIGURE 156-8. Semicircles as seen through the Goldmann tonometer. **A.** The inner edges of the semicircles are touching signifying the correct IOP reading. **B.** Semicircles are not touching because the pressure reading on the tension knob is too low. **C.** Semicircles are overlapping because the pressure reading is too high.

Instruct the patient to look straight ahead and open both eyes as wide as possible. Spread their eyelids with a thumb and forefinger if necessary. **Do not put pressure on the globe while holding the eyelids open.**

Move the tonometer head within one-half inch of the cornea. Use the control stick on the slit lamp to center the applanation head directly over the pupil. Look for two semicircles on the ocular surface as the tonometer head is advanced onto the corneal tear film (**Figure 156-8**). Ensure that the tension knob is set at 10 mmHg. The semicircles will not be touching if the patient's pressure is above 10 mmHg (**Figure 156-8B**). Turn the tension knob clockwise to raise the reading and counterclockwise to lower the reading. Turn the tension knob up until the inside borders of the fluorescein rings are touching (**Figure 156-8A**). Read the IOP on the tension knob. The semicircles will overlap if the pressure is below 10 mmHg (**Figure 156-8C**). Turn the tension knob down until the inside borders of the fluorescein rings are touching (**Figure 156-8A**). Read the IOP on the tension knob.

Clean the tonometer head with an alcohol swab immediately after use. Let it air dry 1 to 2 minutes so that the alcohol evaporates and is not transferred to the corneal surface. Repeat the procedure on the contralateral eye.

HANDHELD TONOMETRY

The Tono-Pen XL and the Tono-Pen Avia (**Figure 156-9**) are lightweight, simple to operate, and can record IOP with the patient in any position. The small contact area is useful in patients with eyelid swelling and corneal surface irregularities. The Tono-Pen calculates IOP using a strain gauge that creates an electronic signal as the 1.5 mm footplate flattens the cornea.[10] A single microprocessor chip analyzes each application of the footplate and averages 4 to 10 valid measurements to form one reading. The instrument should be stored in its case when not in use. An Ocu-Film cover should remain over the tip when it is stored and changed with each new patient (**Figure 156-9**). **The Ocu-Film covers are made of latex. Ask the patient about latex allergies prior to using this device. The tip of the Tono-Pen is very sensitive, is easily damaged, and should never be touched.**

The Tono-Pen XL unit is internally calibrated, thus the instrument calibration should be checked before the first use each day or in the event of unanticipated readings. Calibration should also be performed whenever it is indicated by the LCD display, when batteries are replaced, or after unsuccessful calibration. If the word "bAd" appears in the LCD window, it needs to be calibrated. The Tono-Pen is not used or calibrated daily in the Emergency Department. Thus, it is necessary to check the calibration prior to each use.

The display of "Good" in the LCD window indicates that the Tono-Pen is functioning properly. Press the operation button once. The Tono-Pen will display [8.8.8.8] in the LCD window, followed by a single row of dashes [----], and then a double row of dashes [= = = =]. This indicates that the Tono-Pen is ready to measure IOP.



FIGURE 156-9. The Reichert Tono-Pen XL and Reichert Tono-Pen Avia. The Tono-pen XL has an Ocu-Film cover in place.

To calibrate the Tono-Pen aim the transducer end straight down. Depress the operation button twice within 1.5 seconds. The Tono-Pen will beep and display "CAL" in the LCD window. Wait for the Tono-Pen to beep and display "UP" in the LCD window. This can take as long as 15 seconds. Immediately and quickly invert the Tono-Pen so that the transducer end is pointing straight up. The Tono-Pen will beep and display "Good" in the LCD window if it is functioning properly. Repeat the calibration procedure if "bAd" is displayed in the LCD window.

Place the patient in a seated or supine position. Instruct the patient to look straight ahead. Place two drops of a topical ophthalmic anesthetic agent onto each eye. Fluorescein is not necessary when using the Tono-Pen. Grasp the Tono-Pen like a pencil and hold it perpendicular to the corneal surface (**Figure 156-10**). Gently contact the cornea directly over the pupil or central cornea (**Figure 156-10**). Make contact with the cornea in a series of light taps. **The Tono-Pen should not indent the cornea if used properly, reducing the risk if there is an unidentified ruptured globe or a hyphema.** The Tono-Pen chirps each time a valid IOP measurement is obtained. The microprocessor sounds a final beep after it receives four valid readings. The mean IOP will be displayed in the LCD window. A single row of dashes [----] indicates that an insufficient number of valid readings were collected. Obtain additional measurements after pressing the operation button.



FIGURE 156-10. The Tono-Pen positioned in front of the cornea.

ALTERNATIVE DEVICES

There are many additional handheld tonometers of varying cost, ease of use, and availability. The Perkins MK-2 (Haag-Streit, Essex, UK) and the Kowa HA-2 (Kowa Optimed, Inc., Torrance, CA) are two handheld tonometers utilizing the Goldmann prism technique (i.e., aligning the semicircular images). They are portable, but require a familiarity with Goldmann applanation. The Accupen (Accutome, Malvern, PA) is similar to the Tono-Pen with a few differences. These include ease of use, longer battery life, and not requiring calibration before every use. The Diaton transpalpebral handheld tonometer (Bicom Inc., Long Beach, NY) is designed to measure IOP through a patient's closed eyelids.[11] The Pulsair IntelliPuff (Keeler, Brownhill, PA) is the only portable, handheld, noncontact tonometer. The iCare Rebound (Tiolat Oy, Helsinki, Finland) uses a smaller zone to indent the cornea and claims not to require topical anesthesia.[12] This would be particularly useful for the Emergency Department should it prove to be reliable.

ASSESSMENT

The normal range for IOP is 10 to 22 mmHg. A baseline IOP is specific to each patient and the patient's contralateral eye can serve as a control. We can make general assumptions about certain ranges of IOP in order to make rapid clinical assessments and facilitate patient care. Readings of 0 to 9 mmHg should be discussed with an Ophthalmologist, especially if there is a history of recent eye surgery or recent eye trauma. Readings of 10 to 21 mmHg are normal. Readings of 22 to 25 mmHg should be followed up with an Ophthalmologist within 2 to 3 days. IOP readings greater than 26 mmHg require an emergent consultation with an Ophthalmologist.

COMPLICATIONS

Infectious agents can be transferred via tonometer heads.[9] **It is essential to properly clean each instrument before use, before using it on the contralateral eye, and after use.** The use of a 70% isopropyl alcohol swab is an effective disinfectant for the Goldmann and the Schiøtz tonometers. The Tono-Pen has single-use disposable latex covers.

Incorrect IOP measurements can occur for a variety of reasons. An improperly working plunger on the Schiøtz tonometer can result in falsely low measurements. IOP will be elevated if measured while the examiner's hand is holding the eyelids open and inadvertently pressing on the underlying globe. Measurement during eye movements, blinking, or eyelid movements will elevate IOP. Maneuvers that increase intracranial pressure (e.g., valsalva or breath holding) also increase IOP.

Corneal abrasions can occur while using contact tonometers. It is very important to have a cohesive tear film to avoid cornea abrasions. Instruct the patient to blink several times just prior to tonometry to spread the tear film. Apply artificial tears in patients with extremely dry eyes. The Schiøtz tonometer puts significant weight on the cornea and must be applied very gently. Warn the patient that their eye may be uncomfortable when the anesthetic wears off if a small abrasion is suspected after measuring the IOP. Instruct the patient to instill artificial tears every 4 to 6 hours. Treat larger abrasions with a topical ocular antibiotic of choice and schedule a follow-up visit.

SUMMARY

The practice of tonometry is essential in guiding appropriate eye care. The Goldmann, Tono-Pen, or Schiøtz contact tonometers are readily available in most Emergency Departments. The literature frequently debates the comparative accuracy of each instrument. The Goldmann applanation tonometer is generally considered the clinical standard.[11,12] However, all three instruments are useful for screening IOP in the Emergency Department. Factors such as the patient's ability to ambulate and the presence of periorbital swelling will influence the choice of an instrument. The Emergency Physician should select a tonometer that feels comfortable and use it routinely. The Emergency Physician will be able to measure IOP rapidly and reliably with repeated use of the tonometer.

157 Digital Globe Massage

Carlos J. Roldan and Eric F. Reichman

INTRODUCTION

Digital globe massage has been considered a heroic measure to salvage vision in cases of central retinal artery occlusion (CRAO), an ophthalmologic emergency.[1–8] CRAO is one of several diagnoses to consider in the patient with acute painless loss of vision or a visual field. The typical patient is older, between the ages of 50 and 80 years of age, and with significant systemic illnesses. The CRAO is most likely an embolic event secondary to atherosclerotic disease. The vision loss is sudden, monocular, and painless. The outcome for CRAO is poor if treatment is delayed more than 2 hours. Spontaneous remission and recovery of visual function is rare. This condition requires an emergent consultation with an Ophthalmologist for medical management and the consideration of an anterior chamber paracentesis (Chapter 158). Digital globe massage can be used in an attempt to relieve the obstruction or break up the embolus so it moves distally to restore some blood flow to the retina.

ANATOMY AND PATHOPHYSIOLOGY

The ophthalmic artery is a branch of the carotid artery (**Figure 157-1**). The first branch of the ophthalmic artery is the central retinal artery. This vessel runs along the optic nerve and enters the optic nerve. The central retinal artery is the main blood supply to the retina. The macula has an independent blood supply from

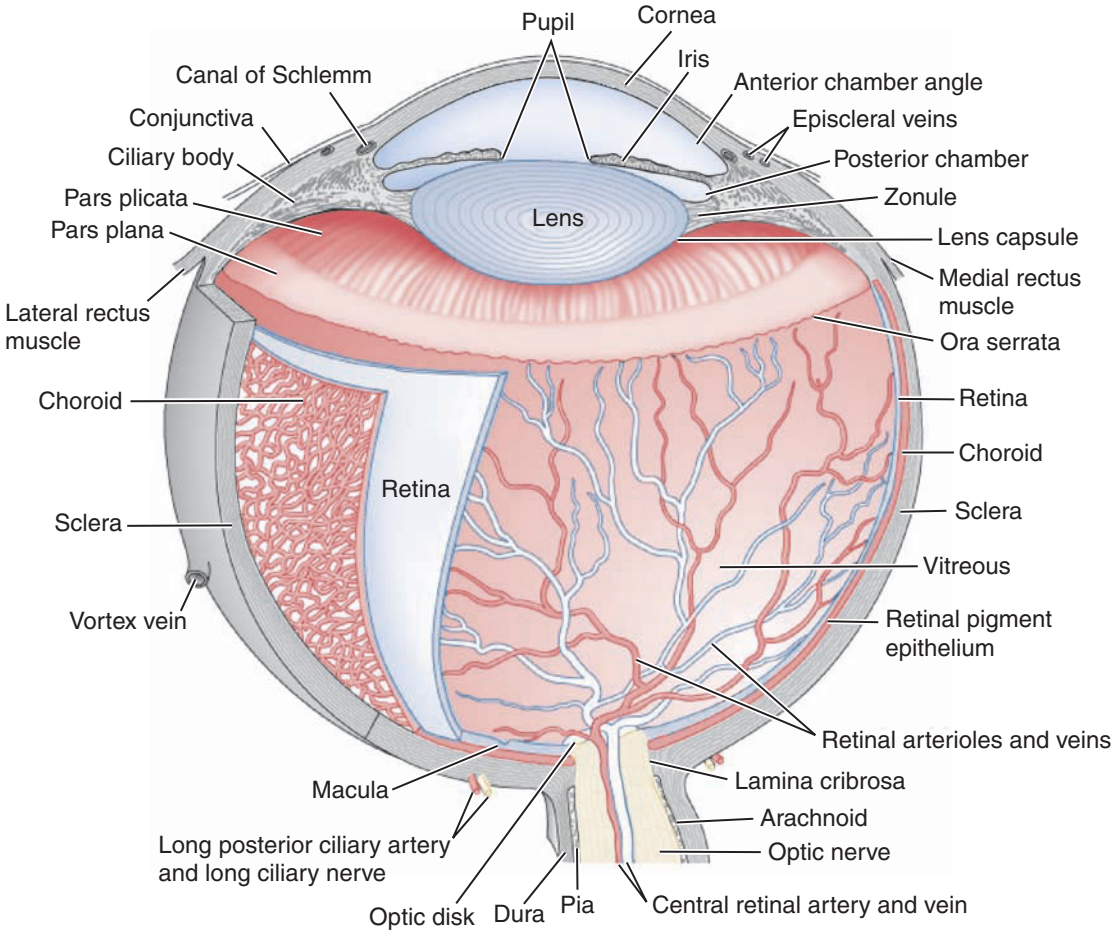


FIGURE 157-1. The anatomy of the eye. (Used with permission from: Riordan-Eva P, Whitcher JP (eds): *Vaughan & Asbury's General Ophthalmology*, 17th ed. New York: McGraw-Hill, 2008.)

other branches of the ophthalmic artery. An area between the macula and the optic nerve receives collateral circulation from the central retinal artery and the ciliary arteries in a small percentage of the population. This explains why a patient with a complete CRAO may have a normal appearing macula and occasionally an area of perfusing retina adjacent to the optic nerve area.

The individual etiology remains unclear in many cases. The main cause of retinal arterial occlusions is an embolic event lodging in the central retinal artery where it narrows to pass through the lamina cribrosa, or in a smaller distal branch arteriole. The embolism may be comprised of aggregated fibrin and platelets arising from an ulcerated vessel wall thrombus, cholesterol from an ulcerated carotid artery plaque, material from cardiac valvular disease, or thrombus formation from giant cell arteritis. The embolus may also result from an invasive procedure such as cardiac angioplasty, carotid angioplasty and stenting, or a carotid endarterectomy.

Abnormal cardiac rhythms are considered an etiology for intracardiac blood clot formation. These may embolize and lodge in the ophthalmic artery or distally in one of the branch arteries. Retrobulbar masses (e.g., a hematoma, neoplasm, or retrobulbar injection) may also lead to an optic nerve and central retinal artery compression.[1]

PHYSICAL EXAMINATION FINDINGS

The patient may display vision compromise ranging from a small visual defect to a decreased ability to finger count or perceive light, and to complete blindness. Grossly, the eye appears normal. However, an afferent pupillary defect may be evident with little or no reaction to direct light and a normal reaction to consensual light. The initial fundoscopic examination may show a near-normal retinal appearance (**Figure 157-2A**). This soon progresses to a pale retina, bloodless or attenuated arterioles, and "boxcar" segmentation of the retinal veins (**Figure 157-2B**). The fundoscopic exam will then reveal a milky and edematous retina with a cherry-red macula if the entire central retinal artery is occluded. If the cilioretinal artery flow is not occluded, there will be an area of perfusion between the optic disc and the macula (**Figure 157-2B**). An embolus may be visible in the vasculature of the optic disc in rare cases. If a branch retinal artery is occluded, an embolus may be visible in the vessel with ischemia and infarction distal to the occlusion.

It has been shown experimentally that the retinal damage is irreversible after 100 minutes of nonperfusion.[3] There is anecdotal evidence that heroic measures to salvage vision after a CRAO have sporadically resulted in the return of vision. A large study showed that the average final visual acuity in patients with a CRAO treated with heroic measures compared to those untreated was only a one-quarter line improvement in Snellen chart visual acuity. If the underlying cause of the CRAO is giant cell arteritis, up to 10% of the cases progress rapidly to bilateral vision loss if the arteritis is left untreated.

MEDICAL MANAGEMENT

Various methods have been employed to reduce intraocular pressure or to dilate the artery in an attempt to facilitate dislodgement

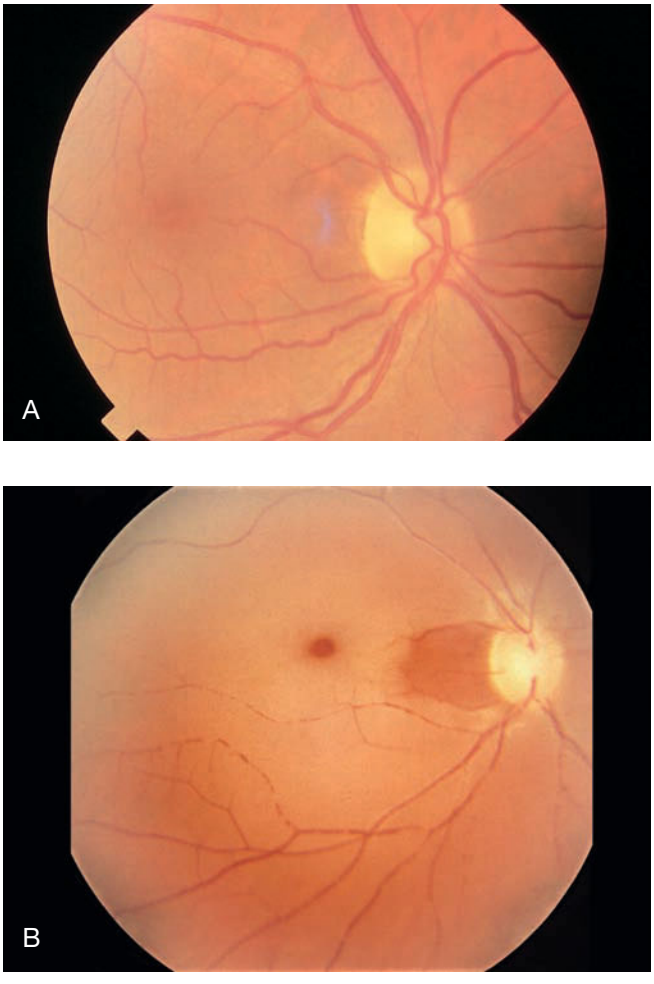


FIGURE 157-2. Fundoscopic images of the eye. **A.** Normal examination. **B.** CRAO with cilioretinal vessel sparing. (Used with permission from: Knoop KJ, Stack LB, Storrow AB, et al: *The Atlas of Emergency Medicine*, 3rd ed. New York: McGraw-Hill, 2010.)

of the embolus.[1–8] None of these have been proven to be of benefit in the management of a CRAO.[6] On the other hand, none of these have been proven to be harmful. Thus, they may prove to be useful in saving the patients vision. The following interventions should be considered as coadjuvants to digital globe masses. Oral nitrates (0.5 or 0.4 mg nitroglycerin pills or spray) may vasodilate the retinal artery. Instruct the patient to breathe into a paper bag to increase blood carbon dioxide levels and induce vasodilation. If available, administer carbogen (95% oxygen and 5% carbon dioxide) by face mask instead of using the paper bag. Oral and intravenous carbonic anhydrase inhibitors (500 mg Diamox or acetazolamide) will reduce intraocular pressure and decrease ophthalmic arterial vascular resistance to forward flow. Intravenous mannitol (1 g/kg of a 20% solution) may cause intraocular fluid to exit the eye and decrease intraocular pressure. Hyperbaric oxygenation treatment can compensate to prevent retinal hypoxemia and ischemia in some cases while awaiting the restoration of arterial flow.[3] Intra-arterial fibrinolysis with urokinase or recombinant tissue plasminogen activator (rTPA) can be successful in improving vision and shows promise.[1,5]

INDICATIONS

Digital globe massage can be performed in cases of CRAO where medical management is contraindicated or not successful. It can also be performed simultaneously with medical management. Treat the patient if they present to the Emergency Department within 24 hours of symptom onset.[7] It should be performed ideally within 90 minutes of the CRAO.

CONTRAINDICATIONS

Digital globe massage is contraindicated if the patient has had ocular surgery. Consult an Ophthalmologist in these cases before performing the procedure. Digital globe massage is contraindicated if there is the possibility of a perforated globe. There are otherwise no contraindications to digital globe massage in a nontraumatic CRAO.

EQUIPMENT

No special equipment is required to perform a digital globe massage.

PATIENT PREPARATION

Perform a fundoscopic examination and visual acuity testing. Document these results in the medical record. Explain the procedure, its risks, and benefits to the patient and/or their representative. This potentially vision-saving procedure should not be delayed. Verbal consent is adequate and the conversation documented in the medical record. Place the patient supine or in a reclining position.

TECHNIQUE

Stand next to the patient's torso and facing them. Instruct the patient to tightly close the eyelids of the affected eye. Place the dominant thumb over the patient's eyelids. Apply firm and steady pressure with the thumb for approximately 5 seconds. Abruptly release pressure by quickly lifting the thumb of the eyelids. Repeat the procedure several more times.[2]

ASSESSMENT

Immediately perform a repeat fundoscopic examination and visual acuity testing. Document and compare these to the preprocedural evaluations. It should be noted that the fundoscopic examination may show improvement while the visual acuity has changed very little or not at all. Depending on the ischemic time, visual acuity may never improve. Repeat the digital globe massage if there is little or no improvement in the fundoscopic examination. If significant improvement is noted, the procedure may be repeated in the hope of further improvement.

AFTERCARE

All patients must be evaluated by an Ophthalmologist in the Emergency Department. If one is not available, consider transferring the patient to another facility to be evaluated by an Ophthalmologist. These patients require inpatient admission for further evaluation and management.

Patients with a CRAO usually have significant comorbidities such as hypertension, atherosclerosis, or diabetes. These patients are at risk for additional morbidity and require prompt medical referral to determine the etiology of the CRAO. Medical testing should include blood pressure evaluation, electrocardiography, echocardiography, blood glucose management, lipid and cholesterol testing, and hyperviscosity studies. Any irregularities or abnormal studies will require further evaluation. Patients over the age of 60 need an immediate erythrocyte sedimentation rate (ESR) test in consideration of the possibility of giant cell arteritis.

COMPLICATIONS

If properly performed, digital globe massage has few immediate complications. Over vigorous digital globe massage can result in a lens dislocation or a ruptured globe.[4] Mechanical trauma can result in injury to the cornea, retinal detachments, and intraocular hemorrhage (e.g., hyphema and intravitreal hemorrhage).

SUMMARY

A central retinal artery occlusion is a true ophthalmologic emergency. The patient will present with sudden, painless, and unilateral loss of vision. Immediate management is required in an attempt to restore the patient's vision. This includes medical management, anterior chamber paracentesis, and digital globe massage. These techniques attempt to reduce intraocular pressure or break up the embolus in order to allow the embolus to move downstream and restore at least partial blood flow to the retina. Despite these interventions, the patient's vision may not recover.

158 Anterior Chamber Paracentesis

Rene Pineda Carizey

INTRODUCTION

Anterior chamber paracentesis is the removal of fluid from the anterior chamber, the area just anterior to the iris and lens, and immediately posterior to the cornea. Although not often formally taught nor performed in the Emergency Department, an anterior chamber paracentesis is a fairly quick, simple, and safe procedure with important diagnostic and therapeutic roles.[1–20] The long-term prognosis is directly related to the duration of symptoms for disease states that present with increased intraocular pressure, such as acute closure glaucoma and central retinal artery occlusion. In a sense, "Time is Eye." The Emergency Physician should become familiar with this technique. Its use can potentially prevent irreversible vision loss, especially when medical management is not sufficient in lowering intraocular pressure.

ANATOMY AND PATHOPHYSIOLOGY

The eye is a fluid-filled, closed system with a one-way valve. Aqueous humor is produced by the ciliary body and flows from the posterior chamber to the anterior chamber. Once in the anterior chamber, the aqueous humor then travels through a fine trabecular meshwork at the anterior chamber angle (the one-way valve) and leaves via the canal of Schlemm.

Intraocular pressure normally measures between 10 and 22 mmHg. This represents the balance between the production and outflow of aqueous humor.[3] Tonometry is used to measure intraocular pressure (Chapter 156). An increase in aqueous humor production, resistance to the outflow of aqueous humor, or additional fluid (e.g., pus or blood) in the vitreous body can severely increase intraocular pressure, potentially causing permanent visual loss due to ischemia. In addition to medical therapies, removing fluid via an anterior chamber paracentesis will reduce intraocular pressure to help prevent further ischemia.

Central retinal artery occlusion (CRAO), usually from an atherosclerotic embolic event, is another potential cause of visual loss that may benefit from an anterior chamber paracentesis in combination with digital ocular massage (Chapter 157) and medical management.[4] Decreasing intraocular pressure increases retinal perfusion in an attempt to propagate the embolus distally and minimize the amount of visual loss. Traumatic retrobulbar hemorrhages and other extraocular causes of elevated intraocular pressure do not benefit from an anterior chamber paracentesis.

INDICATIONS

An anterior chamber paracentesis will immediately reduce intraocular pressure but is not a treatment that resolves the underlying cause of the elevated intraocular pressure. Medical management is usually initiated first to lower intraocular pressure before attempting an anterior chamber paracentesis. An anterior chamber paracentesis is indicated whenever elevated intraocular pressure threatens visual loss and medical management is not successful in lowering intraocular pressure. Reducing the intraocular pressure acutely with an anterior chamber paracentesis in disease states such as acute angle closure glaucoma, uveitis, hyphema, central retinal artery occlusion, and suppurative endophthalmitis will help prevent further irreversible vision loss, especially if used in conjunction with other medical modalities.[5–7]

There are numerous nonemergent indications for an Ophthalmologist to perform an anterior chamber paracentesis. Diagnostically, an anterior chamber paracentesis can be used for aqueous humor sampling for a suspected infection, lymphoma, and intravitreal drug level monitoring.[8,9] It is also performed for isotonic saline injection for flattened anterior chamber reformation and numerous ophthalmologic surgical procedures.

CONTRAINDICATIONS

There are no absolute contraindications to performing an anterior chamber paracentesis since the patient's vision is at risk. Consult an Ophthalmologist prior to the procedure if a ruptured globe is suspected. Relative contraindications include uncooperative patients, patients with allergies to topical ocular anesthetics, and if the Emergency Physician is not comfortable performing the procedure. The patient's airway, breathing, hemodynamic status, and other life-threatening events should always be addressed prior to the procedure.

EQUIPMENT

- Sterile povidone iodine solution
- Topical ophthalmic anesthetic drops, e.g., 0.5% proparacaine or tetracaine
- Broad-spectrum topical antibiotic eye drops, e.g., fluoroquinolone
- Sterile saline minim
- 15° super sharp micro blade
- 1 mL tuberculin syringe
- 27 to 30 gauge, 5/8 inch needle[1,8,11,12]
- Slit lamp

PATIENT PREPARATION

Inform the patient of the reasons for performing an anterior chamber paracentesis, including its risks and benefits. Obtain a signed procedural consent and place it in the medical record. Reassure the patient that a "pressure sensation" might be felt during the procedure but they should not experience pain.

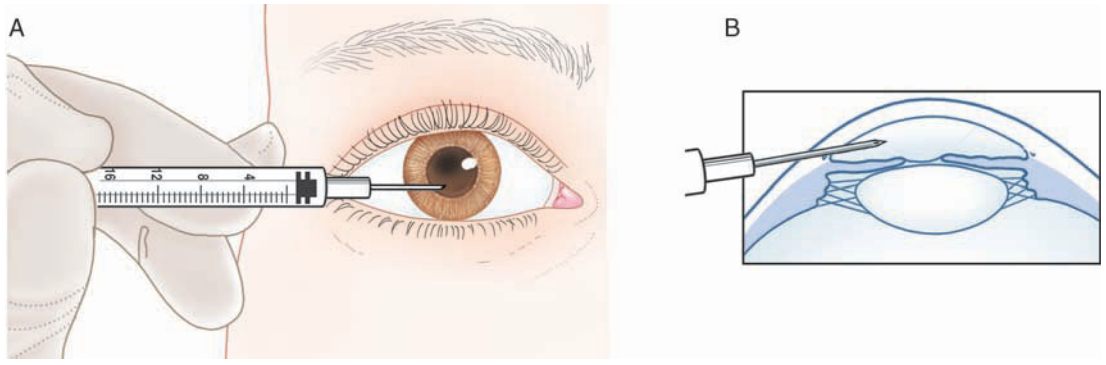


FIGURE 158-1. The hypodermic needle technique. **A.** The needle is inserted obliquely at the limbus. **B.** Transverse view of the eye. The needle enters the cornea at the limbus and is directed anteriorly into the anterior chamber.

Remove all contact lenses prior to placing any topical ocular medications or using fluorescein. **Perform a visual acuity assessment and an intraocular pressure measurement prior to any intervention to document the patient's baseline status and for serial comparisons after the procedure.** If the patient's tetanus status is unknown or their last tetanus booster has been greater than 10 years, administer a tetanus booster intramuscularly. Administer antiemetic and pain medication if the patient is symptomatic. Retching and vomiting increases intraocular pressure and complicates the procedure. Instill one to two drops each of the topical ophthalmic anesthetic and the broad-spectrum ophthalmic antibiotic onto the affected eye. Some Ophthalmologists instill two drops of sterile povidone iodine solution onto the cornea followed by topical ophthalmic anesthetic drops to dilute it.[17,18,20] Place the patient comfortably in a chair. Position their chin on the slit lamp chin rest. Attempt to comfortably immobilize the patient's head. Use an assistant if needed. Check for proper anesthesia by softly brushing the cornea with cotton-tipped swab or rechecking intraocular pressure.

TECHNIQUES

Numerous techniques have been described to perform an anterior chamber paracentesis. The quickest, simplest, and easiest to perform are the hypodermic needle and saline minim techniques. The surgical technique is often performed by an Ophthalmologist.

HYPODERMIC NEEDLE TECHNIQUE

Anesthetize the cornea and position the patient in the slit lamp as described above. Arm a tuberculin syringe with a 27 to 30 gauge needle. Slightly withdraw the plunger to break the bead on the syringe. Position the tip of the needle at the limbus, somewhere between the 4 o'clock and 8 o'clock position (**Figure 158-1A**). **Gently insert the needle through the cornea and angled anteriorly. This will ensure that the tip of the needle will enter the anterior chamber and not injure the ciliary body, iris, or lens (Figure 158-1B).** The anterior chamber holds approximately 0.3 mL of fluid. Slowly withdraw the plunger and aspirate 0.1 mL of fluid from the anterior chamber. Withdraw the needle. Apply topical ophthalmic antibiotic drops immediately after the procedure.

SALINE MINIM TECHNIQUE

A saline minim attached to a hypodermic needle is an alternative to using a syringe (**Figure 158-2**). This technique is simpler to perform when compared to using a hypodermic needle.[11,12,15] A saline minim is a single use, soft sided, disposable container containing 0.5 mL of sterile saline.

Anesthetize the cornea and position the patient in the slit lamp as described above. Prepare the minim. Twist off and discard the tip of the minim. Firmly apply a 27 to 30 gauge needle to the open end of the minim. Grasp the needle-minim unit with the thumb and index finger of the dominant hand. Gently squeeze the minim until one drop of sterile saline is expressed from the tip of the needle. Do not release pressure on the sides of the minim. Position the tip of the needle at the limbus, somewhere between the 4 o'clock and 8 o'clock position (**Figure 158-2**). **Gently insert the needle through the cornea and angled anteriorly. This will ensure that the tip of the needle will enter the anterior chamber and not injure the ciliary body, iris, or lens.** Slowly open the thumb and index finger to release the compression on the minim. The aqueous humor will flow from the anterior chamber into the minim. Do not withdraw enough fluid to dimple the cornea. Withdraw the minim until the needle exits the eye. Apply topical ophthalmic antibiotic drops immediately after the procedure.

SURGICAL TECHNIQUE

Anesthetize the cornea and position the patient in the slit lamp as described above. Position the tip of the 15° super sharp micro blade at the limbus, somewhere between the 4 o'clock and 8 o'clock position. **Gently insert the blade through the cornea and angled anteriorly. This will ensure that the tip of the blade will enter the anterior chamber and not injure the ciliary body, iris, or lens.** Withdraw the blade. Carefully and gently insert a 27 to 30 gauge needle on a tuberculin syringe through the incision. Aspirate 0.1 mL of fluid from the anterior chamber and withdraw the needle. As an

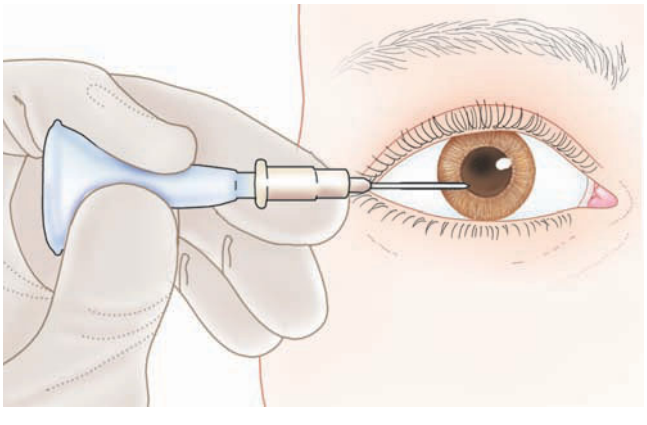


FIGURE 158-2. The saline minim technique.

alternative, a 27 to 30 gauge needle on a saline minim can be used. Apply topical ophthalmic antibiotic drops immediately after the procedure.

ASSESSMENT

After the procedure, immediately perform an intraocular pressure measurement with the same device used before the procedure to measure intraocular pressure. The intraocular pressure and symptomatic complaints should significantly decrease after the anterior chamber paracentesis procedure. Perform serial intraocular pressure measurements in 30-minute intervals for 2 hours to assess for any recurrence of elevated intraocular pressure. Perform and document a postprocedure visual acuity. Readdress any symptomatic complaints of eye pain, nausea, and headache. Significant decreases in intraocular pressure have been shown immediately, 2 hours, 2 days, and up to 2 weeks after an anterior chamber paracentesis with near resolution of symptoms.[5,6,19]

AFTERCARE

An Ophthalmologist should evaluate the patient in the Emergency Department. Immediate surgical intervention may be indicated if there is no improvement in the patient's symptoms or the intraocular pressure is persistently elevated despite medical management and an anterior chamber paracentesis. Patients can usually be safely discharged home once symptoms resolve and the intraocular pressure has normalized. Arrange close follow-up with an Ophthalmologist within the next 24 to 48 hours. Patients are typically discharged with broad-spectrum topical ophthalmic antibiotics, oral pain medications, oral antiemetics, and other antiglaucoma medications including oral acetazolamide, topical ophthalmic beta blockers, ophthalmic pilocarpine, and/or ophthalmic steroids.[10,15] The consulting Ophthalmologist will determine the proper medical management including the medications, their strength, and the frequency of administration. The patient should immediately return to the Emergency Department if they develop increased eye pain, severe nausea and/or vomiting, or any visual disturbances (e.g., decreased vision, photophobia, and halos around lights).

COMPLICATIONS

Mechanical injury to ocular structures (e.g., ciliary body, corneal abrasions, iris, or lens), infection, and bleeding comprise the most serious complications after an anterior chamber paracentesis.[13,14] Inadvertent injection of air into the anterior chamber occurs, but is typically a small amount and resolves spontaneously.[12] Allergic reactions to any of the medications used can also occur.

SUMMARY

Many types of disease pathologies can acutely elevate intraocular pressure and result in potential irreversible vision loss. Immediate reduction of the intraocular pressure by using medical treatments in conjunction with an anterior chamber paracentesis will reduce the amount of ischemic time, thereby reducing the amount of possible permanent visual impairment.

Multiple studies have repeatedly demonstrated the efficacy and safety of an anterior chamber paracentesis when used acutely to reduce intraocular pressure.[11,12] Although performing an anterior chamber paracentesis is often met with apprehension by the Emergency Physician, it is a procedure routinely performed in the office setting. Emergency Physicians should become familiar with an anterior chamber paracentesis because it is safe, simple, effective, relatively quick, and also has the potential to save a patient's vision.

159 Corneal Foreign Body Removal

Eric F. Reichman

INTRODUCTION

Corneal foreign bodies are a common complaint confronting Emergency Physicians and account for approximately 35% of all eye injuries seen.[1] Many objects have been implicated as a source of corneal foreign bodies including, but not limited to glass, metal, wood, dirt, dust, insects, and plant particles.[1] The majority of ocular foreign bodies require prompt removal. More than 75% of retained foreign bodies present on the eye surface are corneal in nature, and if left in place for more than 3 days will result in a keratitis.[2]

The prevailing symptom that forces patients to seek treatment is the sensation of an ocular foreign body or simply the pain associated with the foreign body. A variety of techniques exist for removal of ocular foreign bodies. A discussion of each of these techniques is necessary to determine the proper technique for a given situation.

ANATOMY AND PATHOPHYSIOLOGY

Many foreign bodies are diverted from the surface of the eye by the rapid blinking action of the eyelids and the eyelashes. A foreign body may not necessarily lodge itself into the cornea or the surrounding scleral surface if it is able to get past the eyelids and eyelashes. It may be washed to the inner canthus by a combination of blinking and tear flow. The foreign body may occasionally be carried away via drainage through the lacrimal ducts.[2] Objects that resist these means of diversion may be found in the upper or lower fornices, the channels created by the fold of the inner surfaces of the eyelids in communication with the conjunctival surface of the eye. The foreign body in the upper fornix is typically found lodged in the subtarsal groove on the inner surface of the upper eyelid, inferior to the tarsal plate.[2] Foreign bodies may also travel deeper into the respected fornices where they may be difficult to find. Foreign bodies may lodge themselves into the surface of the conjunctiva overlying the sclera or into the cornea itself, which obviously carries the most risk of serious injury or permanent scarring.

The cornea is <1 mm thick. It is comprised of five layers (from outer to inner layer): epithelium, Bowman's membrane, stroma, Descemet's membrane, and the endothelial layer that lies directly over the anterior chamber.[3] The surface epithelium itself has five layers of squamous cells. Most superficial corneal foreign bodies become embedded in this layer and do not result in scarring. Bowman's membrane has no regenerative capacity, and if injured, may result in scarring and permanent injury.[4] Foreign bodies that violate Bowman's membrane are considered deep corneal injuries. The stroma is composed of collagen and accounts for the largest portion of the cornea. Descemet's membrane is a basement membrane that can be regenerated if injured. The final component of the cornea is the endothelial layer that is composed of a single row of cuboidal cells that can regenerate if damaged.

Healthy cells adjacent to the injury slide over the damaged site and eventually replicate to the previous number of cells present when the corneal epithelium is injured.[3] Conjunctival epithelium migrates over the cornea to aid in its repair. This is true even if the entire surface epithelium of the cornea is removed.

Corneal innervation is provided by sensory nerve fibers located in the surface epithelium. These are concentrated primarily in the center of the cornea and sparsely located in the periphery.[5,6] Injuries

to the corneal epithelium produce pain, tearing, photophobia, and the sensation of a foreign body.[6] More pain occurs when the central portion of the cornea is affected due to the larger distribution of sensory nerves.[6]

Patients are fairly adept at identifying the location of an embedded foreign body due to the corneal innervation. A study evaluated 50 patients with corneal foreign bodies and their accuracy in identifying the foreign body location.[7] Eighteen patients (36%) were unable to identify the foreign body location, 14 (28%) were able to identify the exact location, and 18 (36%) were partially correct in identifying the location based upon vertical and horizontal components. **Always acknowledge the patient's sensation of an ocular foreign body and evaluate the area thoroughly.**

The presence of a metallic foreign body in the cornea can result in a rust ring. This is identified as a brownish ring surrounding the foreign body. **The rust ring, and the metallic foreign body, must be removed from the cornea.** The rust ring may be removed at the time of the foreign body removal or within 24 hours by an Ophthalmologist. Refer to Chapter 160 for the complete details of rust ring removal.

INDICATIONS

In general, all foreign bodies involving the eye must be removed. They do not all need to be removed immediately in the Emergency Department. Foreign bodies that are superficial and located on the cornea, sclera, eyelid, upper fornix, or lower fornix can safely be removed in the Emergency Department by the Emergency Physician. Metallic foreign bodies require prompt removal to avoid the formation of a rust ring. If a rust ring is also present, the foreign body should be removed in the Emergency Department and the rust ring can be removed by the Emergency Physician or by the Ophthalmologist at the 24-hour follow-up visit. Vertical abrasions on the cornea during the fluorescein examination are indicative of a foreign body under the eyelid. This requires the upper eyelid to be everted to evaluate for the presence of a foreign body under the eyelid.

CONTRAINDICATIONS

Corneal foreign bodies located in the direct axis of vision can cause permanent visual disturbances if improperly removed.[4] Consult an Ophthalmologist before removing these foreign bodies, as they often prefer to remove them. Deeply embedded objects or multiple foreign bodies that would require extensive debridement can result in significant scarring.[1] Consult an Ophthalmologist before attempting to remove these foreign bodies. **Avoid any manipulation of the eye if a perforated globe is suspected based upon either the direct examination of the eye or the mechanism of injury.** Foreign bodies embedded deeply within the cornea may be left in place if they are composed of an inert substance such as glass.[1] This will avoid the possibility of additional scarring from extensive debridement as long as the object is well below the corneal surface to allow for healing of the epithelium over the object. This decision must be made in conjunction with an Ophthalmologist. Consult an Ophthalmologist if an infection is associated with the foreign body (e.g., corneal edema, corneal clouding, or a purulent discharge). Refer injuries to an Ophthalmologist that are old, those in which the foreign body has been covered by epithelium, and foreign bodies resistant to removal. Do not attempt to extract a corneal foreign body if the patient is confused or uncooperative as this can result in a perforated globe. Consider the use of intravenous sedation, procedural sedation (Chapter 129), or general anesthesia to extract the foreign body in these patients after consulting an Ophthalmologist.

EQUIPMENT

- Slit lamp
- Cotton-tipped applicator
- Corneal spud
- Ringer's lactate solution or normal saline
- Intravenous (IV) tubing
- 25 or 27 gauge needle
- Tuberculin syringe with needle
- Topical ocular anesthetic solution (e.g., proparacaine and tetracaine)
- Topical ophthalmic antibiotic
- Cycloplegic agents (e.g., cyclopentolate, homatropine, and tropicamide)
- Fluorescein strips or liquid
- Electric burr drill and burrs
- Eye patches
- Adhesive tape
- Benzoin solution
- Wood's lamp (if slit lamp is not available)
- Eidolon BLUMINATOR® (Eidolon Optical LLC, Natick, MA) (if slit lamp is not available)

Having the availability of a slit lamp is preferred when removing a corneal foreign body. There are alternatives if a slit lamp is not available or the Emergency Physician does not feel comfortable with using a slit lamp. The Wood's lamp can provide the appropriate blue light required for fluorescein staining and rust ring removal. This portable device has a built in magnification lens. It has several disadvantages including having to be plugged into an outlet, an awkward shape, and a heaviness that must be balanced while using it. A newer device is the Eidolon BLUMINATOR®. It is small, handheld, self-contained, battery powered, and includes a 7× magnification lens.

PATIENT PREPARATION

Perform a complete eye examination prior to removing a foreign body. Measure visual acuities prior to any ocular procedure and following the procedure to document any changes. Refer to Chapter 153 for the complete details regarding the eye examination. Apply a topical ocular anesthetic agent into the affected eye. Note any irregularities in the contour of the eye, any loss of anterior chamber depth, prolapse of the iris through a corneal laceration, focal injection, a hyphema, or lens opacification. All of these signs may indicate a ruptured globe that requires an emergent Ophthalmology consultation.[4] Vary the beam of light from the slit lamp in its direction of illumination from direct exposure to indirect exposure, and even tangential exposure, to highlight any surface defects.[8] Examine the anterior chamber for cells and flare that occurs in older injuries as a result from a secondary iritis. The patient typically suffers from the discomfort of an anterior uveitis rather than the foreign body itself.[1]

Stain the eye with fluorescein dye. Fluorescein can permanently stain contact lenses and should not be used in their presence. Illuminate the eye with a cobalt blue light, looking for the green reflection of a corneal abrasion. Observe the site for the flow of fluorescein stain away from the site of a corneal puncture as anterior chamber fluid flows forth, otherwise known as the Seidel sign.[4,8] A positive Seidel sign indicates a ruptured globe. Irrigate

the fluorescein stain from the eye after the examination is complete to avoid any chemical-induced irritation.

Explain the process of ocular foreign body removal to the patient and/or their representative. Discuss the benefits and risks of the procedure. Obtain a signed informed consent to perform this procedure. Instill additional topical ophthalmic anesthetic solution as necessary.

TECHNIQUES

EYELID FOREIGN BODIES

Evert the upper eyelid.[8] Refer to Chapter 153 and **Figures 153-12** through **153-15** for the complete details regarding the eyelid eversion. Instruct the patient to look downward as a cotton-tipped applicator is used to gently press on the upper eyelid over the tarsal plate. Grasp the eyelashes with the thumb and index finger. Pull the upper eyelid outward, downward, and upward to evert it over the applicator. Examine the undersurface of the eyelid for foreign bodies. Remove any foreign bodies by sweeping the area with a saline-moistened cotton-tipped applicator (**Figure 159-1**). Double evert the eyelid by lifting the inferior edge of the eyelid created by the initial eversion. This is best accomplished by using a cotton-tipped applicator or an appropriate lid retractor. Examine the sclera and conjunctiva for foreign material. Allow the upper eyelid to return to normal. Release the eyelid and instruct the patient to blink their eyes.

Evert the lower eyelid by pulling the lower eyelashes forward while the patient looks upward.[4] Examine the area in similar fashion to the upper eyelid. Sweep the scleral and palpebral (eyelid) conjunctival area with a saline-soaked cotton-tipped applicator if the patient experiences a foreign body sensation but no debris can be visualized.

IRRIGATION

Superficial foreign bodies on the conjunctiva or the cornea can sometimes be removed by using an irrigation technique. A brief description is presented in this section. Refer to Chapter 155 for the complete details regarding eye irrigation. **Never use Morgan or Mediflow lenses for eye irrigation in the face of a foreign body as it may lodge the object further into the cornea.**

The most appropriate solution to use is Ringer's lactate solution followed by normal saline. Tap water can be used in the prehospital setting. Ringer's lactate solution causes less irritation because the range of its pH (6.0 to 7.2) is closer to the normal pH (7.4) of the eye in comparison to the pH (4.5 to 6.0) of normal saline.[4]

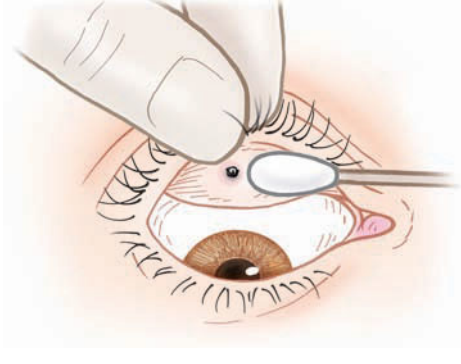


FIGURE 159-1. Evert the eyelids and remove the foreign body with a moistened cotton-tipped applicator.

Place the patient supine with their head tilted toward the side being irrigated to aid in proper runoff of the irrigant. Hang the IV fluid bag above the patient's head. Insert the IV tubing spike into the port on the IV fluid bag. Flush the patient's eye with sterile IV solution through the open end of the IV tubing while holding the patient's eyelids open. Flush from the scleral surface with the flow of solution directed over the cornea, thus washing the object out of the eye.[1,4,8] **Never direct the solution onto the object in order to avoid embedding it deeper into the soft underlying tissues. Never direct the flow directly onto the surface of the cornea to avoid secondary injury.** Use a forceps or cotton-tipped applicator to remove objects flushed onto the palpebral conjunctiva.[4] **Never use a forceps on the eye itself.**

COTTON-TIPPED APPLICATOR

Use a cotton-tipped applicator premoistened with saline to remove a foreign body from the conjunctiva overlying the sclera or the eyelids.[8] Gently touch the premoistened tip of the cotton-tipped applicator to the conjunctival surface and lift off the foreign body. **Do not use the cotton-tipped applicator to remove a foreign body from the cornea.[8]** It can result in a large corneal abrasion by removing the surface epithelium.

MANUAL EXTRACTION

Extract the foreign body with a corneal spud or hypodermic needle if it is not removed via irrigation or if it is embedded superficially into the corneal surface. A corneal spud is a stainless steel device that comes in a variety of shapes. It generally consists of a sharpened metal tip attached to a handle.[1] It is used to lift off or to carve out a corneal foreign body.[1] Many physicians prefer to use a tuberculin syringe. It allows for better control of the needle by using the syringe portion as the grip. The author always uses a saline-filled tuberculin syringe. This allows the Emergency Physician to apply saline drops to moisten the eye as well as to flush away the foreign body after it is dislodged from the cornea. An 18 gauge needle has been described for the removal of large foreign bodies because of its wide diameter.[1] The instrument used is physician dependent. **Proper explanation of the extraction procedure using a needle will often ease a nervous patient and ensure better compliance by limiting unexpected movements.**

Perform the procedure under direct visualization with the slit lamp. Place the patient seated at the slit lamp with their head firmly in place against the forehead rest to avoid any unexpected movement (**Figure 159-2A**). If a slit lamp is not available, the foreign body can be removed using the blue light of a Wood's lamp or Eidolon BLUMINATOR®. Hold the needle, or spud, between the thumb and index finger of the dominant hand as one would a pencil with the bevel facing the Emergency Physician. Stabilize the dominant hand on the patient or the slit lamp apparatus using the remaining fingers. Instruct the patient to focus their vision on a given point to avoid any eye movement.

Approximate the tip of the needle, or spud, to the foreign body with the naked eye before utilizing the slit lamp microscope in order to avoid inadvertent injury. Approach the foreign body from the periphery and not across the patient's field of vision (Figure 159-2B). Gently tease out the foreign body using the beveled edge of the needle, or spud, in a tangential direction in relation to the eye to avoid inadvertent deep puncture if the patient suddenly moves (Figure 159-2C). Use the tip to gently pry the foreign body loose if absolutely necessary, but extreme care must be exercised (Figure 159-2D). Remove the loose foreign body with a moistened cotton-tipped applicator or with gentle irrigation.

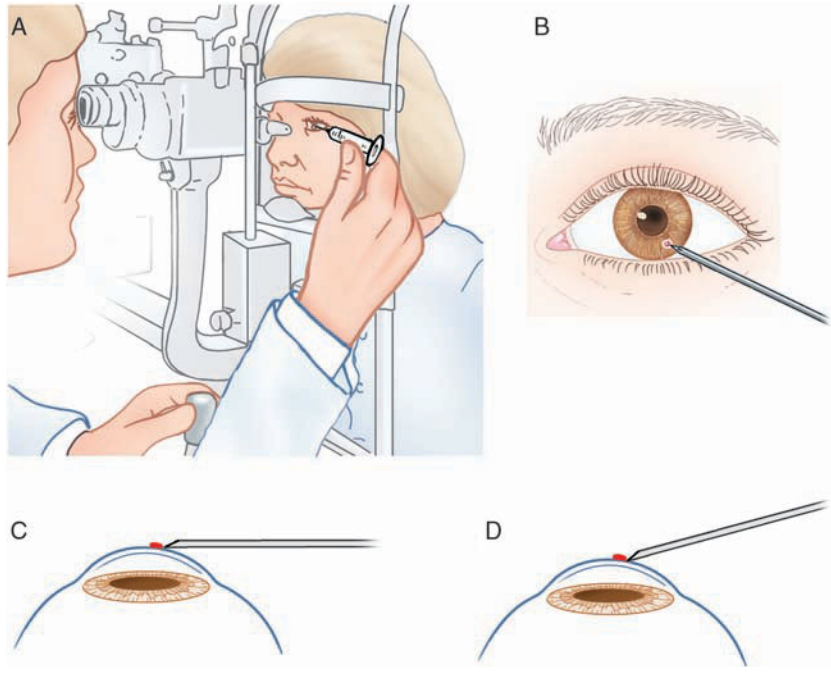


FIGURE 159-2. A hypodermic needle to remove a corneal foreign body. **A.** Position the patient in the slit lamp. Stabilize the hand holding the needle. **B.** Approach the foreign body from the periphery. **C.** Hold the needle tangential to the cornea to remove the foreign body. **D.** Slightly angle the needle to "pry" the foreign body off the cornea.

ELECTRIC BURR DRILL EXTRACTION

An electric battery powered drill equipped with various sized diamond dental burrs, if available, can be used for foreign body removal (**Figure 159-3**). Its use is typically associated with an increased tissue defect when compared to using a needle or a spud.[9] **Use caution as the burr drill can also embed the foreign body deeper into the cornea.**

Choose a burr size that is slightly larger than the diameter of the foreign body. Load the burr onto the drill. Grasp the device like a pencil using the thumb and middle finger. Press the finger bar on the drill with the index finger to turn on the drill and rotate the burr bit. Approach the foreign body tangentially to the eye (**Figure 159-4**). Gently place the rotating burr bit on the area to be debrided using short applications of one to two rotations of the burr. Lift the burr from the cornea after each application to examine the area and determine if the foreign body has been removed.

ASSESSMENT

Carefully examine the cornea under the slit lamp with and without the use of fluorescein dye. Ensure that the foreign body is completely removed. Consult an Ophthalmologist if the foreign body has broken off, is deeply embedded within the cornea, or is associated with a rust ring. Measure and record the patient's visual acuity after the extraction procedure. Compare this to the pre-extraction visual acuity. Consult an Ophthalmologist if there is a difference in the pre-extraction and post-extraction visual acuity.

AFTERCARE

A corneal abrasion will be present upon removal of the foreign body. The defect is usually larger than the original foreign body and should be treated as a typical corneal abrasion. Place a broad-spectrum ophthalmic antibiotic ointment (e.g., an aminoglycoside) on the eye. Instruct the patient to instill topical broad-spectrum antibiotics every 4 hours if the eye is not patched.[1,4,5,8] The ophthalmic nonsteroidal anti-inflammatory drugs are safe to use and provide effective pain relief.[12–14] Currently available are bromfenac, diclofenac, and ketorolac.

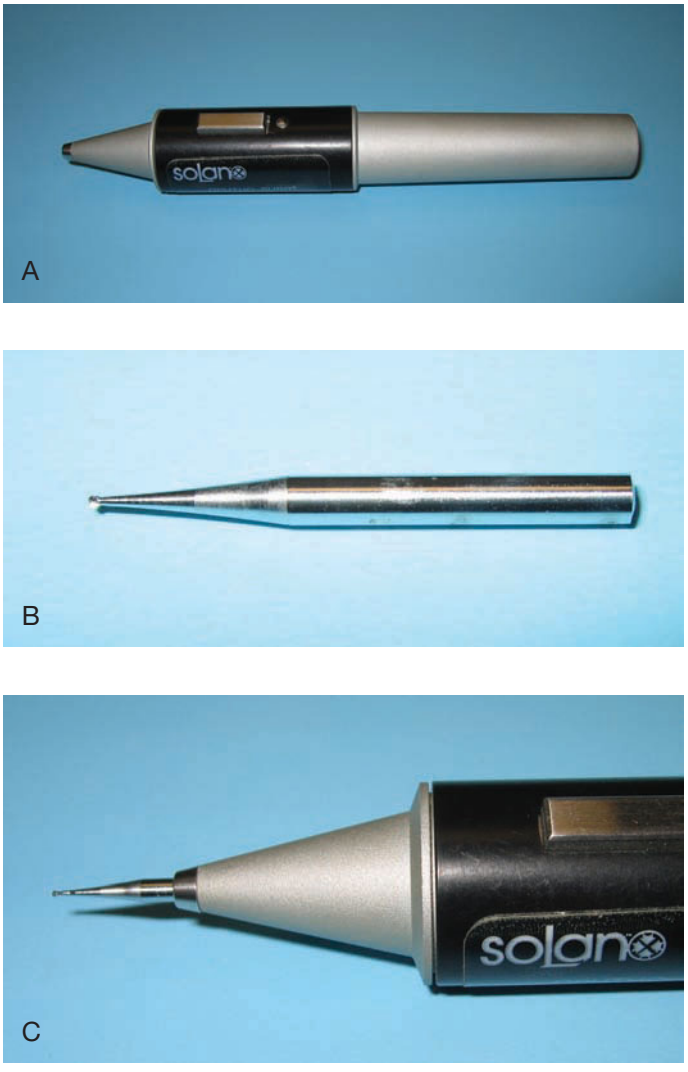


FIGURE 159-3. The burr drill used to remove a corneal foreign body. **A.** The drill. **B.** The burr bit. **C.** The burr drill with a burr bit inserted.

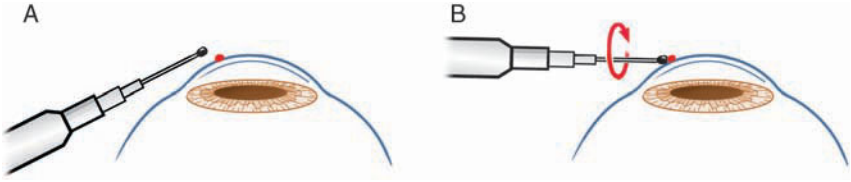


FIGURE 159-4. Removal of a corneal foreign body with a burr drill.

The use of an eye patch is controversial and usually not required. Refer to Chapter 161 regarding the complete details of eye patching. **The use of eye patches should be considered cautiously as they may be associated with additional discomfort, delayed healing, and the conversion of a corneal abrasion into a corneal ulcer.[10] Consider patching the eye closed if the defect is large and painful. Avoid pressure patching the eye in the case of small, superficial, or minimally painful abrasions. Avoid the use of eye patches in cases of organic foreign bodies and in patients who wear contact lenses, as the bacterial milieu is favorable for the development of a local infection.[4] Since most patients will not need eye patching, it is best to consult an Ophthalmologist before patching an eye.**

The proper method of applying an eye patch is to first administer all necessary medications. Instruct the patient to close both eyes. Apply a folded patch to the affected eye (rounded edge pointed downward) over which is placed an unfolded patch. Prep the skin with a benzoin solution to aid with tape adherence. Apply strips of tape from the medial aspect of the forehead, over the patch, and to the lateral cheek. Apply the tape tightly enough to prevent eye opening but lightly enough to not cause discomfort. Apply strips of tape repeatedly over the patch until it is entirely covered. Apply the final pieces of tape over the center of the patch while holding the cheek soft tissue superiorly. This will ensure that the cheek, when released, will pull the bandage taut and avoid loosening.[4,8]

Cycloplegics (e.g., 1% cyclopentolate) can be used to alleviate pain or to limit pain in cases of significant corneal defects or an anterior uveitis.[1] **Topical steroids have no place in the treatment of traumatic corneal defects.[1]** Oral analgesics are appropriate in cases of persistent discomfort. **Do not prescribe topical ocular anesthetic agents due to their abusive potential and the direct deleterious effects of the anesthetic on the corneal epithelium.[4]**

Refer all patients to an Ophthalmologist for reexamination in 24 hours, especially if an eye patch has been applied. A rust ring can be removed by the Ophthalmologist at the follow-up visit. Instruct the patient not to operate a vehicle if the eye is patched closed. These instructions also hold true if the eye is not patched but a procedure was performed to remove a foreign body.

Many eye injuries occur while at work due to failure to comply with wearing eye protection, resulting in a significant loss of working hours.[6,7,11] Take the time necessary to explain the importance of wearing safety goggles if the injury occurred while at work, gardening, or participating in hobbies (e.g., woodworking, drilling, auto repair, etc.).

COMPLICATIONS

A foreign body will occasionally not be able to be removed in the Emergency Department. Refer the patient to an Ophthalmologist for definitive treatment before further attempts at removal result in severe ocular injury and the potential for violation of the anterior chamber (i.e., perforation of the globe). **Notify an Ophthalmologist immediately if inadvertent puncture of the globe occurs from attempts at foreign body removal as a surgical emergency now exists.**

Improper placement of eye patches can cause a corneal ulcer or delayed corneal healing.[8] Caution the patient against driving while the eye is patched due to impaired depth perception.[8]

Continued discomfort at the 24-hour follow-up may indicate the foreign body was not completely removed, a corneal rust ring from a metallic object has formed, a penetrating eye injury, anterior uveitis, or an infection.[1] Contaminated corneal foreign bodies or those consisting of vegetative material can also lead to corneal ulceration from the introduction of bacteria.[1]

Corneal defects will not always be completely healed at the 24 hour follow-up. The eye may require one additional day of patching if the defect is still a significant size. Treat the defect by applying a topical antibiotic for several more days if the defect is markedly smaller than the original injury.[1]

Care must be taken to avoid further damage to the eye when treating children or patients who are uncooperative. Intravenous sedation and analgesia can be used in these situations. Consult an Ophthalmologist for treatment under general anesthesia if sedation is contraindicated or if the Emergency Physician is not comfortable with removing the foreign body under procedural sedation.[4]

SUMMARY

Corneal foreign bodies are routinely encountered in the Emergency Department. They must be definitively treated in order to avoid long-lasting ocular disability. Documentation of a complete history and physical examination of the eye is mandatory before attempting to remove a foreign body. The most reliable method of corneal foreign body removal is the use of a hypodermic needle or corneal spud, taking care to avoid additional ocular trauma. Administer appropriate antibiotics and/or cycloplegics after removal of the foreign body. The application of an eye patch is not required after the foreign body is removed in most cases. The decision to apply an eye patch is best done in consultation with an Ophthalmologist. Refer the patient to an Ophthalmologist in 24 hours for evaluation of proper healing and the immediate treatment of any evolving complications.

160 Corneal Rust Ring Removal

Eric F. Reichman

INTRODUCTION

Corneal rust rings occur commonly when metallic foreign bodies become embedded in the cornea. Removal of the rust ring is imperative to avoid permanent staining of the cornea, persistent inflammation, or disruption of corneal integrity (necrosis) with loss of stromal substance.[1–3] Two techniques for the removal of rust rings are discussed: hypodermic needle extraction and corneal burr drill

removal. The use of topical deferoxamine as a chemical chelator should only be used by an Ophthalmologist and is mentioned only for the sake of completeness.

ANATOMY AND PATHOPHYSIOLOGY

The cornea is approximately 0.5 mm thick. It is comprised of five layers (from outer to inner layer): epithelium, Bowman's membrane, stroma (largest layer), Descemet's membrane, and the endothelial layer which lies directly over the anterior chamber. Corneal rust rings are formed from the oxidation of iron present in metallic foreign bodies. As little as 3 hours of corneal contact are required to form the brown stain of a rust ring.[1]

INDICATIONS

All corneal metallic foreign bodies require prompt removal to avoid the possibility of rust ring formation. A rust ring requires complete removal in a timely fashion in order to avoid the damaging effects of rust on the cornea. While foreign bodies should be removed in the Emergency Department, the rust ring can be left for the Ophthalmologist to remove within 24 to 48 hours if the Emergency Physician does not feel comfortable removing the rust ring.

CONTRAINDICATIONS

Corneal foreign bodies and rust rings that are located in the direct axis of vision can cause permanent visual disturbances if improperly removed.[2] Consult an Ophthalmologist before removing these, as they often prefer to remove them. Do not attempt to extract a rust ring if the patient is a young child, confused, or uncooperative as this can result in a perforated globe. These patients may require the use of intravenous sedation, procedural sedation, or general anesthesia to extract the rust ring.

EQUIPMENT

- Slit lamp
- 25 or 27 gauge needle
- Tuberculin syringe with a needle
- Burr drill
- Burr bits
- Topical ocular anesthetic agent (e.g., proparacaine or tetracaine)
- Topical ophthalmic antibiotic
- Cycloplegic agents (e.g., cyclopentolate, homatropine, or tropicamide)
- Ringer's lactate solution or normal saline
- Fluorescein strips or liquid
- Wood's lamp (if slit lamp is not available)
- Eidolon BLUMINATOR® (Eidolon Optical LLC, Natick, MA) (if slit lamp is not available)

Having the availability of a slit lamp is preferred when removing a corneal rust ring. There are alternatives if a slit lamp is not available or the Emergency Physician does not feel comfortable with using a slit lamp. The Wood's lamp can provide the appropriate blue light required for fluorescein staining and rust ring removal. This portable device has a built-in magnification lens. It has several disadvantages including having to be plugged into an outlet, an awkward shape, and a heaviness that must be balanced while using it. A newer device is the Eidolon BLUMINATOR®. It is small, hand-held, self-contained, battery powered, and includes a 7× magnification lens.

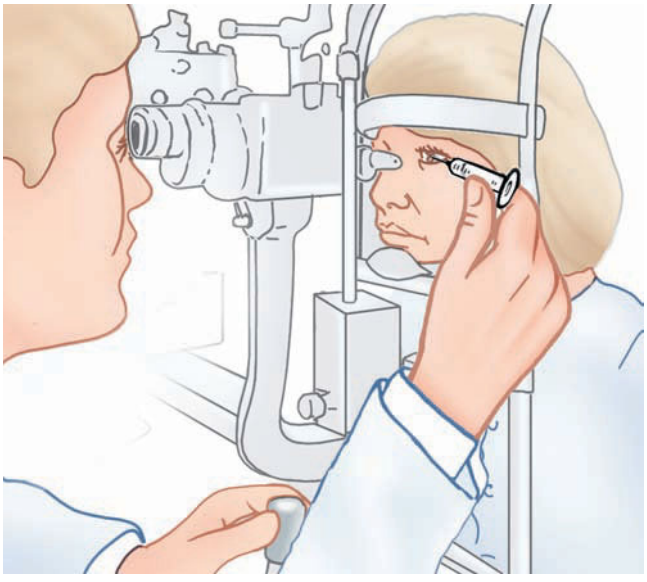


FIGURE 160-1. Positioning of the patient and the examiner's hand.

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed informed consent to perform this procedure. Apply a topical ocular anesthetic agent into the affected eye. Determine the patient's visual acuity in the affected eye. Seat the patient at the slit lamp with their head firmly in place to avoid any unexpected movement (**Figure 160-1**). Examine the eye via the slit lamp and rule out the possibility of an intraocular foreign body with a corneal perforation. Perform a complete eye examination to rule out any other ocular problems. Remove the foreign body, if still present, with the hypodermic needle or tuberculin syringe. Refer to Chapter 159 for the complete details regarding corneal foreign body removal. The rust ring will often be removed simultaneously with the metallic foreign body. Make an attempt to remove the rust ring if it remains after removal of the foreign body.

TECHNIQUES

MANUAL EXTRACTION

Scrape out the rust ring in a similar fashion to the removal of a metallic foreign body (**Figure 160-2**). Refer to Chapter 159 for the complete details regarding corneal foreign body removal. **The entire area of rust stained epithelium must be completely removed without any residual rust.**

Extract the rust ring with a corneal spud or hypodermic needle. A corneal spud is a stainless steel device that comes in a variety of

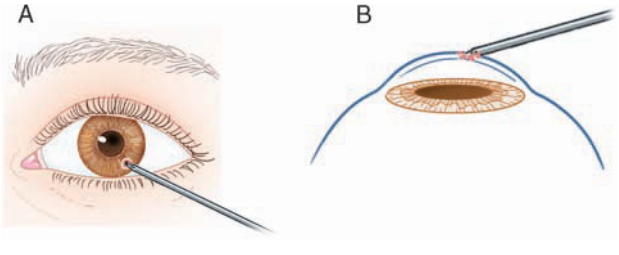


FIGURE 160-2. Manual extraction of the rust ring.

shapes. It generally consists of a sharpened metal tip attached to a handle.[1] It is used to lift off or to carve out a corneal foreign body or rust ring.[1] Many physicians prefer to use a tuberculin syringe. It allows for better control of the needle by using the syringe portion as the grip. The author always uses a saline-filled tuberculin syringe. This allows the Emergency Physician to apply saline drops to moisten the eye as well as to flush away the rust ring after it is dislodged from the cornea. The instrument used is physician dependent. **Proper explanation of the extraction procedure using a needle will often ease a nervous patient and ensure better compliance by limiting unexpected movements.**

Perform the procedure under direct visualization with the slit lamp. Place the patient seated at the slit lamp with their head firmly in place against the forehead rest to avoid any unexpected movement (**Figure 160-1**). If a slit lamp is not available, the foreign body can be removed using the blue light of a Wood's lamp or Eidolon BLUMINATOR®. Hold the needle, or spud, between the thumb and index finger of the dominant hand as one would a pencil with the bevel facing the examiner. Stabilize the dominant hand on the patient or the slit lamp apparatus using the remaining fingers. Instruct the patient to focus their vision on a given point to avoid any eye movement.

Approximate the tip of the needle, or spud, to the rust ring with the naked eye before utilizing the slit lamp microscope in order to avoid inadvertent injury. Approach the rust ring from the periphery and not across the patient's field of vision (Figure 160-2A). Gently tease out the rust ring using the beveled edge of the needle, or spud, in a tangential direction in relation to the eye to avoid inadvertent deep puncture if the patient suddenly moves. Use the tip to gently pry the rust ring loose if absolutely necessary, but extreme care must be exercised (Figure 160-2B). Remove the loose rust ring with a moistened cotton-tipped applicator or with gentle irrigation.

ELECTRIC BURR DRILL EXTRACTION

An electric battery-powered drill equipped with diamond burrs, if available, can be used for rust ring removal (**Figure 159-3**). The burr bit cuts away corneal tissue very slowly. Corneal rust rings were induced in rabbits and comparisons were made between manual extraction versus electric drill extraction.[1] Both were equally effective for rust ring removal, but the burr caused a deeper corneal defect. **Use caution when using an electric burr device.** There was no difference in corneal scarring between the two techniques. The burr drill can also be used to extract rust in the bulbar conjunctiva.[4]

Choose a burr size that is slightly larger than the diameter of the rust ring. Load the burr onto the drill. Grasp the device like a pencil using the thumb and middle finger. Press the finger bar on the drill with the index finger to turn on the drill and rotate the burr bit. Approach the rust ring tangentially to the eye (**Figure 160-3**). Gently place the rotating burr bit on the area to be debrided using short applications of one to two rotations of the burr. Lift the burr from the cornea after each application to examine the area and determine if the rust ring has been removed. **Thoroughly inspect the base of the crater to ensure that it is free of rust.**[4] Continue the process until the rust ring is removed. Use a slightly larger burr bit if rust still remains along the periphery of the crater.

DELAYED REMOVAL

The rust ring may be removed after it ages.[2,8] Allow the rust ring to remain for 24 to 48 hours. During this time the iron deposits will kill the surrounding corneal epithelial cells. The rust ring will "soften" and be easily removed in one piece with a needle, spud, or burr drill. **Do not allow the rust ring to remain for longer than 24 to 48 hours, ideally 24 hours, as it can cause significant damage to the cornea.**

CHEMICAL CHELATION

Topical deferoxamine has been used experimentally for the nonsurgical removal of rust stains on the cornea.[6] It has been shown to remove rust, though perhaps not as reliably as the methods previously described. The potential exists for resultant eye irritation, corneal ulceration, or persistence of the rust stain.[6] The clinical use of deferoxamine should be limited for use only in very select situations such as children with multiple lesions or when the central axis of vision is involved.[7] This technique is reserved for the Ophthalmologist and is therefore not described in this text.

ASSESSMENT

Measure and document visual acuities before and after the procedure. Consult an Ophthalmologist if the postprocedural visual acuity is different from the preprocedural visual acuity.

AFTERCARE

A corneal defect resembling a corneal abrasion will be present after the rust ring is removed. The defect is usually larger than the original foreign body and should be treated as a typical corneal abrasion. Apply topical ocular antibiotic ointment in the eye. The use of an eye patch is controversial but considered by most as unnecessary. Instruct the patient not to operate a vehicle. Administer cycloplegics to alleviate pain from an actual or potential anterior uveitis.[2] Oral analgesics are appropriate in cases of persistent discomfort. Consider prescribing topical nonsteroidal anti-inflammatory drugs (e.g., bromfenac, diclofenac, or ketorolac) for pain relief. Refer the patient to an Ophthalmologist for reexamination in 24 hours. The patient requires daily follow-up and corneal staining to ensure proper healing.[12]

Instruct the patient on the importance of safety goggles.[5] Many eye injuries occur while at work due to failure to comply with wearing eye protection, resulting in a significant loss of working hours.[5,9,10] Take the time that is necessary to explain the importance of wearing safety goggles if the injury occurred while at work, gardening, or participating in hobbies (e.g., woodworking, drilling, and auto repair). The prevention of ocular foreign bodies and rust rings is preferable to treating them.[11]

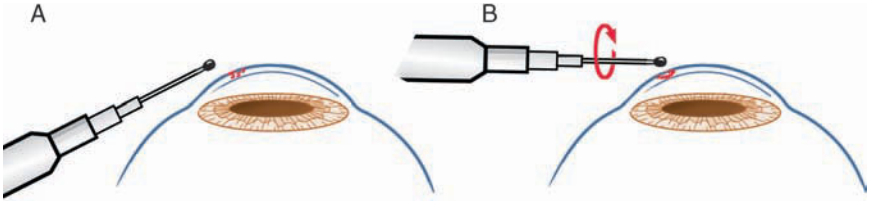


FIGURE 160-3. Burr drill extraction of the rust ring.

COMPLICATIONS

Abandon multiple attempts at removal of the rust ring to avoid severe ocular injury and the potential for violation of the anterior chamber if the depth of the rust cannot be determined or if repeated debridement is unable to completely remove the rust ring. The eye can be left unpatched for 24 hours and the patient referred to an Ophthalmologist for definitive removal the following day in these situations or in cases of hesitancy in removing a rust ring. Delayed removal is often easier than the initial attempts due to further oxidation and injury of the corneal epithelium resulting in "softening" of the rust. The "softened" rust ring is easily scraped out in 24 to 48 hours.[2] If not completely removed, the rust ring can lead to chronic inflammation, corneal necrosis, corneal vascularization, or permanent scarring.[3]

SUMMARY

Removal of corneal rust rings is imperative in order to avoid permanent ocular injury. It is best accomplished with a small gauge hypodermic needle or with an electric burr device. An alternative approach is to leave the rust for delayed removal by an Ophthalmologist in 24 hours when the rust has "softened." It is essential to completely remove the rust ring to prevent future ocular morbidity. The procedure is simple to perform with readily available equipment.

161 Eye Patching and Eye Shields

Rebecca R. Roberts

INTRODUCTION

Eye shields are used to protect the eye from further injury when the integrity of the globe is compromised or potentially compromised. The best results are obtained when early repair of globe disruption occurs, before any contents leak out or change position.[1,2] In contrast, eye patches are intended to prevent movement of the eyelid over an injured but intact cornea.[3,4] In the past, eye patching was performed to protect the eye from bright light, facilitate healing of a corneal abrasion, or protect the cornea from injury during sleep. While there have been no substantial changes in the indications for eye shields and their method of application, eye patching has become increasingly controversial.[5–8]

EYE SHIELDS

INDICATIONS

Eye shields serve as temporary protection for patients in whom a penetrated or ruptured globe is suspected.[9,10] The purpose is to prevent further injury, with resultant extravasation of the contents of the globe and resultant outcome of poor vision.[2,11] The signs associated with a ruptured globe include bloody chemosis, increase or decrease in the depth of the anterior chamber, irregular or peaked iris, positive Seidel test, vitreous hemorrhage, low intraocular pressure, hyphema, and loss of visual acuity.[9,10,12–14] **If a ruptured globe is suspected, further examination is contraindicated.** Instead, an eye shield is applied immediately and remains in place while other injuries are managed, tests are obtained (e.g., orbital computed tomography scans), and the consulting Ophthalmologist is contacted.[2,10]

CONTRAINDICATIONS

The only contraindication to the application of an eye shield arises when the surrounding face and orbits are so extensively damaged that the metal shield or its edges will directly injure the globe. The protective function of the shield relies on its edges being supported by the orbital rim, frontal bone, and maxillary bone.

EQUIPMENT

- Metal or plastic eye shield
- 1 inch tape

If commercially available eye shields are not available, a clean, disposable paper drinking cup may be used.[4,15] Use a scissors to make 3/4 to 1 inch deep cuts around the open end of the cup (**Figure 161-1**). Make approximately six to eight cuts around the circumference of the cup. Fold the flaps on the open end of the cup outward. Styrofoam cups are not suitable because the flaps can easily break off and cause further injury to the globe.

PATIENT PREPARATION

The first procedure in patients with a suspected globe disruption is the application of the eye shield.[10,13] There should be no preparations except to dry the area of skin that will receive the securing tape. Specifically, the eye should not be irrigated, no gauze or patch should touch the eye, and no antibiotic or anesthetic ointments or drops should be applied. Ocular tonometry is also contraindicated.[10] All of these are likely to cause further injury to the exposed globe.[2,16] Contact an Ophthalmologist immediately to expedite globe repair.[9,10,13]

TECHNIQUE

Apply the commercial eye shield (**Figure 161-2A**) or the one improvised from a paper cup (**Figure 161-2B**) over the injured eye. Ensure that its edges do not contact structures any closer to the eye than the orbital rim. Tear off four to six strips of 1 inch tape, each 4 to 5 inches long. Apply the strips of tape diagonally from the center of the forehead to the cheek above the mandible to hold the shield in place (**Figures 161-2A & B**).[15] **Care must be taken to avoid taping the nasolabial folds, lips, mustache (if any), and skin over the mandible.** Otherwise, mandibular movement may cause the eye shield to move and potentially injure the eye. If the patient requires

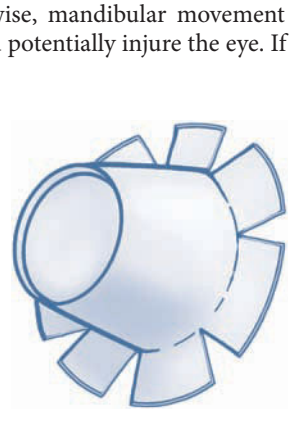


FIGURE 161-1. A paper cup may be used if a commercial eye shield is not available. The top of the cup is cut in multiple places and the resulting "flaps" are bent down to create a flat surface.

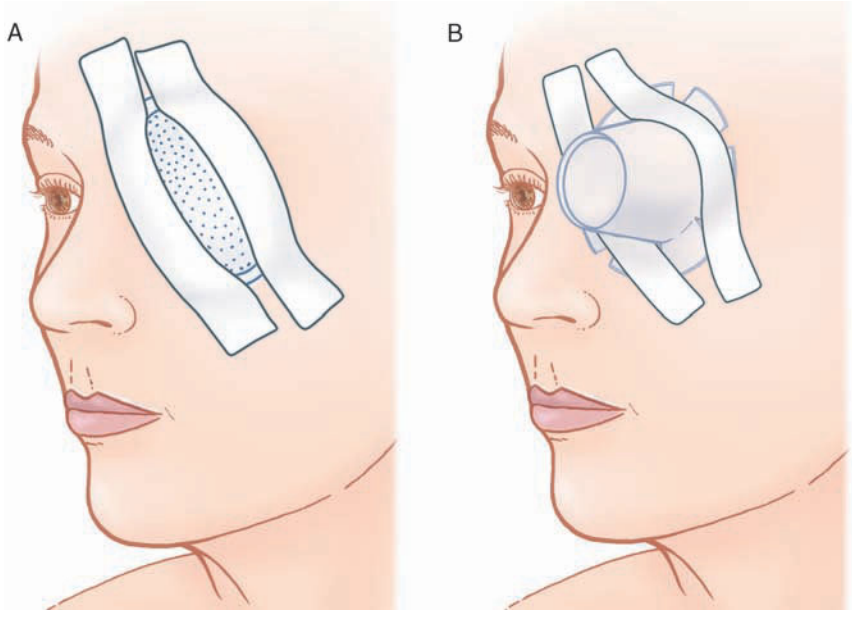


FIGURE 161-2. Eye shields. **A.** A commercial eye shield is applied. **B.** An improvised eye shield is applied.

the use of an oxygen mask, the mask must be trimmed around the eye shield to prevent it from displacing the eye shield and causing further eye injury.

AFTERCARE

The eye shield position should frequently be checked for any movement or loosening of the tape due to blood, perspiration, or other fluids. **The shield must remain in place until tests demonstrate that the globe is intact or the consulting Ophthalmologist arrives.** Do not allow the patient to eat or drink. Additional therapy includes tetanus prophylaxis, prophylactic intravenous antibiotics, and parenteral antiemetics for nausea, as vomiting will cause extrusion of the contents of the globe.[1,2,10,13,14,16] Ideally, position the patient with their head elevated if not contraindicated.

COMPLICATIONS

Poor positioning or shield movement can further injure the eye or cause extravasation of the globe contents. The patient must be handled gently at all times because even wincing or squinting of the eye can increase intraocular pressure sufficiently to cause the extravasation of the contents of the globe.

EYE PATCHING

INDICATIONS

The indications for eye patches are steadily being reduced as a growing body of literature shows no benefit and potential harm. In the past, patches were indicated for corneal injuries due to abrasions as well as to thermal, light, or chemical burns.[3] Patches were believed to promote healing and provide pain relief by decreasing movement of the eyelid across the recovering cornea.[3,4] Secondarily, patches block light in photophobic patients with ciliary spasm or reactive iritis due to corneal injuries.

Most of these assumptions are now questioned. Patching is believed to decrease corneal oxygenation, increase eye temperature, and increase corneal infection risk.[11,17,18] They can also cause injury if the eye opens underneath a pressure patch. A number of trials and meta-analyses comparing patients with corneal abrasions receiving patching versus no patching have found no difference in pain scores or healing time for small abrasions less than 10 mm in diameter.[5–8,19] There was a decreased healing time for patched patients with abrasions greater than 10 mm in diameter.[17,18] Therefore, patching is still recommended for those with large defects, but most authors also recommend further study in this group.[7] More recently, soft contact lens bandages have been used for patients who must maintain binocular vision.[20,21] Eye patches were also indicated during sleep to protect the cornea in patients with facial nerve palsy (e.g., Bell's palsy) and the inability to completely close their eyes.[22] Others are currently recommending ophthalmologic lubricants with or without an eye shield in this group.[23]

CONTRAINDICATIONS

Absolute contraindications to eye patching are corneal abrasions due to the wearing of contact lenses or from organic foreign bodies. There is an increased incidence of infection and more pathogenic bacteria harbored by contact lens wearers.[17] **Do not place an eye patch on any patient considered at risk for penetration or rupture of their globe.**[10] Eye patching will increase intraocular pressure and may cause extravasation of the contents of the globe. Patients must be carefully assessed for the presence of corneal ulcers masquerading as abrasions.[3] Eye patching of a corneal ulcer may place pressure on the ulcer, deepen the ulcer, perforate the cornea, or promote infection.

Relative contraindications are related to abrasion size and individual patient needs. Small abrasions heal well without patching. Patients who require binocular vision to function will benefit from not patching.[7,17,18] Patches that come loose and allow eyelid movement are more painful for patients than no patch. Contraindications to ophthalmoplegics used in conjunction with patches are patients with known glaucoma or narrow angles on physical examination.[3] Paradoxically, the contraindication to contact lens bandages is an abrasion in a patient who was wearing contact lenses or from organic foreign bodies, again because of the risk of infection.[9]

EQUIPMENT

- Cycloplegic drops to reduce photophobia, 1% cyclopentolate or 5% homatropine[4,11,17]
- Broad-spectrum antibiotic ointment or drops

- Cotton eye patches
- 1 inch tape
- Contact bandage, soft lens with minus 0.5 diopters of power[21]

PATIENT PREPARATION

Conduct a complete eye exam to ensure the integrity of the globe and the absence of an infection or foreign body. Document the visual acuity for both eyes.[15] Patients should receive tetanus prophylaxis if immunizations are not up to date.[4] Apply cycloplegic drops and antibiotic ointment to the affected eye.[3,4] Refer to Chapter 153, on the examination of the eye, for complete details regarding the instillation of drops and ointment into the eyes. For patients with small corneal abrasions, no further treatment is required.

EYE-PATCHING TECHNIQUE

After patient preparation as above, instruct the patient to close both eyes and to keep them both shut for the remainder of the procedure. Tear off four to six strips of 1 inch tape, each 4 to 5 inches long, and have them at the bedside. Obtain two cotton eye patches. Fold the first patch in half. Apply it to the affected eye (both eyes should remain closed). Place the second patch, unfolded, over the first patch (**Figure 161-3A**). Apply the pre-torn strips of tape diagonally from the center of the forehead to the cheek just above the mandible (**Figure 161-3B**).[3,4] Lift the lower cheek up slightly before securing the first two strips of tape to ensure the correct amount of pressure.[3,4] The patch will hold the eye more securely if the nasal and temporal strips are placed in a slight arc concave toward the center of the eye. Care must be taken to avoid taping the nasolabial folds, lips, mustache (if any), and the skin near the mandible.[3,4] Otherwise, eating and speaking will be uncomfortable for the patient and the patch will rapidly loosen. If the patient has a significant amount of facial hair, the tape may not stick.

SOFT CONTACT BANDAGE TECHNIQUE

For patients who require immediate use of both eyes, soft contact lenses can be applied as a corneal bandage.[20,21] Prepare the patient as described previously. Apply ophthalmic antibiotic drops rather than ointment to the affected eye. Remove the contact lens from the storage bottle. Rinse the storage solution from the contact lens. Place the contact lens on the index finger of the dominant hand. Using the nondominant hand, open the patient's eyelids. Instruct the patient to look straight ahead. Gently apply the contact lens directly to the cornea. The patient should remain in the Emergency Department for a recheck in 15 to 30 minutes to make sure that the contact lens fits properly and they are able to tolerate it.[21]

ASSESSMENT

Make sure that the patient with an eye patch does not feel the lid of the injured eye moving when they blink the unaffected eye.[4] Ensure that the tape does not interfere with the patient's speech, chewing movements, or smiling.

AFTERCARE

Instruct the patient to remove the patch if it becomes loose. Eye patches should be changed or removed after 24 hours to reduce the risk of infection.[3,4] Most patients will need oral pain medications for the first 24 hours in addition to the patch.[4] Topical nonsteroidal anti-inflammatory ophthalmic drops have been useful alone or in conjunction with a contact lens bandage for pain relief.[11,21,24,25] The patient must be reexamined in 24 hours by an Ophthalmologist for assessment of the healing process and to check for infection or other complications. They can expect complete resolution in 2 to 3 days. Instruct the patient not to drive or operate dangerous equipment due to the loss of binocular depth perception.[3,18] The elderly may need assistance even for walking, especially up or down stairs.[3] Discourage the patient from reading, as this will cause involuntary movement of the patched eye.

COMPLICATIONS

Infection is rare but is most likely to occur in contact lens wearers, from an abrasion from an organic foreign body, or in patients who have used a patch for a prolonged period.[3,4,9] Patches applied too tightly can raise intraocular pressure high enough to cause retinal artery occlusion, leading to retinal ischemia, infarct, and blindness. Allergy to ophthalmic medications, the patch, or the tape materials can occur. Falls, auto accidents, and injuries due to lack of binocular depth perception can occur.[3,4] Healing times may be prolonged with loose patches that allow movement of the eyelid over the cornea.[3,4] The eyelashes may get caught between the eyelids and the cornea and further abrade the cornea.[3] For all of these reasons, eye patching has fallen out of favor. Contact lens bandages can cause infective ulcerative keratitis or corneal revascularization.[21]

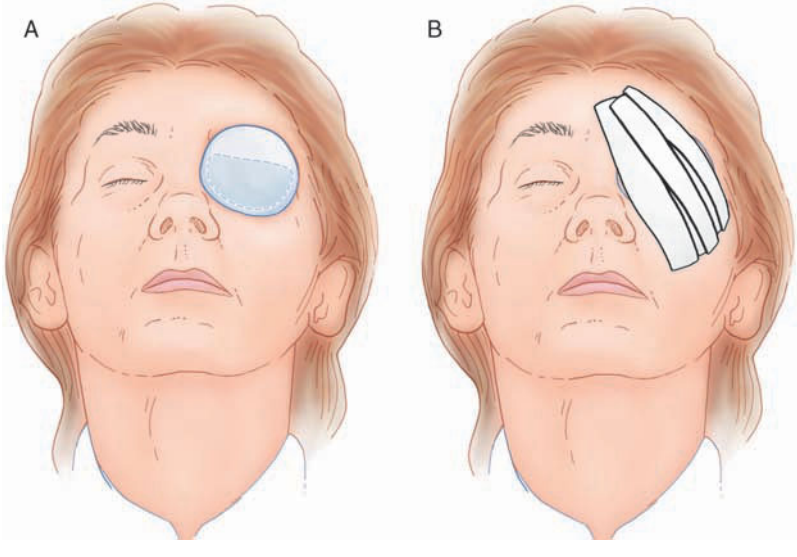


FIGURE 161-3. Eye patching. **A.** A folded patch is applied over the eyelid then covered by an unfolded patch. **B.** The patch is secured with tape.

SUMMARY

The eye is one of the most delicate and complex structures of the body. It is injured far more frequently than would be predicted based on its relative size.[26] Preservation of vision is essential to maintaining quality of life. In addition, the cornea is one of the most sensitive organs of the body. Tiny injuries to the cornea can result in significant pain and loss of function. It is therefore essential that the Emergency Physician be skilled in eye injury management. The application of an eye patch or eye shield is a simple, rapid, and straightforward procedure. Despite this, the improper application of these devices can result in significant morbidity.

162 Lateral Canthotomy and Cantholysis or Acute Orbital Compartment Syndrome Management

Jamil D. Bayram and Sami H. Uwaydat

INTRODUCTION

Acute orbital compartment syndrome is defined as an acute elevation of intraorbital pressure with resultant rapid ocular dysfunction. Patients typically present with ocular pain, proptosis, and blurry vision. Clinical signs of an acute orbital compartment syndrome include decreased visual acuity, elevated intraocular pressure (>40 mmHg), an afferent papillary defect, chemosis, mydriasis, diminished retropulsion of the affected globe to direct manual pressure, ophthalmoplegia, and fundoscopic signs of retinal ischemia (rare).[1–28]

Orbital compartment syndromes have been described in multiple clinical settings. The presentation that Emergency Physicians will most likely encounter is an acute posttraumatic retrobulbar hemorrhage leading to an orbital compartment syndrome, with subsequent rapid loss of vision.[1,2] Orbital compartment syndromes have been documented following blepharoplasty, retrobulbar anesthesia, orbital and sinus surgery, orbital fractures with intraorbital emphysema, spontaneous subperiosteal hemorrhages, and spontaneous retrobulbar hemorrhages.[3–9] Orbital compartment syndromes may also occur as the result of chronic and progressive disease processes (e.g., neoplasms, infections, and inflammations).[10]

Acute orbital compartment syndromes demand prompt recognition because irreversible loss of vision and even permanent blindness occurs without rapid treatment.[11] Once the diagnosis of an acute orbital compartment syndrome is made, emergent surgical intervention is indicated. An immediate lateral canthotomy and cantholysis are indicated within 1 hour of injury and ocular dysfunction. Medical interventions aimed at reducing intraocular pressure (e.g., mannitol, acetazolamide, topical beta-blockers, etc.) should be considered adjunctive therapy and not a substitute for surgical intervention.

ANATOMY AND PATHOPHYSIOLOGY

The orbit of the eye is a closed space posterior to the orbital septum and contained within the bony orbit. The lateral wall of the orbit is formed by the zygomatic bone. The posterior wall is formed by the sphenoid bone. The medial wall is formed by the ethmoid bone. The roof is formed by the frontal bone. The floor is formed by the maxillary bone. The globe is enclosed in a fascial envelope within the bony orbit.

The medial and lateral canthal tendons provide structural fixation of the eyelids to the orbital rim. The lateral canthal tendon (LCT) is located posterior and inferior to the lateral canthal fold (**Figure 162-1**). The LCT originates from the superior and inferior lateral tarsal plates (**Figure 162-1**) and attaches to the lateral orbital tubercle of the zygoma (**Figures 162-1 & 162-2**). The LCT consists of a superior crus from the superior tarsal plate and a inferior crus from the inferior tarsal plate. The LCT measures 10.6 mm (SD ± 0.9 mm) in length from its attachment site to the lateral canthal angle. It is 10.2 mm (SD ± 0.8 mm) in width at its origin at the lateral ends of the tarsal plates. It attaches 1.5 mm (SD ± 0.3 mm) behind the orbital margin and approximately 9.7 mm (SD ± 0.8 mm) below the frontozygomatic suture at the lateral orbital tubercle.[12] Immediately anterior to the LCT is Eisler's pocket, a collection of adipose tissue. Posterior to the LCT, at its attachment site to the lateral orbital tubercle is the check ligament of the lateral rectus muscle (**Figure 162-2**).

Any increase in intraorbital contents (e.g., retrobulbar hematoma, intraorbital emphysema, and retrobulbar abscess) will result in an elevation of intraorbital pressure because the orbit is a closed space. The globe itself may partially accommodate some of the elevation in intraorbital pressure by prolapsing forward (**Figure 162-3**). This will result in ocular pain and proptosis. The intraorbital pressure rises dramatically as the orbit approaches maximal distention. This rise in intraorbital pressure leads to a chemosis, elevated intraocular pressures, and compression of the intraorbital cranial nerves. If the compression is severe enough, the patient develops an ophthalmoplegia and an afferent papillary defect.

The exact mechanisms by which orbital compartment syndromes result in blindness remain speculative.[13–24] A common theory is that as the intraorbital pressure increases, orbital venous outflow is impeded and leads to diminished retinal and optic nerve arterial perfusion pressures. This results in an afferent pupillary defect, diminished visual acuity, and, rarely, fundoscopic signs of retinal ischemia. Over time, the elevated intraorbital pressure leads to irreversible optic nerve and/or retinal ischemia. Experimental studies have demonstrated that irreversible ischemic injury to the retina may occur within 90 minutes of vascular insufficiency.[18–21] Additional theories suggest that direct mechanical compression or

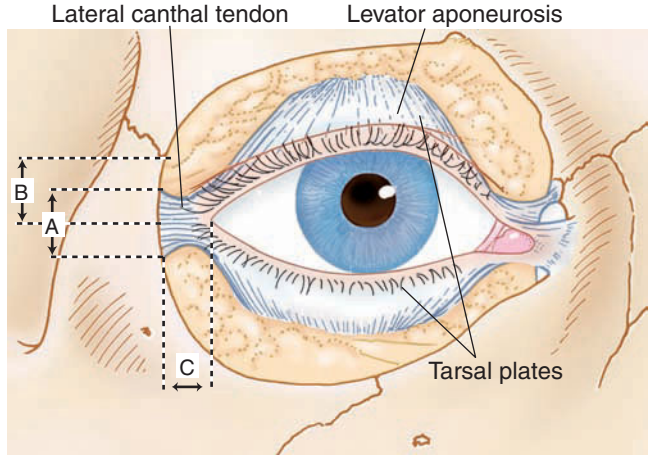


FIGURE 162-1. The lateral canthal tendon, or LCT (*A* = the vertical height of the LCT, *B* = the distance from the frontozygomatic suture to the midpoint of the LCT origin, and *C* = the length of the LCT as measured from the canthal margin to its origin).

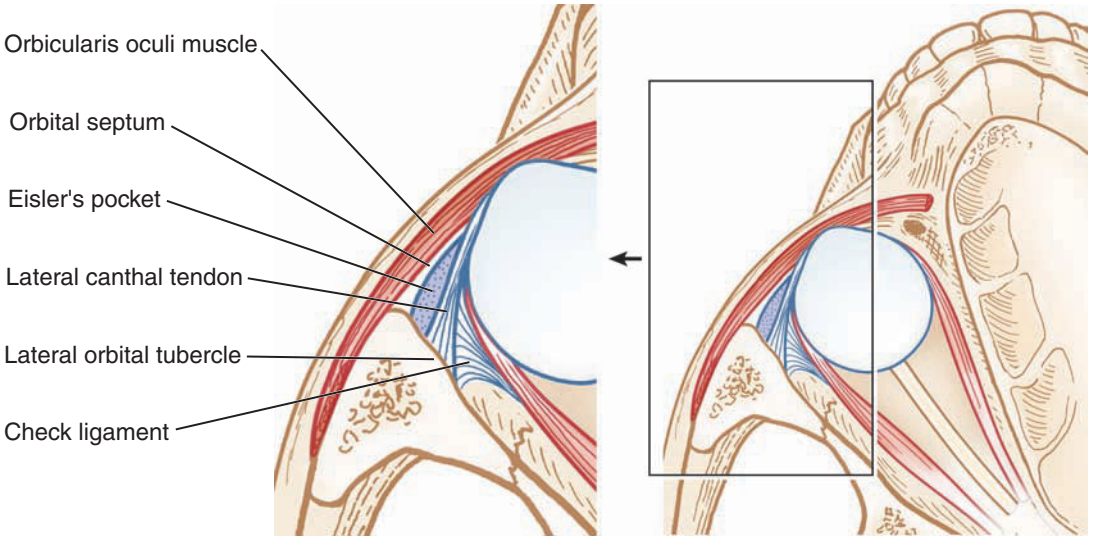


FIGURE 162-2. An axial view of the orbital contents. Identification of the LCT will require dissection of the conjunctiva and fascial tissues with a hemostat and iris scissors. A pocket of adipose tissue (Eisler's pocket) will be encountered beneath the superficial tissue layers. The LCT lies just posterior to this adipose tissue collection.

longitudinal traction on the optic nerve may contribute to the loss of vision in orbital compartment syndromes.[22,24] Elevated intraorbital pressure may also occur from large volume fluid resuscitation in patients without ocular trauma.[29]

A history of progressive loss of vision following orbital trauma suggests a reversible disease process (e.g., retrobulbar hemorrhage). If loss of vision is immediate and complete following orbital trauma, the chance of recovery of vision is poor.[25] This is because the loss of vision in the latter case is due to direct optic nerve, retinal, or vascular injury rather than an orbital compartment syndrome.

INDICATIONS

An acute orbital compartment syndrome is an indication for immediate orbital decompression.[23] Multiple case series have documented the efficacy of immediate orbital decompression in restoring visual acuity to affected patients.[24–28]

CONTRAINDICATIONS

There are no definite contraindications to performing this procedure, as permanent loss of vision may result from untreated acute orbital compartment syndromes. The patient's airway, breathing, circulation, and any life-threatening injuries must be addressed prior to performing this procedure. If the patient is very young, confused, or uncooperative, sedation and restraint or procedural sedation (Chapter 129) will be required to prevent iatrogenic injury to the globe.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Topical ocular anesthetic solution, proparacaine or tetracaine
- Lidocaine 2% with epinephrine

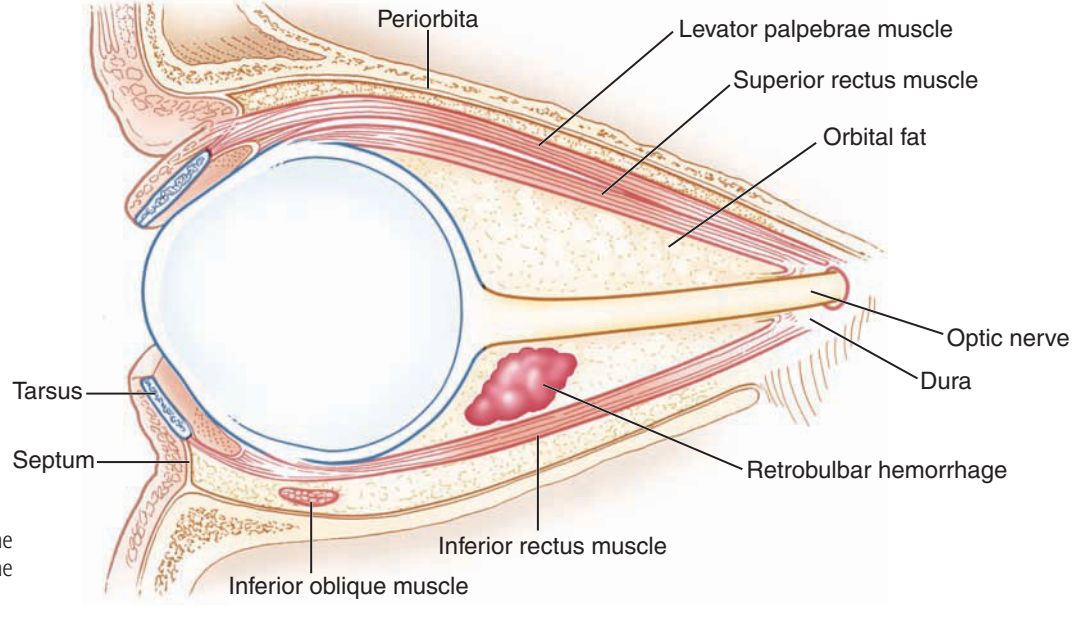


FIGURE 162-3. A sagittal view of the orbital contents. Note the location of the retrobulbar hemorrhage.

- 30 gauge 0.5 inch needle on a 3 cc Luer Lock syringe
- Ocular tonometer (applanation, Schiøtz, or Tono-Pen)
- Sterile saline or sterile water
- Straight mosquito hemostat
- Iris scissors
- Tissue forceps
- 2 × 2 gauze squares
- Topical ocular antibiotic ointment (e.g., bacitracin, ciprofloxacin, erythromycin, gentamicin, neosporin, polysporin, or sulfacetamide)
- #10 disposable scalpel (optional)
- Disposable hot tip cautery pen (optional)

PATIENT PREPARATION

Explain the procedure to the patient and/or their representative, including the risks, benefits, and outcome if it is not performed. This is a painful procedure for the awake and alert patient, so lucid patients will require parenteral medications for analgesia and sedation in addition to local anesthetics. Consider the use of procedural sedation (Chapter 129) if not contraindicated. Measure and record the visual acuity. Perform a brief ophthalmologic examination. Apply topical ocular anesthetic solution to the conjunctiva of the affected eye. Measure and record the intraocular pressure.

TECHNIQUE

Place the patient supine. Clean the eyelids and surrounding skin of any blood, dirt, and debris. Apply povidone iodine or chlorhexidine solution to the eyelids and allow it to dry. Do not let these solutions drip into the eye. Irrigate the lateral canthal fold region with sterile saline or sterile water. Using aseptic technique, identify the lateral canthal fold (**Figure 162-4**). Inject 1 mL of local anesthetic solution with epinephrine subcutaneously using a 30 gauge, 0.5 inch needle on a 3 mL syringe along the lateral canthal fold. The goal is to anesthetize the tissue extending laterally from the canthal fold to the orbital rim. **Caution must be exercised to avoid inadvertent needle puncture of the globe.**

Insert a straight mosquito hemostat at the lateral canthal fold. Place one jaw of the hemostat anterior and one jaw posterior to the lateral canthal fold. Advance the tips of the hemostat laterally until the orbital rim is encountered. Clamp and compress the intervening tissue for approximately 1 minute. This will minimize any bleeding precipitated by the lateral canthotomy. Remove the hemostat. Cut all the tissue layers along the lateral canthal fold up to the orbital rim (lateral canthotomy) with an iris scissors (**Figure 162-4**). **All tissue layers, from the skin to conjunctiva, must be incised down to the orbital rim.** Use a #10 scalpel blade to cut the tissues in cases of severe distortion of the anatomy due to edema or if iris scissors are not readily available. A disposable hot cautery pen, if available, can be used to achieve hemostasis.

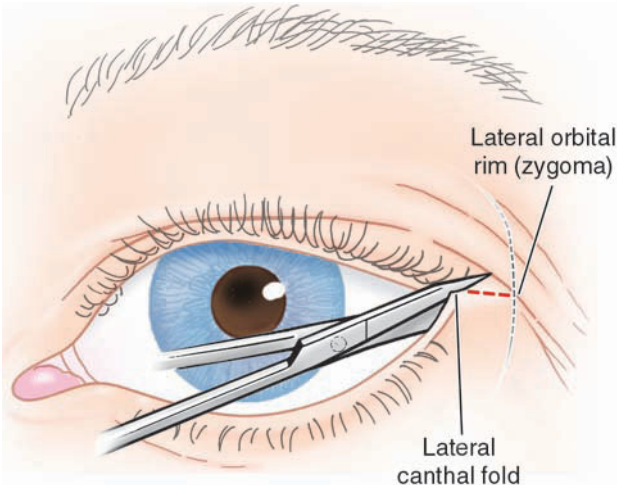


FIGURE 162-4. Illustration of lateral canthotomy. Iris scissors are used to cut all tissue layers along the lateral canthal fold up to the orbital rim.

Gently grasp the lower eyelid with a hemostat or forceps and retract it outward. Identify the LCT located just posterior and inferior to the lateral canthal fold (**Figures 162-1 & 162-2**). Dissect the conjunctiva and fascial tissues with a hemostat or iris scissors. A pocket of adipose tissue (Eisler's pocket) will be encountered beneath the superficial fascial planes (**Figure 162-2**). The LCT lies just posterior to this adipose tissue collection (**Figure 162-2**). Completely divide the LCT vertically at its midportion with an iris scissors or #10 scalpel (lateral cantholysis) to transect the inferior crus of the tendon.

ASSESSMENT

A successful lateral canthotomy and cantholysis will cause an immediate decrease in intraocular pressure to less than 40 mmHg. Recheck the intraocular pressure. **If the intraocular pressure remains elevated, reexplore the lateral canthal tendon region to make sure that the inferior crus has been completely transected. If transected, cut the superior crus of the tendon to transect it.** Occasionally, the intraorbital and intraocular pressures will remain elevated despite successful cantholysis. These refractory cases necessitate emergent decompression of the deep orbital wall.[7] Such decompressions call for operative techniques that are to be performed by Ophthalmologists and Otolaryngologists.

The resolution of proptosis, afferent pupillary defects, and restoration of visual acuity will usually not occur immediately. Patients who respond to surgical intervention will gradually regain their visual acuity over a period of hours to days.

AFTERCARE

Apply a topical antibiotic ointment along the canthotomy site. In orbital compartment syndromes, elevated intraocular pressures merely reflect elevated intraorbital pressures. Therefore, any attempts to decrease intraocular pressures will not reliably reduce retrobulbar optic nerve compression. Medical interventions decreasing intraocular pressure may be used following, or in conjunction with, a lateral canthotomy and cantholysis. These interventions are similar to those employed for the management of elevated intraocular pressures in patients with acute angle-closure glaucoma. This includes the use of topical beta-blockers, central acting alpha agonists, intravenous mannitol, and carbonic anhydrase inhibitors. **These medications are not a substitute for surgical orbital decompression.**

Many patients with an orbital compartment syndrome have other injuries requiring hospital admission following their Emergency Department evaluation and treatment. Ensure a timely Ophthalmologic consultation for a complete eye exam and possible repair of the canthotomy and cantholysis sites once the orbital compartment syndrome resolves. Repair of the lateral canthal fold and lateral canthal tendon is controversial. Many Ophthalmologists do not advocate suture repair, as a majority of wounds heal without complication by secondary intention. Patients with no other acute medical or surgical conditions,

restored vision, a normal ophthalmologic examination, and normal postprocedural intraocular pressures may be discharged after evaluation by an Ophthalmologist.

COMPLICATIONS

Time constraints, abnormal anatomy (resulting from traumatized tissue), and lack of familiarity with the lateral canthotomy and cantholysis techniques can make this a challenging procedure. Hemorrhage is often minimal and can be controlled with direct pressure. The use of a disposable cautery pen can be helpful. Mechanical injuries can include globe perforation, injury of the lateral rectus muscle, scleral lacerations, and secondary ectropion. Most of these complications can be prevented by knowing and identifying the anatomic landmarks, reviewing the procedure before it is performed, and using extreme care in performing the canthotomy and cantholysis. Despite the use of aseptic technique, infections at the canthotomy and cantholysis sites can occur. They should be treated with parenteral antibiotics that cover typical skin flora.

SUMMARY

Emergency Physicians must be able to promptly recognize and be prepared to manage an acute orbital compartment syndrome, defined by an acute elevation of intraorbital and intraocular pressure with resultant ocular dysfunction. Patients will present with ocular pain, proptosis, an afferent pupillary defect, and diminished visual acuity. An acute orbital compartment syndrome requires emergent treatment to preserve vision. An immediate lateral canthotomy and cantholysis are indicated, preferably within 1 hour of injury and ocular dysfunction. Medical management should be considered an adjunctive therapy. Many patients will regain their visual function if the procedure is performed soon after the injury and before permanent ischemic changes occur.

163 Globe Luxation Reduction

Jeffrey S. Schlab

INTRODUCTION

Luxation of the globe is a rare event whereby the eyelids slip behind the midcoronal plane of the eye in an extremely proptosed eyeball (**Figure 163-1**). The orbicularis oculi muscle then goes into spasm, which maintains the luxation of the globe. Extraocular eye movements become severely limited. The optic nerve and retinal vasculature are subjected to an abnormal amount of traction, resulting in possible damage to these structures or the retina.[1] The end result is partial or full blindness in the affected eye if it is not reduced before irreversible ischemic changes occur.

ANATOMY AND PATHOPHYSIOLOGY

There are three major causes of globe luxation: spontaneous, voluntary, and traumatic. Spontaneous luxation tends to occur in individuals with shallow orbits.[2] Structural abnormalities—such as laxity of the supporting muscles and fascia as well as anomalous extraocular muscles—can predispose to spontaneous luxation.[2–4] Pathologic processes that cause proptosis can predispose to luxation. The literature documents cases of luxation associated with orbital tumors, Graves' disease, cerebral gummas, histiocytosis X, and craniofacial dysostosis.[1,5,6] Voluntary luxation occurs in individuals who learn to cause globe propulsion by using a digit or use of their extraocular muscles. Some patients use a Valsalva maneuver to luxate their globe(s) voluntarily. Traumatic luxation results from trauma to the globe or the surrounding bony orbit. It can occur from motor vehicle accidents or even relatively minor trauma to the face.[7,8] Traumatic luxation can also occur from intentional eye gouging or even during the forceps-assisted delivery of a neonate.[9,10]

The normal anatomic relationship of the globe to the surrounding structures is seen in **Figure 163-2**. The midcoronal plane of the eye is a transverse section through the eye in the coronal plane. It is through the widest portion of the eye and divides the eye into anterior and posterior halves. When the eyelids get behind the midcoronal plane, the orbicularis oculi muscle is pulled taut and begins to go into spasm. This spasm prevents spontaneous reduction of the globe.

INDICATIONS

Globe reduction is indicated to relieve traction on the optic nerve and retinal vessels. The patient's visual acuity has the potential of being compromised without prompt reduction. Sustained globe luxation is physically and psychologically uncomfortable for the patient, may result in permanent loss of vision, and is difficult to reduce without general anesthesia.

CONTRAINDICATIONS

Obvious rupture of the globe and extensive orbital fractures that require immediate surgical intervention are relative contraindications to globe reduction. Edema and retrobulbar hemorrhage can make reduction outside the Operating Room impossible.[1,6]

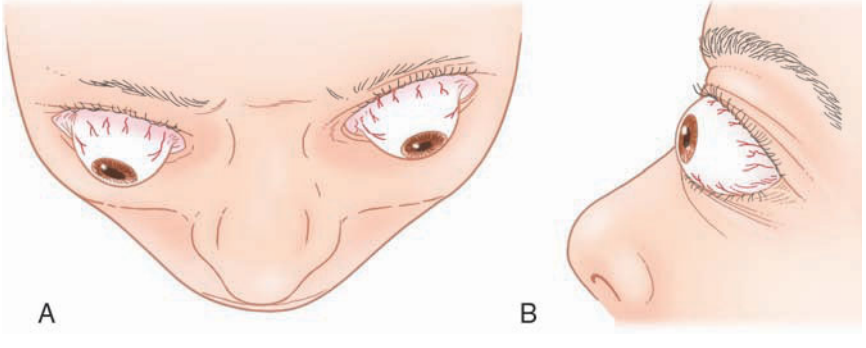


FIGURE 163-1. The luxated globe. **A.** Superior view. **B.** Lateral view.

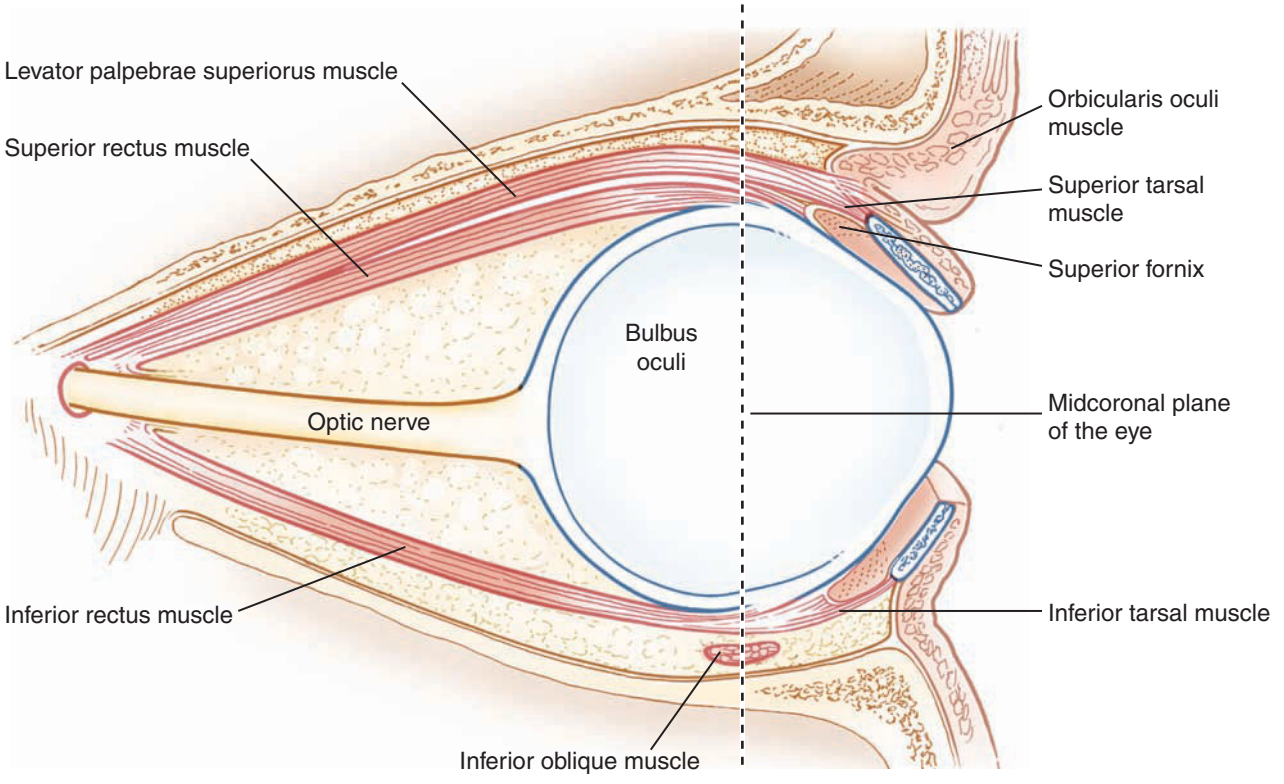


FIGURE 163-2. Anatomy of the eye and orbit.

EQUIPMENT

- Topical ocular anesthetic agent (e.g., 0.5% proparacaine or tetracaine)
- Sterile gauze and gloves
- Sutures or eyelid retractors
- Local anesthetic solution (1% lidocaine), if eyelid retaining sutures need to be placed
- 3 mL syringe
- 27 gauge needle

PATIENT PREPARATION

Prior to any attempt at reduction, a directed eye exam addressing the integrity of the globe, visual acuity, pupillary reactivity, and range of ocular motion should be performed. Describe the procedure to the patient and/or their representative. Answer any questions about the procedure and obtain an informed consent for the procedure. Relaxation of the patient and the orbicularis muscles are essential for procedural success. The use of a parenteral anxiolytic and analgesic or procedural sedation (Chapter 129) is recommended if not contraindicated.[11] Place the patient supine. Instill a topical ocular anesthetic agent onto the affected eye. Allow 1 to 2 minutes for the anesthetic to take full effect.

TECHNIQUE

Reduction of a globe luxation ideally requires two people (**Figure 163-3**).[11,12] Instruct an assistant to apply steady upward and outward traction on the upper eyelid and downward and outward traction on the lower eyelid by grasping and pulling on the eyelashes. Instruct the patient to maintain a constant downward gaze. The downward gaze posture negates the retracting action of the levator palpebrae superioris muscle and simultaneously relaxes the superior rectus muscle.[12] While traction is being applied to the eyelids, apply steady and gentle pressure with a gloved thumb to the exposed superior sclera of the globe in a simultaneously downward and posterior direction. Physical contact over the sclera minimizes discomfort and avoids possible

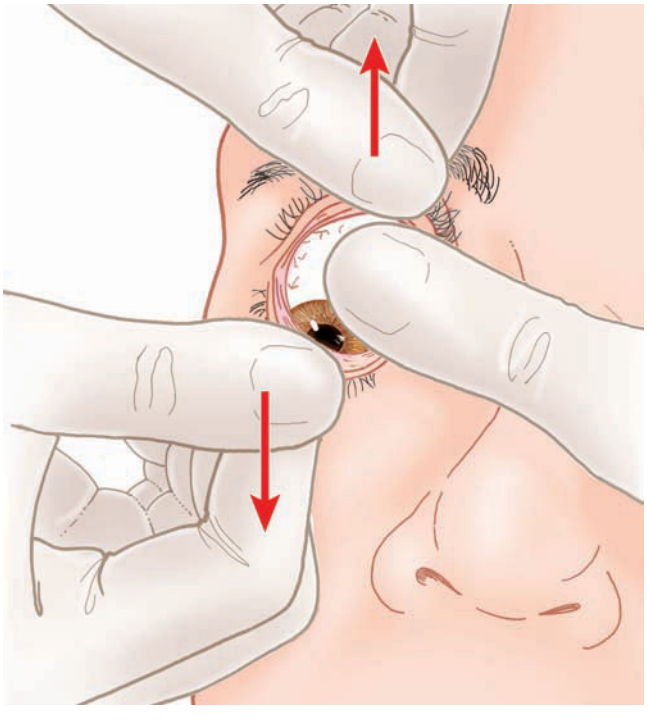


FIGURE 163-3. Reduction of a globe luxation.

corneal abrasions.[12] Continue to apply constant and gentle pressure until the globe is manipulated back into the orbit.[1,6]

ALTERNATIVE TECHNIQUE

Occasionally the patient's eyelashes are small or not accessible, or an assistant is not available. In these cases, an eyelid retractor may be placed behind the eyelids to provide countertraction. Other authorities have recommended the placement of a suture through the anesthetized skin of the eyelids to help retract them.[1,4,6] **Extreme care must be taken to prevent penetration of the globe by the anesthetic needle or the suture needle if retaining stitches are placed in the eyelids.** If either of these techniques are used, the globe is then reduced in the same manner as described previously.

ASSESSMENT

A repeat and complete eye examination must be performed after the procedure and documented in the medical record. Pay special attention to visual acuity, pupillary reflexes, and range of extraocular muscle movement.[1,6,10] Full visual acuity may not return to baseline for several days or longer.[4] A search for the possible causes of a nontraumatic luxation should be initiated in the Emergency Department.[1] This includes but is not limited to thyroid function testing and orbital imaging to rule out a tumor. This evaluation should be performed after consultation with an Ophthalmologist. Conduct a search for associated injuries such as a bony periorbital fracture, globe rupture, retroorbital hematoma, or intracranial injury in the cases of traumatic luxation.

AFTERCARE

Patients with spontaneous luxations that reduce without difficulty and who are without visual impairment may be discharged home after consultation with an Ophthalmologist. These patients require follow-up with the Ophthalmologist within 24 hours.[1,6] They should be instructed to avoid Valsalva maneuvers.[1] All patients with traumatic luxation require emergent Ophthalmologic consultation and imaging of the orbits.[1,6]

COMPLICATIONS

It is not uncommon for eyelashes to be retained in the conjunctival fornices after this procedure.[10] A thorough evaluation and removal of any free eyelashes is warranted to prevent corneal abrasions or injury.[1,6,10] If one or two attempts at reduction are not successful, instill saline drops to the eye and apply an eye shield to prevent further injury while an emergent Ophthalmologic consult is obtained.[1,6] Refer to Chapter 161 for the complete details regarding the application of an eye shield.

SUMMARY

Globe luxation is a rare entity that can be effectively dealt with in the Emergency Department. Prompt intervention by an Emergency Physician can result in the preservation of visual acuity. After a brief initial eye examination, uncomplicated cases can be reduced by the Emergency Physician. Complicating factors—such as the presence of trauma, an open globe injury, or the inability to reduce the globe—warrant emergent Ophthalmologic consultation. Predisposing factors for a spontaneous luxation should be investigated.

164 Hordeolum (Stye) Incision and Drainage

Sami H. Uwaydat and Jamil D. Bayram

INTRODUCTION

A hordeolum is a suppurative infection of one of the eyelid glands. The nomenclature that describes infectious and inflammatory conditions of the eyelid glands is at times confusing. A brief description of the eyelid margin anatomy may help resolve some of the confusion. The patient usually presents with an acutely painful, erythematous, localized, and tender mass on either the upper or lower eyelid. A hordeolum may be associated with a blepharitis.

ANATOMY AND PATHOPHYSIOLOGY

The eyelid is composed of numerous structures (**Figure 164-1**). The eyelid skin is thin and vascular. The orbicularis oculi muscle encircles the eyelids and controls their movements. The hair follicles which form the eyelashes are fine and delicate in comparison to hair on other body areas. Numerous glands are contained within the eyelids. The glands of Zeis are modified sebaceous glands associated with the hair follicles. The glands of Moll are modified sweat glands that open into the base of the hair follicles. The tarsus is a rigid fibrous plate containing the sebaceous Meibomian glands. The orifice of the elongated Meibomian glands can be seen posterior to the eyelashes at the eyelid margin. The inner aspect of the eyelids is lined by the thin and delicate conjunctiva.

A hordeolum can be located internally or externally in relation to the eyelid and tarsal plate. They are essentially an abscess of the eyelid. An internal hordeolum is a bacterial infection of the Meibomian gland and usually points to the inside or conjunctiva (**Figure 164-2**). An internal hordeolum is usually larger than an external hordeolum. If the infection blocks the neck of the Meibomian gland, the infection points toward the conjunctival surface of the eyelid. If the neck of the Meibomian gland is not blocked, the infection often points to the eyelid margin. An external hordeolum, also known as a stye, is a bacterial infection of the glands of Zeis or Moll. These tend to be small, superficial, and point to the eyelid skin or, more commonly, the eyelid margin. The most common causative agent in both internal and external hordeola is *Staphylococcus aureus*.[1]

Patients with a hordeolum almost always present with localized pain, redness, and swelling of the eyelid margin. It is usually a benign process but can progress to a preseptal or septal cellulitis. It may rarely result in a corneal epithelial defect,[2] periorbital necrotizing fasciitis,[3] and bacteremia.[4]

A chalazion is a chronic, more than 2 weeks, granulomatous inflammation of a sebaceous Meibomian gland. Acute chalazion lesions, those less than 2 weeks old, are often difficult to distinguish from an acute hordeolum. Clinically, the management of an acute chalazion and an acute hordeolum are the same and it is not necessary to differentiate the two processes. A chalazion may persist for many months and slowly enlarge over time. A chronic chalazion is characterized by a painless localized swelling of the eyelid margin with no inflammatory signs and feels rubbery upon palpation. A chronic chalazion does not require an urgent intervention and should be managed by an Ophthalmologist. A chalazion that is acute, large, or causes local irritation may require an incision and drainage. Recurrent chalazia require an evaluation by an Ophthalmologist to rule out a malignancy.

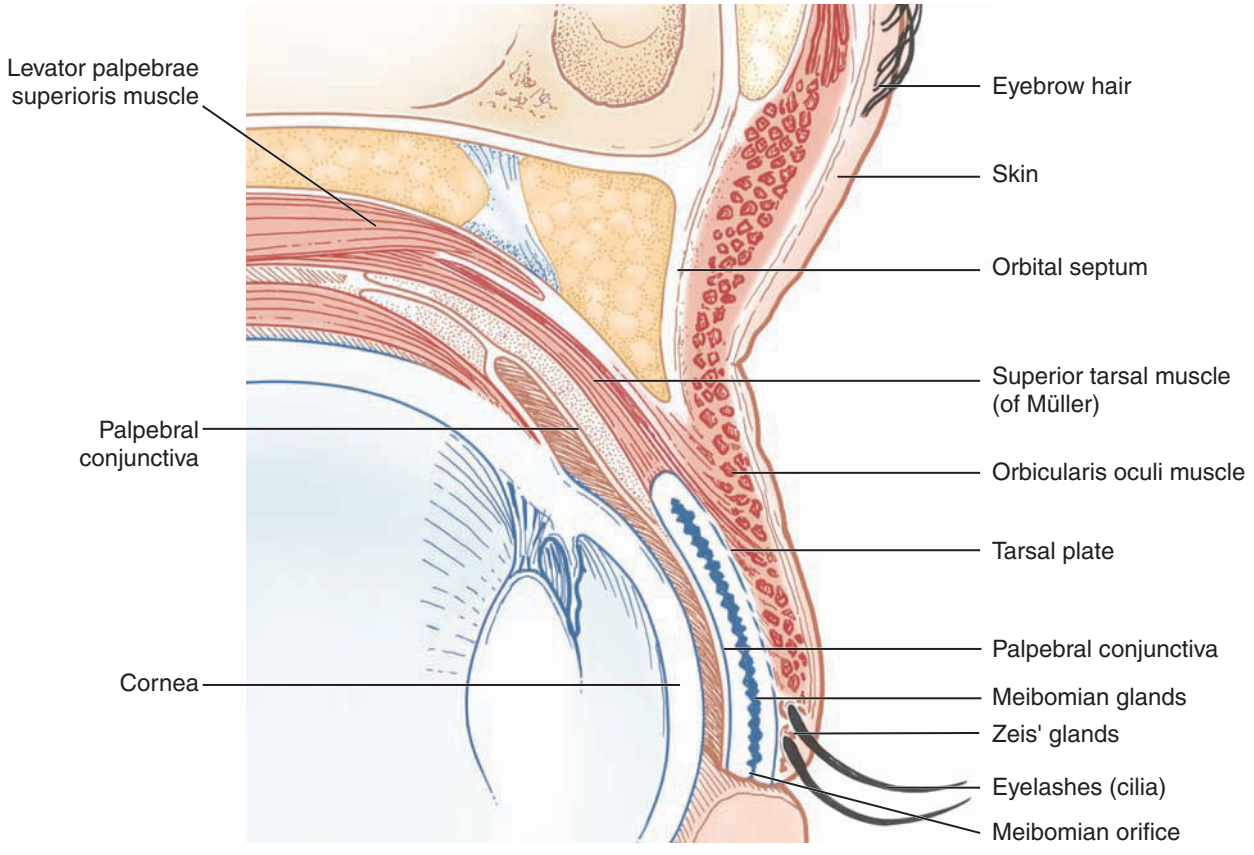


FIGURE 164-1. Eyelid margin anatomy. The type and location of the infected gland determine whether it is an internal hordeolum or an external hordeolum (stye).

MANAGEMENT

Hordeola are initially managed conservatively. Warm compresses should be applied over the eyelid for 10 to 15 minutes at a time, and three to six times per day. An alternative and portable solution to warm compresses would be to place 8 to 10 ounces of dry rice in a sock and heat it in a microwave (typically for 30 seconds). The rice tends to maintain the heat for a longer period compared to the warm compresses. Apply diluted baby shampoo to the eyelid margins with a washcloth or cotton-tipped applicator for daily eyelid scrubs. Topical antibiotic ointments (e.g., erythromycin) can be placed in the conjunctiva or on the eyelid margin three times per day. The purpose of topical antibiotics is to prevent the infection spreading to adjacent hair follicles. Oral antibiotics are indicated only if the signs and symptoms of a cellulitis develop. Most hordeola will spontaneously drain and resolve within 5 to 7 days with conservative management. Treat any accompanying blepharitis to prevent the formation of additional hordeola.

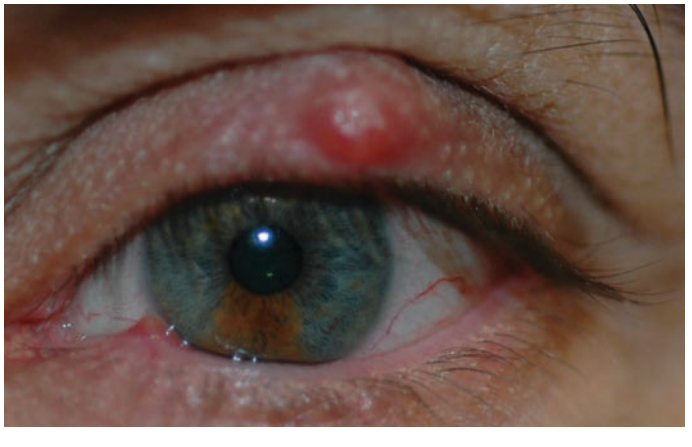


FIGURE 164-2. An internal hordeolum with redness and swelling.

INDICATION

Surgical excision is warranted if the hordeolum does not resolve with conservative management and the patient has significant discomfort. A hordeolum can be excised if it causes a cosmetic deformity, blocks the visual axis, or is of a significant size.

CONTRAINDICATIONS

Not all hordeola should be incised and drained in the Emergency Department. Hordeola close to the lacrimal puncti or the medial canthus are best managed conservatively until surgery can be coordinated with an Oculoplastic surgeon. Drainage in patients on blood thinners and in those who are unable to follow commands is contraindicated. Sedation is required for children, the confused patient, and the uncooperative patient. Consult an Ophthalmologist prior to sedating a patient to incise and drain a hordeolum. A recurrent hordeolum should be referred to an Ophthalmologist for biopsy and evaluation of the lesion for a malignancy. Consult an Ophthalmologist prior to the procedure if the hordeolum affects visual acuity or ocular movements.

EQUIPMENT

- Buffered local anesthetic solution (e.g., lidocaine with epinephrine and $NaHCO_3$)
- 30 gauge, 0.5 inch needle on a 3 mL syringe
- 0.5% proparacaine drops
- Povidone iodine or chlorhexidine swabs
- Small drape with central opening
- Sterile 4 × 4 gauze squares
- Sterile cotton-tipped applicators
- Sterile marking pen
- Corneal eye shield
- #11 or #15 scalpel blade on a handle
- Wescott scissors
- Desmarres chalazion clamps, multiple sizes
- Meyerhoefer chalazion curettes, multiple sizes
- Castro-Viejo forceps
- Topical ophthalmic antibiotic ointment without steroids, e.g., erythromycin
- Eye pad
- Culture swabs
- 1-inch tape

A chalazion clamp is a device specifically designed to aid in the incision and drainage of a chalazion or hordeolum (**Figure 164-3**). It is similar to a forceps, except the distal ends are expanded and has a clamp mechanism. One of the distal ends is an open circle used to surround the hordeolum. The other distal end is flat, solid, and acts to prevent injury to underlying structures. Just proximal to the distal expanded ends is a screw mechanism that allows the distal ends to be closed and clamped securely in place.

PATIENT PREPARATION

Perform a brief ophthalmic examination including visual acuity, motility, and an anterior segment assessment. Document the size and location of the hordeolum. Explain the procedure, its risks, and benefits to the patient and/or their representative. Place a signed informed consent in the medical record. Many patients are apprehensive when a surgical procedure is performed close to their eye. It is imperative that the patient remains still during this procedure, given that sharp instruments will be exchanged over the globe. A thorough explanation of the surgical steps should alleviate some of the patient's fears. Consider the use of parenteral sedation or procedural sedation (Chapter 129).

Place the patient supine. Support their head with a headrest or a foam doughnut. Place one drop of proparacaine in the cul-de-sac of the affected eye. Mark the circumference of the hordeolum with a sterile skin marker (**Figure 164-4A**). This is important as the injection of local anesthetic solution will obscure the margins of the hordeolum. Gently wipe the eyelid skin with an alcohol swab. **Do not allow the alcohol to get onto the eye.** Clean the skin of the eyelid with povidone iodine or chlorhexidine solution. **Do not allow these solutions to get onto the eye.** If they do get onto the eye, irrigate the eye copiously with normal saline. Arm a 30 gauge needle onto a 3 mL syringe. Draw up 1 mL of buffered local anesthetic solution with epinephrine. Inject the solution around and into the hordeolum (**Figures 164-4A & B**). **Direct the syringe tangential to the skin (for an external hordeolum) or conjunctive (for an internal hordeolum) so as to avoid inadvertent penetration of the globe.** Place a corneal shield, if available, over the cornea.

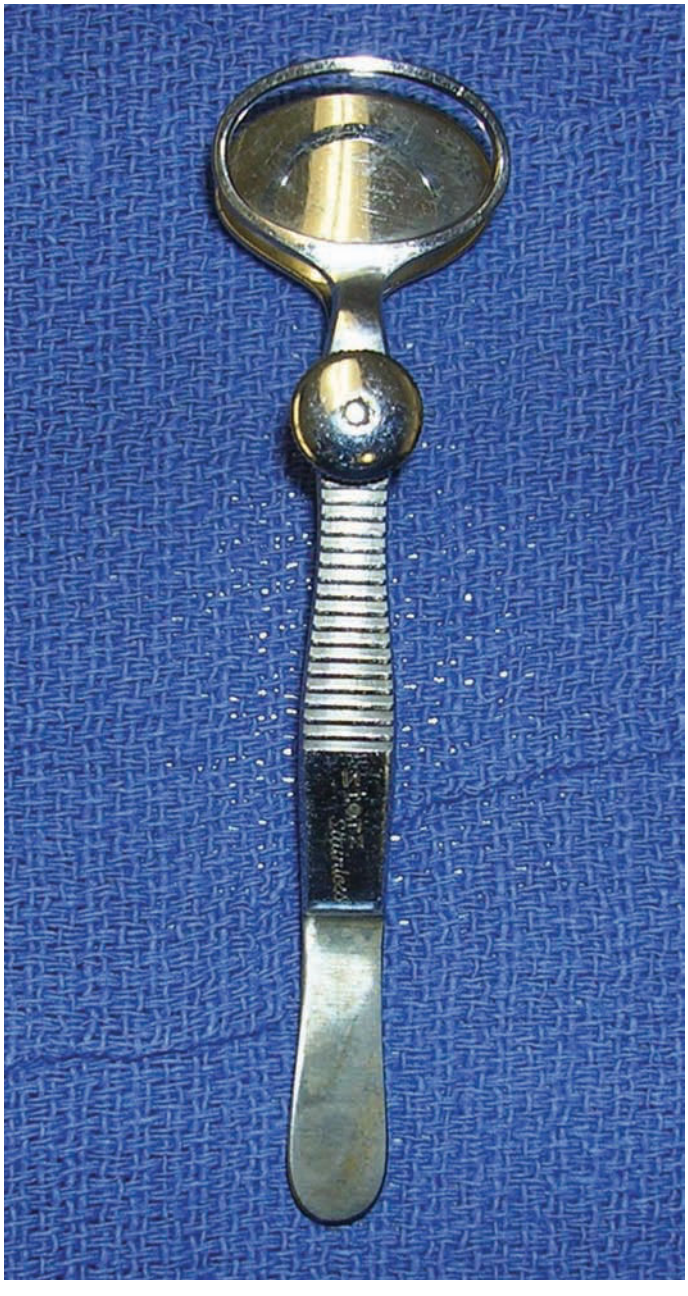


FIGURE 164-3. The chalazion clamp.

TECHNIQUES

INTERNAL HORDEOLUM

Cleanse and anesthetize the area as described above. Apply a chalazion clamp to the eyelid. Place the loop of the clamp on the conjunctival surface of the eyelid and encompassing the marked edges of the hordeolum (**Figure 164-4C**). Place the plate of the clamp on the skin surface of the eyelid. Gently close the clamp by turning the screw mechanism. Gently flip the clamp to expose the hordeolum. Make a superficial cruciate incision in the hordeolum with a #11 or #15 scalpel blade (**Figures 164-4C & D**). Gently insert the chalazion curette to scoop out the purulent material (**Figure 164-4D**). Alternatively, use a sterile cotton-tipped applicator. Grasp the edge of the inflammatory tissue with the Castro-Viejo forceps. Carefully use Wescott scissors to dissect the planes between the hordeolum and the tarsus (**Figure 164-4E**). Release the chalazion clamp gently

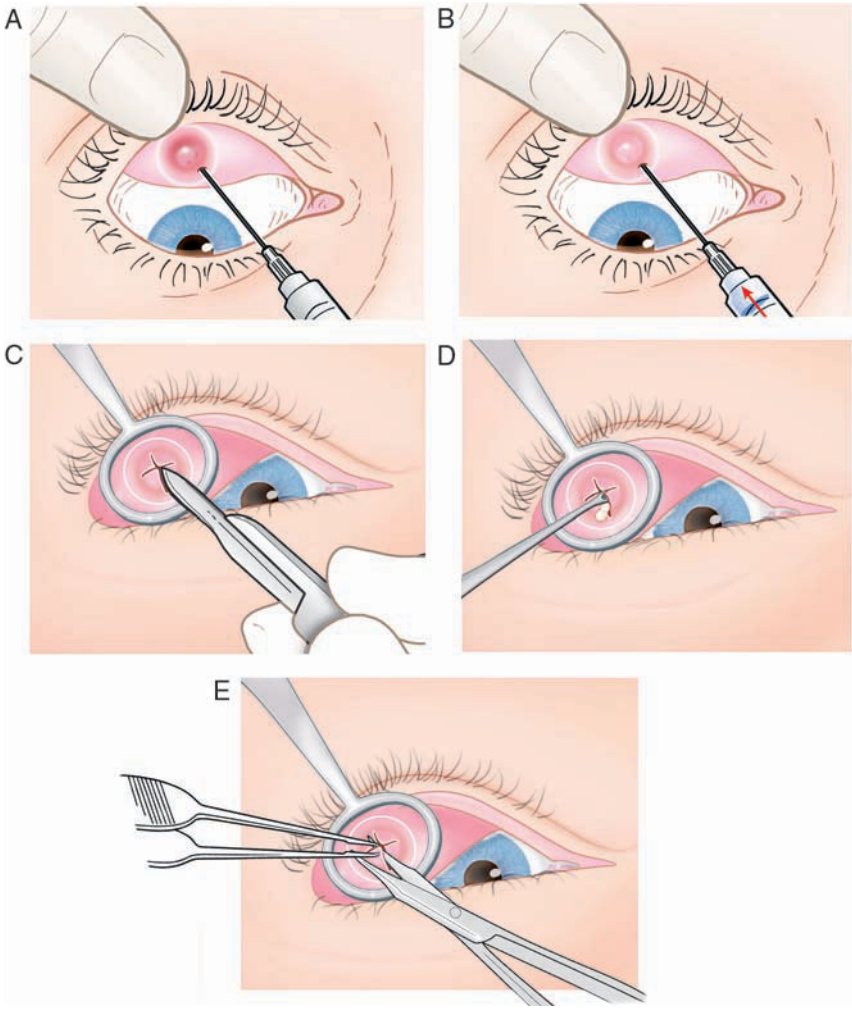


FIGURE 164-4. Incision and drainage of a hordeolum. **A.** The hordeolum is identified and a circle is drawn around its margins. A needle is inserted to inject local anesthetic solution. **B.** Local anesthetic solution is injected into and around the hordeolum. **C.** A chalazion clamp is applied and an incision is made over the hordeolum. **D.** Purulent material is expressed for the incision using a chalazion curette. **E.** Inflammatory tissue is removed.

and remove it from the eyelid. Apply gentle pressure with a gauze square to the incision to control any bleeding. **Be careful to not touch the eye with the gauze and cause a corneal abrasion.** Culture the expressed purulence. Place ophthalmic erythromycin ointment in the cul-de-sac. Apply a pressure patch over the eye (Chapter 161).

EXTERNAL HORDEOLUM

Cleanse and anesthetize the area as described above. Make an incision over the hordeolum with a #11 or #15 scalpel blade. **Do not cut the eyelid margin and the underlying tarsus.** Gently roll a sterile cotton-tipped applicator over the eyelid skin and toward the incision to express the purulent material. Apply gentle pressure with a gauze square to the incision to control any bleeding. **Be careful to not touch the eye with the gauze and cause a corneal abrasion.** Culture the expressed purulence. Place ophthalmic erythromycin ointment on the eyelid skin. Apply a pressure patch over the eye (Chapter 161).

ASSESSMENT

Palpate the eyelid at the end of the procedure. If a residual pus collection is detected, attempt to express the pus with a cotton-tipped applicator. If this fails, a second incision parallel to the first one is required to completely drain the hordeolum. **Do not undermine the delicate eyelid tissues to express the purulent material.** While not required, some physicians may perform a repeat fluorescein examination to ensure that they did not cause a corneal abrasion during the procedure.

AFTERCARE

The follow-up instructions are simple and straightforward. Instruct the patient to remove the pressure patch in 1 to 2 hours. It was placed to minimize any edema and bleeding from the procedure. If significant bleeding is noted when the patch is removed, the patient should immediately return to the Emergency Department. They should apply a warm compress (or warm rice in a sock) to the eyelid every 3 to 4 hours for the first 24 hours. An eyelid skin incision should remain clean and dry for 24 hours. Prescribe topical ophthalmic antibiotic ointment (e.g., erythromycin if no contraindications exist) to be applied on the skin incision or in the cul-de-sac three times a day for 3 to 4 days. Someone must follow up on the culture results in 12 to 24 hours. If MRSA is detected, the patient must be notified and they require follow-up with an Ophthalmologist within 24 hours or return to the Emergency Department for the consideration of oral antibiotics. Treat any associated blepharitis to prevent the formation of a new hordeolum.

The patient should follow up with an Ophthalmologist within 5 to 7 days for an evaluation of the eyelid. They need to be evaluated sooner if the cultures are positive for MRSA. They should immediately be seen by an Ophthalmologist or return to the Emergency Department if any of the following develop: uncontrollable bleeding, increase in eyelid pain and/or swelling, the appearance of yellow or green pus in the eye or on the eyelid, and fever.

Oculoplasty referral is warranted to evaluate a recurrent hordeolum or chalazion to rule out malignancy.[5] Recurrent bilateral hordeolum may indicate an underlying immunodeficiency (e.g., IgM).[6]

COMPLICATIONS

Numerous complications are possible both during and as a result of the incision and drainage procedure. Inadvertent injury to the globe (e.g., corneal abrasion or corneoscleral perforation) or eyelid structures (e.g., lacrimal duct or punctum) may occur.[7] Early complications include infections such as a cellulitis or conjunctivitis. Most bleeding can be controlled with gentle pressure or tying off of the offending vessel with fine absorbable sutures. **Never use a portable hot cautery unit on the eyelid to control bleeding.** Uncontrolled bleeding is rare but can occur and will require an Ophthalmologist to control. Late complications occur from excessive scarring at the incision site. If an external incision was made, the contracting scar can lead to an ectropion, eyelid retraction, uneven eyelid margins, and trichiasis. If an internal incision was made, conjunctival scarring can lead to an entropion and chronic conjunctivitis.

SUMMARY

Patients with an acute hordeolum often present to the Emergency Department with a painful, localized, red, and swollen eyelid margin. They should be initially managed conservatively. Subsequent incision and drainage may be required to alleviate patient's discomfort. The incision and drainage procedure is simple to perform and can be done by the Emergency Physician.

SECTION 13

Otolaryngologic Procedures

165 External Auditory Canal Foreign Body Removal

Rebecca R. Roberts

INTRODUCTION

Foreign bodies are commonly found in the external auditory canal (EAC) of children and sometimes in adults.[1] Children commonly place small objects such as food (e.g., beans, peas, corn, and seeds) or small round objects (e.g., beads, rocks, and toys) in the EAC.[2–5] Adults are more likely to suffer from items used to clean or scratch the ear (e.g., cotton swab, paper, paper clips, and pencil lead) and insects that crawl into the ear.[4] The EAC and tympanic membrane (TM) are exquisitely sensitive and delicate.[3,6] Foreign bodies in the EAC are extremely irritating to patients; especially live insects that will scratch the TM in an effort to escape. Injuries can occur unless proper care is taken in the removal of EAC foreign bodies.

ANATOMY

The EAC is S-shaped and 2.5 cm long in adults.[7] The lateral or distal third is cartilaginous, with thick skin. It has more hair follicles, glands, and subcutaneous tissue than the medial or proximal two-thirds of the EAC. The medial EAC is bony, with a thinner and more fragile layer of skin.[7,8] The narrowed isthmus is located between the cartilaginous and bony portions.[2,7] The canal ends medially at the TM, which is situated obliquely to increase the surface area for carrying sound energy to the middle ear.[8] The anteroinferior EAC is 0.6 mm longer than the posterosuperior portion.[7] Auriculotemporal branches of cranial nerves V, VII, IX, and X and the greater auricular nerve of the cervical plexus supply sensation to the EAC.[7]

INDICATIONS

All EAC foreign bodies must be removed. The only question is how quickly this must be done, who should do it, and which is the safest of available techniques. The method used is individualized to the patient, type of foreign body, Emergency Physician preference and experience, and the availability of an Otolaryngologist. Some foreign bodies are very easily and safely removed with the equipment available in any Emergency Department. Others—due to impaction, large size, sharp edges, location in the canal, involvement of the TM or middle ear structures, or patient age—will require removal under general anesthesia or even an approach to removal from outside the canal.[2,6,9]

The most urgent indication for immediate removal is an alkaline button battery because of the extensive and severe damage it may cause in a very short time.[1] These are most commonly found in the EAC of a young child. There are two mechanisms for the rapid destruction of surrounding tissues by the batteries. The moisture and cerumen in the EAC have a high conductivity, which causes conduction of electric current from the battery and results in localized electrical burns. Local inflammation from those burns will cause fluid exudation into the EAC. This increases the electrical conduction injury and causes the battery to begin leaking alkaline electrolyte solution, which can penetrate deeply into underlying tissues, with resultant liquefaction necrosis.[3,10] **Therefore, irrigation with water or saline is contraindicated in button battery removal and another technique must be used.[1]**

CONTRAINDICATIONS

Rather than contraindications to removal, these can also be thought of as indications for referral to an Otolaryngologist for removal of the foreign body. The major contraindication to removal in the Emergency Department is probable injury with direct removal. Examples are foreign bodies that have perforated or impaled the TM. Removal will cause further damage to the TM as well as potential disruption of the middle ear ossicles and loss of hearing. These foreign bodies require removal under general anesthesia with the aid of an operating microscope.[2,3,5,9] Another contraindication is a large object that has impaled itself in the wall of the EAC. Direct removal will require anesthesia and possibly an approach from outside the EAC to avoid denuding the skin of the EAC.[3] Finally, objects that are difficult to remove and a patient (usually a young child) who cannot hold still or be held still for the procedure should be referred to an Otolaryngologist.[2,5,9] These cases are likely to result in injury if the foreign body is removed in the Emergency Department.

Irrigation is almost always safe to attempt.[11] The most important contraindication for irrigating the EAC is an acute or chronically ruptured TM.[9,11–14] Water forced into the middle ear can lead to otitis media, labyrinthitis, mastoiditis, disruption of the ossicles, and loss of balance or hearing. Some authors recommend alternate methods for any patient who has never had an ear exam to document the integrity of the TM.[9,11,12] Completely impacted foreign bodies that leave no space for the irrigant fluid to flow behind it will only be driven deeper into the EAC, making subsequent removal even more difficult.[1,15] A relative contraindication for irrigation with water is an organic object, such as a dry bean, seed, or rice.[15] Organic foreign bodies will absorb water and swell, making removal more difficult. Irrigation can be attempted if the object is very small and irrigation is expected to rapidly succeed in removal before swelling occurs. Otherwise, irrigate the object with alcohol, remove it with instruments, or extract it with suction.

Directly grasping the foreign body with forceps is contraindicated for large or spherical objects that will not allow clear passage of the forceps jaws along its sides. Attempts to grab this type of object will only drive it deeper into the EAC.[15]

EQUIPMENT

Anesthesia

- 1%, 2%, or 4% lidocaine solution or gel
- 1 mL syringe
- 5 mL syringe
- 27 or 30 gauge needle
- EAC speculum

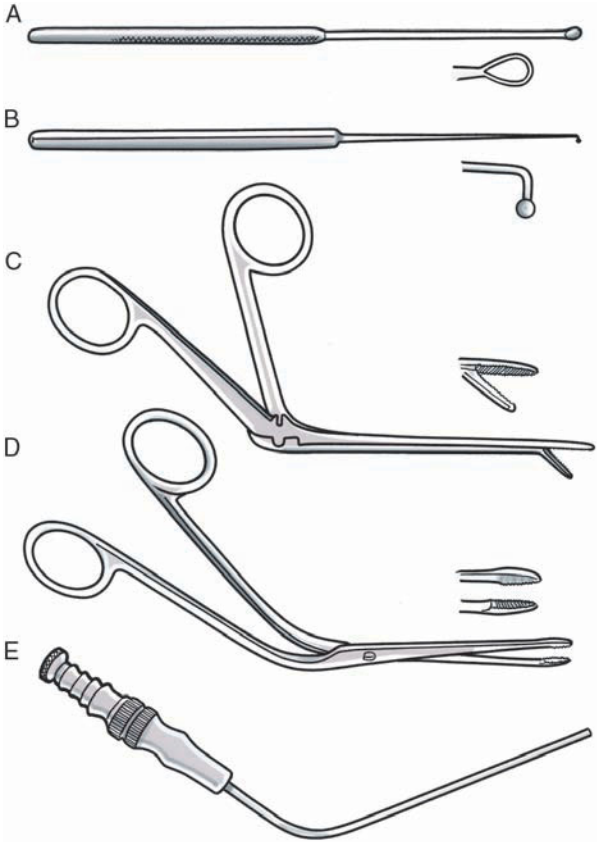


FIGURE 165-1. Instruments used for removal of foreign bodies from the external auditory canal. **A.** Cerumen loop. **B.** Right-angle ball hook. **C.** Alligator forceps. **D.** Hartman forceps. **E.** Frazier suction catheter.

Irrigation

- 10 or 20 mL syringe
- Butterfly catheter with any size needle (after needle and most of tubing is cut off)
- Kidney basin
- One Chux or other water barrier
- Tap water or saline at or slightly above body temperature[6,8,11,13,14]

Alternate Irrigation Equipment[8]

- Plastic portion of 18 gauge angiocatheter
- Dental jet-irrigation device (e.g., Water-Pik)
- DeVilbiss irrigator and a compressed air source
- Metal ear syringe

Instruments to Pass Behind Object and Pull It Out (Figures 165-1 to 165-4)

- Ear curettes or cerumen spoon, metal or disposable plastic
- Wire loop
- Blunt or ball right-angle hook

Instruments Used to Grasp Object Directly (Figures 165-1 & 165-3)

- Alligator forceps
- Hartman forceps
- Lighted forceps (Bionix Medical Technologies, Toledo, OH)



FIGURE 165-2. Examples of plastic disposable curettes. Note the variety of head shapes. (Photo courtesy of Bionix Medical Technologies, Toledo, OH.)



FIGURE 165-3. Lighted, disposable, and single patient use devices to aid in cerumen removal. From left to right: articulating curette, open loop curette, and grasping forceps. (Photo courtesy of Bionix Medical Technologies, Toledo, OH.)



FIGURE 165-4. The EasiEar metal curette (Splash Medical Devices LLC, Atlanta, GA).

Suction

- Frazier suction tips
- Intravenous tubing with flange created at tip using a heat source
- Vacuum or suction source
- Connection tubing
- Hemostat

Cyanoacrylate Glue[16]

- Ear speculum
- Cyanoacrylate wound/tissue glue or Superglue
- Paper clip or cotton-tipped applicator
- Superglue removal equipment

Cyanoacrylate Glue Removal[17]

- Acetone to debond glue from skin
- Cotton balls
- Cotton-tipped applicators
- Irrigation or instruments for final removal

Commercially Available Devices

- Hognose otoscope tip
- Katz extractor

Pediatric Immobilization

- Sheets
- Commercial immobilization device (e.g., Papoose board)

PATIENT PREPARATION

Explain the procedure and potential complications to the patient and/or their representative. The discussion should include discomfort, dizziness, minor bleeding, postprocedural otitis externa, and TM perforation. Discuss the importance of remaining still during the procedure. Warn the patient that they may experience an occasional loud noise, especially if suction is used. The most convenient position for adult patients is to remain seated with the affected ear facing the Emergency Physician. Children can sit on the lap of a parent or attendant with the affected ear facing the Emergency Physician. The parent or attendant should wrap one arm around the child's arms and body while stabilizing the head with their other arm.[3] Smaller children can be swaddled in a papoose made from a sheet and tape or a commercial immobilization device.[3] Place the patient supine with their face toward the ceiling. **Do not place the patient with the affected ear facing up, as this may cause the foreign body to move farther into the EAC.**

All removal techniques require the EAC to be straightened before inserting any device. In the adult, this is accomplished by pulling the pinna up and back while simultaneously pulling it straight out from the head.[8] In the small child, pull the pinna down, back, and slightly out from the head.[6,8]

The patient may require anesthesia of the EAC. Fill the EAC with 5 to 10 mL of 1% lidocaine using the syringe tip, an angiocatheter without the needle, or a butterfly catheter with the needle cut off. This will result in substantial but short-lived topical anesthesia for the procedure.[15] If the effect wears off before the procedure is complete, the topical application of lidocaine can be repeated as needed or longer-acting agents may be used. Although usually not necessary, local anesthetic solution may be injected to provide analgesia. Fill a 1 mL syringe with local anesthetic solution and apply a 2-inch long, 27 or 30 gauge needle. Position a plastic or metal ear speculum into the EAC. Insert the needle through the speculum. Inject 0.25 mL subcutaneously in the superior and inferior quadrants of the EAC distal to the isthmus. If needed, all four quadrants can be injected.[15] Refer to Chapter 168 for a complete discussion of EAC anesthesia. A final option is to use procedural sedation and analgesia (Chapter 129) to control the patient and remove the foreign body.[24]

TECHNIQUES

PRECAUTIONS FOR USING INSTRUMENTS IN THE EAC

There are two major precautions the Emergency Physician must take to avoid pushing the foreign body further into the EAC or causing damage to the EAC and TM. First, the procedures must be performed under direct vision. Second, the hand holding the instruments must remain firmly in contact with the patient's head at all times to stabilize the hand and avoid abrading or lacerating the EAC wall or damaging the TM should the patient abruptly move.[2,8] Even a very cooperative patient may move due to an involuntary reflex cough.[6]

IRRIGATION

Irrigation is the safest method of foreign body removal.[2,8,9,18] It is most successful for nonimpacted and smaller foreign bodies. Tuck a water barrier into the patient's gown or collar. Place a kidney basin under the ear and against the cheek to catch the irrigation solution and the foreign body. Instruct the patient or an assistant to hold the basin in place. Attach a butterfly needle to a 10 or 20 mL syringe. Cut the needle and most of the tubing, leaving only 1 to 2 cm of the tubing (**Figure 165-5**). This remaining tubing will usually be curved, which is optimal for precisely directing the irrigation stream. Others use a 14 or 16 gauge plastic angiocatheter.[19] It is important to remember that wider diameter instruments deliver fewer pounds per square inch of pressure with a reduced chance of injury.[19]

Draw up body temperature or slightly warmer tap water or saline into the syringe. **Be sure to use only body temperature or slightly warmer fluid to avoid complications from caloric stimulation.**[8,11] Straighten the EAC by manipulating the pinna. Insert the butterfly tubing or angiocatheter 1 cm into the EAC with the tip aimed upward and away from the foreign body (**Figure 165-5**).[13] Rapidly inject the irrigating solution. This will cause the fluid to shoot past the foreign body, bounce off the TM, and carry the foreign body out of the EAC along with the irrigating solution.[2,9]

Care must be taken to make sure that the irrigation stream and foreign body can easily exit the EAC, to prevent an increase in hydrostatic pressure, which could damage the TM.[12] Sometimes irrigation will not completely remove the foreign body but move it more laterally, where an instrument can be safely used to grasp and remove it. All water or saline should be removed from the EAC to prevent an otitis externa.[8,11]

Many physicians have used mechanical dental irrigation devices (e.g., Water-Pik) to irrigate the EAC and remove either cerumen or a foreign body. These devices shoot a stream of fluid from its tip. While they will often remove the cerumen or foreign body, the direct fluid stream can rupture a TM.[11,19,22]

The OtoClear Ear Irrigation Tip (Bionix Medical Technologies, Toledo, OH) is an improvement for EAC irrigation (**Figure 166-6**). This device is designed as disposable and single patient use. It attaches to the Luer hub of a syringe. The OtoClear tip can also be attached to a spray bottle or dental irrigating device, allowing these devices to be safely used. When inserted into the EAC, its flared base fits snugly and prevents it from being inserted too far. Holes in the base allow for the egress of irrigation fluid into the kidney basin

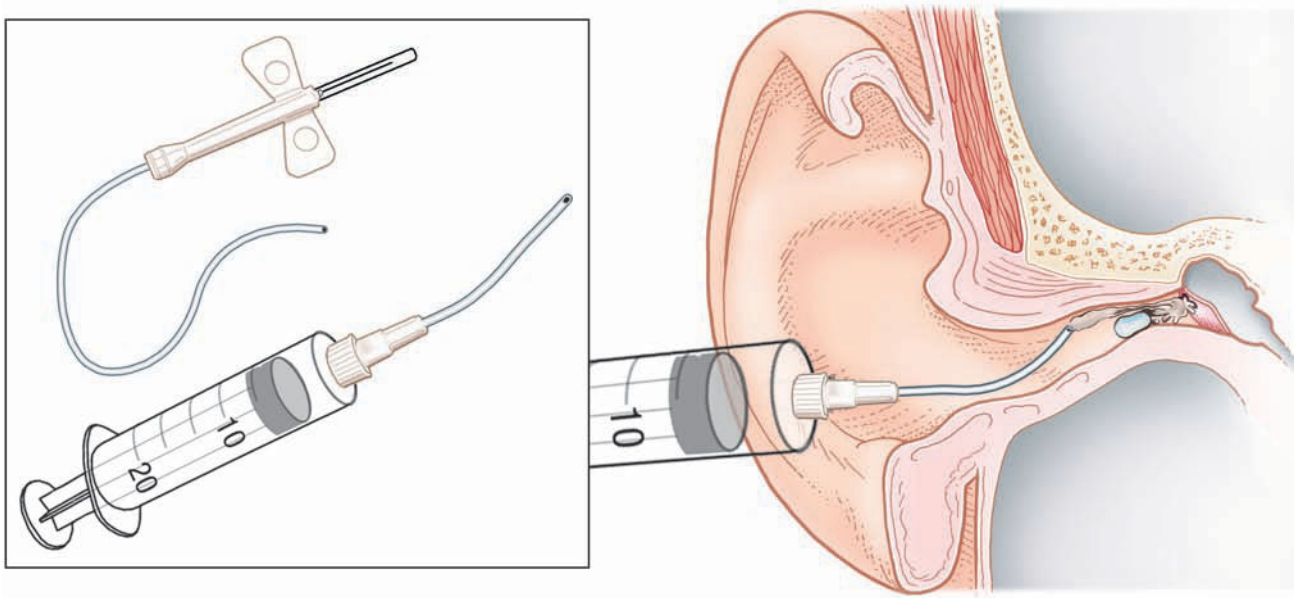


FIGURE 165-5. Irrigation with butterfly catheter tubing attached to a syringe. The stream of fluid is aimed toward the top of the external auditory canal and above the foreign body.

held against the skin. The OtoClear tip directs fluid toward the walls of the EAC (**Figure 166-6**). While this prevents damage to the TM, in some cases it may not provide enough flow or pressure to remove a foreign body.

SLIDING A FOREIGN BODY OUT WITH AN INSTRUMENT FROM BEHIND

This technique requires either a cerumen spoon or wire loop for small objects or a right-angle hook for larger ones (**Figures 165-1A, B, & 165-4**). Straighten the EAC by manipulating the pinna. Pass the tip of the instrument over and behind the foreign body with the spoon, loop, or hook in the same plane as the EAC wall. Rotate the instrument 90° to bring the loop or hook behind and directly in contact with the back (medial) side of the foreign body. Gently pull the instrument out of the EAC, pulling the foreign body out with it.[2,8] Take extra care so that the EAC and TM are not injured during the instrument insertion or removal.

The EasiEar Disposable Comfort Curette (Splash Medical Devices LLC, Atlanta, GA) is an improvement to the standard disposable plastic curette (**Figure 165-4**). It is a stainless steel, single patient use, and disposable curette. The rounded wire head is smooth. It lacks the jagged and sharp plastic edges that are often found on molded plastic curettes. The EasiEar has no abrasive edges, seams, or surfaces to potentially abrade the EAC. This design may prevent EAC abrasions and lacerations, and procedure-related bleeding. The spring wire shaft provides some flexibility and enhanced maneuverability when compared to molded plastic curettes, making the foreign body removal process easier. The angled head and flexible shaft allow it to be manipulated within the EAC to remove a foreign body.

GRASPING FOREIGN BODIES WITH FORCEPS

If this maneuver is to be successful, there must be sufficient space between the EAC wall and the foreign body, or a projecting edge that can be grasped, so as to avoid pushing it further into the EAC.[2,4,9] This technique is contraindicated if the object is spherical and located against the TM, which can be injured during the procedure.[4] The most commonly used instruments include the alligator forceps (**Figure 165-1C**) and the Hartman forceps (**Figure 165-1D**). A lighted forceps (Bionix Medical Technologies, Toledo, OH) may also be used (**Figure 165-3**). Straighten the EAC by manipulating the pinna. Insert the forceps into the EAC and grasp the foreign body (**Figure 165-6**). Gently withdraw the instrument and the foreign body, taking care not to abrade the EAC wall. If the foreign body is located too far medially or instrumentation would cause pain or damage to the TM, irrigation may be able to move the foreign body laterally for subsequent grasping.

SUCTION REMOVAL

Frazier suction catheters (**Figure 165-1E**) are most useful with small foreign bodies. Otherwise, this technique will be unsuccessful or will push the object farther into the EAC. Attach the Frazier suction catheter to the suction tubing. Turn on the suction source. Straighten the EAC by manipulating the pinna. Gently insert the catheter into the EAC. Place a thumb over the hole in the catheter handle to direct the suction through the tip of the catheter. Gently advance the suction catheter until the tip is in contact with the foreign body. Withdraw the Frazier suction catheter and foreign body from the EAC.

For impacted smooth, spherical objects, suction with plastic intravenous tubing can be used.[1,20] Cut a short length of plastic intravenous tubing and attach one end to the suction source. Fashion the other end into a small flange shape using a heat source and any metal object with a rounded end, such as the tip of a hemostat or larger clamp. Heat the jaws of the hemostat and insert them into the plastic tubing just enough to create a flange. Turn on the suction source. Place a hemostat onto the tubing to temporarily clamp the suction tubing. Straighten the EAC by manipulating the pinna. Gently advance the flange tip into the EAC until it contacts the foreign body, taking care not to push it inward (**Figure 165-7**). Remove the hemostat from the tubing to activate the suction. Gently but quickly remove the tubing and attached foreign body from the EAC.

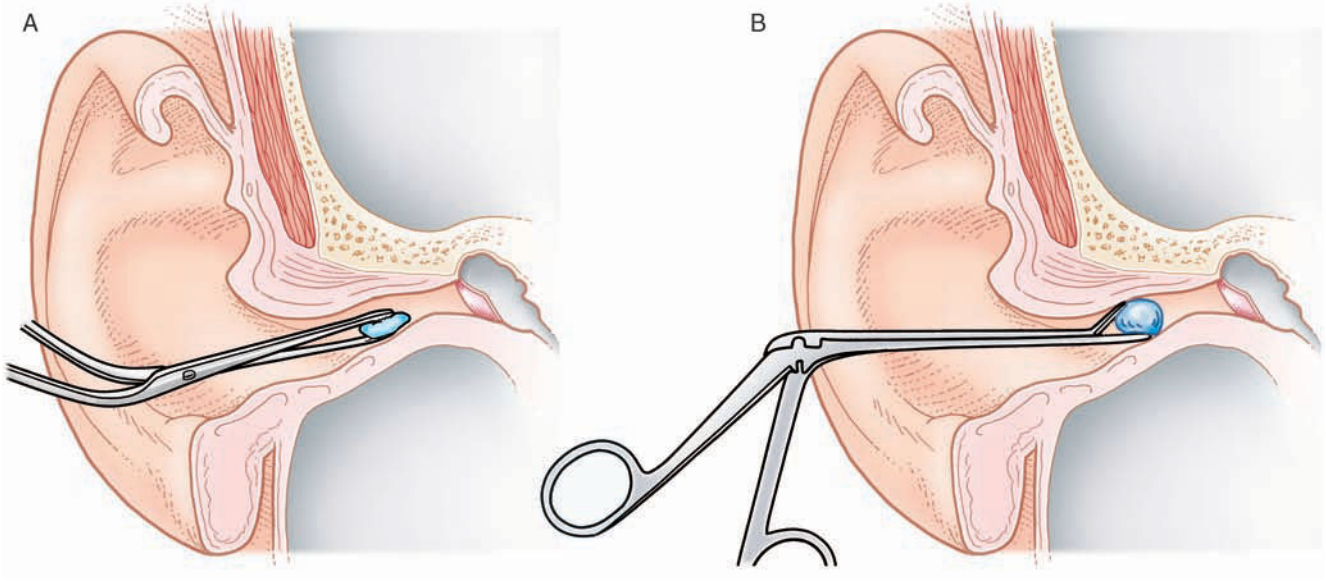


FIGURE 165-6. Forceps removal of a foreign body. **A.** Hartman forceps. **B.** Alligator forceps.

CYANOACRYLATE GLUE–ASSISTED REMOVAL

Cyanoacrylate glue can be used to extract impacted spherical objects that allow no space for irrigation or instrument removal and are located laterally or distally in the EAC.[1,16] However, this technique can be fraught with complication.[17] **Always use an ear speculum to decrease the chance of gluing the foreign body to the EAC or TM and to prevent creating a glue foreign body.** Insert an ear speculum into the EAC with the tip near the foreign body. **Do not touch the foreign body with the speculum so as to prevent it from being impacted.** The ear speculum will prevent the Emergency Physician from touching the EAC with glue.

Obtain a long, thin object (e.g., straightened paper clip or the stick end of a cotton-tipped applicator). Moisten the tip of the paper clip or applicator stick with a very tiny amount of cyanoacrylate glue. A larger amount can drop off into the EAC. Insert the ear speculum. Straighten the EAC by manipulating the pinna.

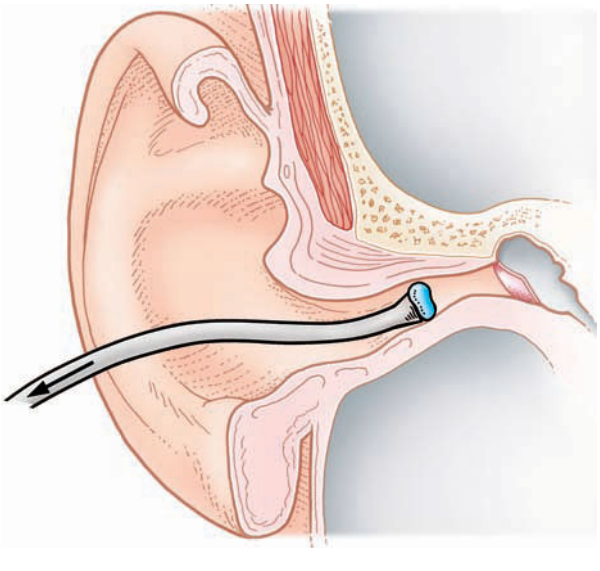


FIGURE 165-7. Suction removal of a foreign body.

Quickly insert the paper clip or applicator stick through the ear speculum, before the glue dries, until it just touches the foreign body. Maintain this position for 30 to 60 seconds to allow bonding of the glue to the foreign body. Remove the paper clip or applicator stick with the foreign body attached and the speculum all together.

REMOVAL OF CYANOACRYLATE GLUE

For either iatrogenic or patient-introduced cyanoacrylate glue, debonding from the patient's tissues by acetone must precede the removal.[1,17] Failure to do this will result in tearing of the skin or TM. **Do not apply acetone if the TM cannot be visualized or is not intact.**[11] Infuse acetone into the EAC using cotton balls or swabs. Allow it to remain in the EAC for 5 minutes. Since acetone evaporates rapidly, several applications may be necessary. Once the glue mass is free, it can be removed by irrigation, instruments, or suction.

HOGNOSE OTOSCOPE TIP

The Hognose (IQDr. Incorporated, Manitou Springs, CO) is a disposable, latex free, and single-use device that attaches to a standard otoscope (**Figure 165-8**). It comes in three sizes (3, 4, and 5 mm), each with a color-coded tip. The size represents the cup size at the tip of the device. The tip is soft, self-molding, and looks like the nose of a hog. It has an insufflation port and suction tubing attached to its side. The adapter on the suction tubing attaches to standard wall suction tubing.

Attach the Hognose to the otoscope similar to attaching a disposable speculum to an otoscope. Turn on the otoscope light source. Attach the hognose tubing to suction tubing and a suction source. Turn the suction source on to low or medium. Grasp the otoscope with your dominant hand. Straighten the EAC by manipulating the pinna. Insert the Hognose into the EAC while visualizing the foreign body through the otoscope head. When the tip of the Hognose is just next to the foreign body, place an index finger over the insufflation port to engage the suction at the device tip. Gently advance the otoscope until the tip of the Hognose is against and attached to the foreign body. If you suddenly see black through the otoscope, the soft tip has collapsed on itself. Remove the finger over



FIGURE 165-8. The Hognose otoscope tip attached to an otoscope. (Photo courtesy of IQDr. Incorporated, Manitou Springs, Co.)

the insufflation port and re-approach the object. While maintaining suction, withdraw the Hognose with the foreign body attached.

GATORNOSE OTOSCOPE TIP

The Gatornose (IQDr. Incorporated, Manitou Springs, CO) is a disposable, latex free, and single-use device that attaches to a standard otoscope (**Figure 165-9**). It twists onto an otoscope like a speculum. It comes with three different jaw types that attach to the body of the device. These jaws are small flat jaws, large flat jaws, and open loop jaws. A trigger on the body of the device controls jaw opening and closing.



FIGURE 165-9. The Gatornose otoscope tip attached to an otoscope. Note the three types of jaws that are available to snap onto the base of the device. (Photo courtesy of IQDr. Incorporated, Manitou Springs, Co.)



FIGURE 165-10. The Katz Extractor. The balloon at the tip inflates and deflates by pushing and releasing the plunger, respectively. (Photo courtesy of InHealth Technologies, Carpinteria, CA.)

Attach the Gatornose to the otoscope similar to attaching a disposable speculum to an otoscope. Turn on the otoscope light source. Grasp the otoscope with your dominant hand. Insert the ring finger into the trigger. Pull the trigger to close the Gatornose jaws. Straighten the EAC by manipulating the pinna. Gently insert the Gatornose jaws just into the EAC. Push the trigger to open the Gatornose jaws and be able to view through the otoscope. Gently advance the otoscope while visualizing the foreign body through the otoscope head. Position the jaws above and below or anterior and posterior to the foreign body. Pull the trigger to close the jaws onto the foreign body. Withdraw the otoscope with the foreign body in the jaws of the Gatornose.

KATZ EXTRACTOR

The Katz Extractor Oto-Rhino Foreign Body Remover (InHealth Technologies, Carpinteria, CA) is a device designed to extract foreign bodies from the nasal and auditory passages (**Figure 165-10**). It is a disposable single-use device consisting of a balloon-tipped catheter attached to a syringe. Always test the device before using it. Push the plunger to inflate the balloon and inspect it for any air leaks. Release the plunger to deflate the balloon.

Grasp the device with the dominant hand (**Figure 165-11**). Gently insert the catheter along the wall of the EAC until the balloon is just past the foreign body (**Figure 165-11A**). Inflate the balloon by depressing the plunger on the syringe (**Figure 165-11B**). Withdraw the catheter and foreign body from the EAC while maintaining the balloon in the inflated state (**Figure 165-11C**). If the foreign body has a central hole (e.g., candy or bead), insert the catheter through the hole rather than behind it.

LIVE INSECT REMOVAL

A live insect in the EAC is one of the most painful and upsetting foreign bodies. The patient suffers as the insect moves, vibrates, tries to flap its wings, or pushes against the sensitive TM in an effort to escape.[3] In the past, mineral oil was infused to smother and kill the insect prior to removal.[4,15,21] However, this method has several disadvantages. A significant time passes while the patient is still suffering and the insect dies. Due to being stuck in the viscous oil, the insect is more difficult to remove and frequently breaks into multiple pieces. The EAC is also now impossible to anesthetize with a local infusion of lidocaine, which is repelled by the oil.

A preferred technique is to immobilize the insect with an infusion of 1% lidocaine into the EAC.[21] A topical anesthetic composed of benzocaine and antipyrine (e.g., Auralgan) may also be used. The

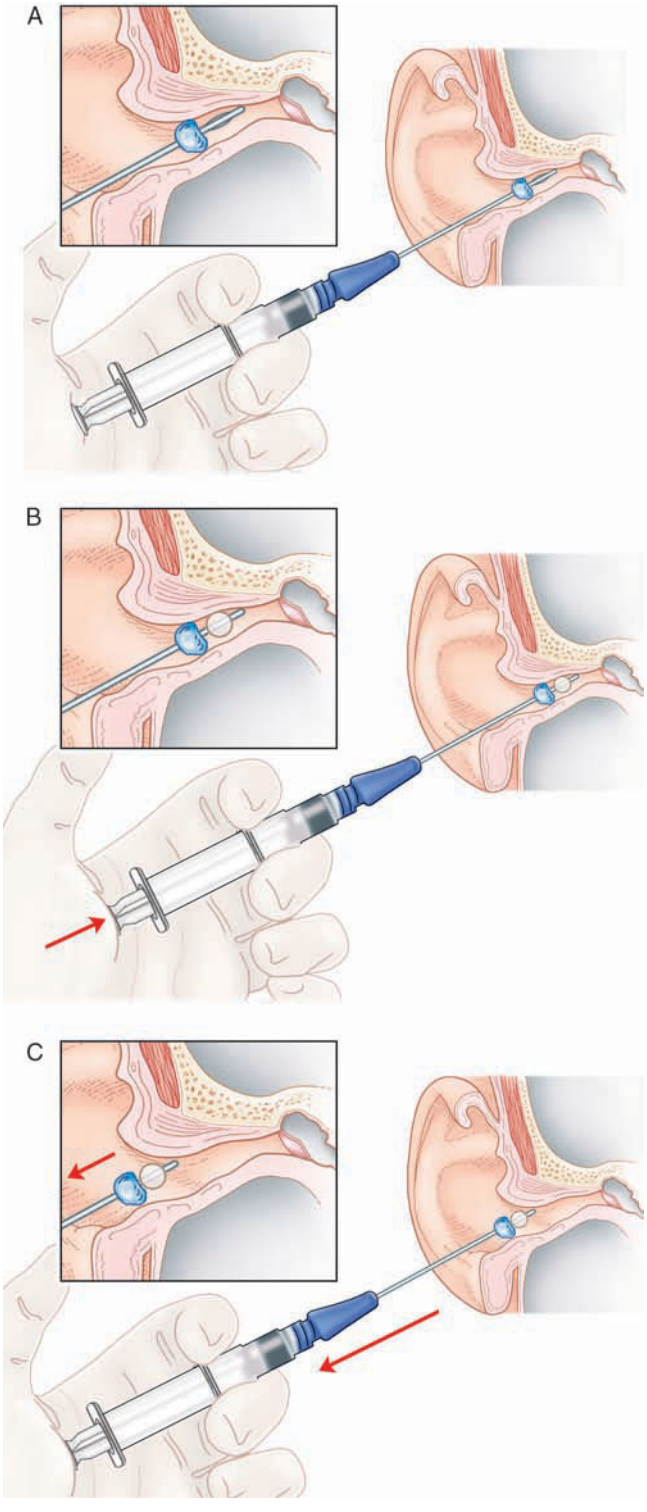


FIGURE 165-11. The Katz Extractor removing an EAC foreign body. **A.** The device is inserted until the balloon is just past the foreign body. **B.** The balloon is inflated. **C.** The Katz extractor is removed with the balloon inflated and the foreign body is removed.

local anesthetic results in the insect becoming inert much more quickly than with oil. The EAC and TM are thus anesthetized for patient comfort and the immobilized insect is more likely to be removed in a single piece than with mineral oil.

The insect can now be easily removed by irrigation or instrument removal. Sometimes both techniques are used. Irrigation can be used to move the dead insect more distally in the EAC, followed by instrument removal. It is recommended that the EAC be inspected and irrigated after the insect is removed to make sure that no tiny parts of the insect remain in the EAC, as they can cause an otitis externa.[3]

ASSESSMENT

After the foreign body has been removed, it is crucial to reexamine the patient to confirm that the EAC, TM, and hearing are all normal and have not been damaged.[3,4,18] In children, but also adults with mental or psychiatric problems, it is prudent to examine the other ear, the nostrils, and any other orifice that may be harboring an unsuspected foreign body.[3–5] Any remaining irrigation fluid in the EAC should be removed to prevent an otitis externa.[8]

AFTERCARE

Most authors recommend prescribing several days of topical otic drops to prevent or treat subclinical otitis externa, which is often precipitated by abrasion of the EAC or inflammation due to foreign body impaction.[3] Often recommended are topical combinations of antibiotics and steroids in solution or suspensions. Commonly prescribed agents include otic quinolones, Corticosporin Otic, Otic Domeboro, Otobiotic, Pediotic suspension, and VoSol to name a few. Consult an Otolaryngologist for patients with injuries, hearing deficits, severe otitis externa, or in whom removal was unsuccessful. Otherwise, the patient can receive follow-up with their Primary Care Physician in 48 to 72 hours. Instruct the patient in the proper application of ear drops. They should return to the Emergency Department if they develop ear pain, ear discharge, fever, decreased hearing, vertigo, headache, or a stiff neck.

COMPLICATIONS

Numerous complications can result from the removal of a foreign body from the EAC.[3–5,8,11,12,14,15,18] The complication rate for irrigation is reported as 1 per 1000 cases.[14,18] It is higher for all other techniques.[8,11] Irrigation can push a foreign body further into the EAC. If the irrigating solution is cold, caloric stimulation can result in vomiting, vertigo, bradycardia, and syncope.[1,11] Middle ear debris can be forced through a preexisting or iatrogenic TM defect, resulting in an otitis media, damage to the ossicles, labyrinthitis, mastoiditis, loss of hearing and balance, or a central nervous system infection.[9,11–14] Otitis externa can result from abrasions to the EAC or water left behind after irrigating. Butterfly tubing is less likely than an angiocatheter to damage the EAC or TM because of its more pliable nature, larger diameter, and curved tip.

It is known that mechanical dental irrigation devices, even at low pressures, can rupture the TM.[11,19,22] For this reason, they are not recommended for the removal of foreign bodies from the EAC.

Instrumentation and suction should be used with caution to prevent secondary injury. This includes EAC lacerations or abrasions, TM rupture, pushing of foreign bodies further into the EAC, and disruption or removal of the ossicles. Abrasions or lacerations to the EAC can result in an otitis externa.

Cyanoacrylate glue can cause complications and is the least favorite technique of this author. The Emergency Physician may glue their fingers together or to the instruments. The foreign body may be glued to the pinna, EAC, or the TM. Removal of the glue can abrade and irritate the skin and/or TM.

SUMMARY

Foreign bodies in the EAC are common. With adequate anesthesia, careful planning, and gentle handling, most foreign bodies can be successfully removed in the Emergency Department from the EAC.[23] The removal techniques require equipment that is readily available in the Emergency Department. The removal techniques are easy to perform, quick, and simple to learn. An impacted button battery is a true emergency and requires immediate removal. An emergent consultation with an Otolaryngologist is required if the button battery cannot be removed or if any evidence of injury is present after the button battery has been removed.

166 Cerumen Impaction Removal

Rebecca R. Roberts

INTRODUCTION

Removal of impacted cerumen is one of the most common otolaryngologic procedures performed by nonotolaryngologists.[1] This procedure is also believed to be the most common cause of iatrogenic otolaryngologic complications referred to specialists.[2] Approximately 8 million ears are irrigated annually in the United States to remove cerumen.[3,4]

ANATOMY AND PATHOPHYSIOLOGY

The S-shaped external auditory canal (EAC) is 2.5 cm long in adults.[5] The lateral or distal third is cartilaginous, with thicker skin, more hair follicles, glands, and subcutaneous tissue than the medial or proximal two-thirds, which is bony and has a thinner, more fragile layer of skin.[5,6] The narrowed isthmus is located between the cartilaginous and bony portions.[5] The canal ends medially at the tympanic membrane (TM), which is situated obliquely to increase the surface area for carrying sound energy to the middle ear.[6] The anteroinferior EAC is 0.6 mm longer than the posterosuperior portion.[5] Auriculotemporal branches of cranial nerves V, VII, IX, and X and the greater auricular nerve of the cervical plexus supply sensation to the EAC.[5]

Cerumen is a mixture comprising secretions of the ceruminous glands of the lateral two-thirds of the EAC, the pilosebaceous glands located at the roots of EAC hairs, and sloughed squamous epithelial cells.[5,7] Cerumen forms a barrier against infection, has antimicrobial activity, and protects the skin of the EAC as it is water repellant. It is expelled naturally by migration assisted by chewing movements.[7,8]

There are many reasons for cerumen to become impacted.[4,6,7] The most common is self-cleaning with cotton-tipped applicator swabs that can push cerumen further into the EAC. The abundant hairs in the EAC, more common in males than females, can obstruct cerumen migration. A small (especially in children), tortuous, or scarred EAC will obstruct cerumen migration. Some people produce large quantities of cerumen. Diseases such as Parkinson's can alter the consistency of the cerumen and inhibit its migration. Hearing aids, stethoscope earpieces, or any other object in the EAC may compact the cerumen. Deficits in the substances that cause sloughed squamous epithelial cells to separate will inhibit the movement of cerumen. Nonimpacted cerumen exposed to water can swell and obstruct the EAC.

INDICATIONS

Recently, the term "impaction" has been defined more clearly as cerumen that causes patient symptoms or prevents a necessary examination of the EAC or TM.[4] The primary indication for removal of cerumen is symptomology of impaction.[2,4] The most common complaint is hearing loss, which is often abrupt and expressed as a "blocked ear." Hearing remains normal or nearly so as long as there is a small space in the EAC through which sound can pass and cause vibration of the TM. The hearing loss becomes subjectively significant when the canal is completely obstructed or when the TM is compressed by cerumen and cannot freely move.[4,6,8] Other typical symptoms of cerumen impaction include fullness, itching, odor, pain, tinnitus, vertigo, unsteady gait, or reflex cough due to vagus nerve stimulation.[4,6,7] Other indications for removing cerumen include the need to examine the ear canal and TM or to test hearing.[4,8,9] Cerumen can cause feedback sound loops in those with hearing aids or damage the appliance.[4]

CONTRAINDICATIONS

There are several general contraindications to cerumen removal. An uncooperative patient or young patient that cannot follow instructions or be safely restrained can suffer an iatrogenic injury. Previous ear surgery with scarring of the EAC or TM risks iatrogenic injury. A known or suspected cholesteatoma is a contraindication to cerumen removal. Do not attempt removal if the anatomy of the EAC or TM cannot be clearly defined or is distorted.

The remaining contraindications to cerumen removal are specific to each removal technique. Nearly all cerumen can be safely removed by using one of the techniques listed. Often, two or more techniques can be used together with increased success.[6,9]

The most important contraindication for EAC irrigation is an acute or chronically ruptured TM.[4,7–12] Fluid forced into the middle ear can lead to otitis media, labyrinthitis, mastoiditis, disruption of the ossicles, and loss of balance or hearing.[4,10,12] Some authors recommend alternate methods for any patient who has never had an ear exam to document the integrity of the TM.[9,10] Most patients can provide the information of having a history of a ruptured TM. A relative contraindication is moderate to severe otitis externa.[4,7,8]

The major contraindication to instrument removal is a patient, usually pediatric, who is so uncooperative that injury to the EAC or TM is likely to occur with movement.[6,12,13] The second contraindication is cerumen pushed directly against the TM. In these circumstances, the TM can be abraded or perforated during cerumen removal with instruments.

The major contraindication to suction removal is a single, hard, irregular, and impacted cerumen plug. Suction will be unsuccessful. Suction works best if there are multiple tiny cerumen fragments or very soft cerumen.[9]

Cerumen softening or cerumenolytic agents should not be used if the patient has a ruptured TM. Other contraindications to softening agents are an allergy to the agent or an otitis externa.[4,7,14,15]

EQUIPMENT

Anesthesia

- Local anesthetic solution or suspension (e.g., viscous lidocaine, lidocaine solution, or Auralgan)
- 3 mL syringe

Irrigation

- 10 to 20 mL syringe
- Butterfly catheter with any size needle

- Kidney basins
- Chux or other water barrier
- Tap water or saline at or slightly above body temperature[5,6]

Alternate Irrigation Equipment[4]

- Plastic portion of 18 gauge angiocatheter
- Oral jet irrigation (Water-Pik); no longer recommended (see "Complications," below)
- DeVilbiss irrigator and a compressed air source
- Metal ear syringe

Instruments to Separate and Loosen Cerumen (Figures 166-1 to 166-4)

- Ear curettes or cerumen spoon, metal or disposable plastic
- Wire loop
- Blunt or ball right-angle hook

Instruments to Grasp Cerumen Directly (Figures 166-1 & 166-3)

- Alligator forceps
- Hartman forceps
- Lighted forceps (Bionix Medical Technologies, Toledo, OH)

Suction

- Frazier suction catheters
- Suction source
- Connection tubing
- Hemostat

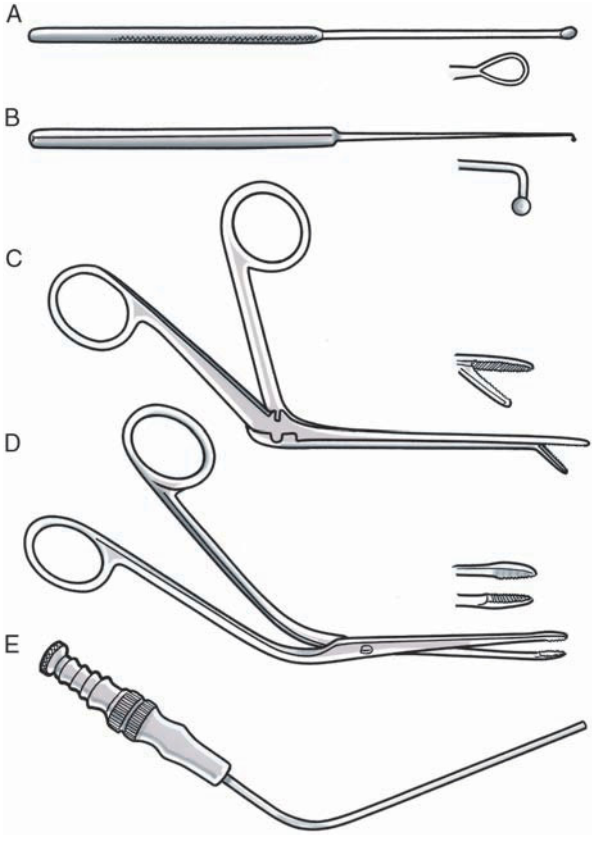


FIGURE 166-1. Instruments used for removal of cerumen from the external auditory canal. **A.** Cerumen loop. **B.** Right-angle ball hook. **C.** Alligator forceps. **D.** Hartman forceps. **E.** Frazier suction catheter.



FIGURE 166-2. Examples of plastic disposable curettes. Note the variety of head shapes. (Photo courtesy of Bionix Medical Technologies, Toledo, OH.)



FIGURE 166-3. Lighted, disposable, and single patient use devices to aid in cerumen removal. From left to right: articulating curette, open loop curette, and grasping forceps. (Photo courtesy of Bionix Medical Technologies, Toledo, OH.)



FIGURE 166-4. The EasiEar metal curette (Splash Medical Devices LLC, Atlanta, GA).

Cerumen Softening Agents

- Warm tap water
- Hydrogen peroxide
- Olive, mineral, vegetable, or almond oil
- 5%, 10%, or 15% sodium bicarbonate solution
- Commercial agents (e.g., Cerumenex, Cerumol, Auralgan, and Waxsol)
- Colace
- Glycerine
- Alcohol
- Propylene glycol

Pediatric Immobilization

- Sheets
- Commercial immobilization device (e.g., Papoose board)

PATIENT PREPARATION

Explain the procedure and potential complications to the patient and/or their representative. The discussion should include discomfort, dizziness, minor bleeding, postprocedural otitis externa, and TM perforation. Discuss the importance of remaining still during the procedure. Warn the patient that they may experience an occasional loud noise, especially if suction is used. The most convenient position for adult patients is to remain seated with the ear facing the Emergency Physician. Children can sit on the lap of a parent or attendant with the affected ear facing the Emergency Physician. The parent or attendant should wrap one arm around the child's arms and body while the stabilizing the head with their other arm.[16] Smaller children can be swaddled in a papoose made from sheets and tape or a commercial immobilization device.[16]

Turn the affected ear toward the ceiling and fill the EAC with 5 to 10 mL of local anesthetic solution or suspension using the syringe tip, an angiocatheter, or a butterfly catheter with the needle cut off. This will result in substantial but short-lived topical anesthesia for the procedure.[17] If the effect wears off before the procedure is complete, the topical application of local anesthetic can be repeated as needed or longer-acting agents may be used. All cerumen removal techniques require the EAC to be straightened. In the adult, this is accomplished by pulling the pinna slightly up and back while simultaneously pulling it straight out from the head.[6] In the small child, pull the pinna down, back, and slightly out from the head.[6,18]

TECHNIQUES

PRECAUTIONS FOR USING INSTRUMENTS IN THE EAC

There are two major precautions the Emergency Physician must take to avoid pushing cerumen further into the EAC or causing damage to the EAC and TM. **First, the procedures must be performed under direct vision.[6] Second, the hand holding the instrument must remain firmly in contact with the patient's head at all times to stabilize the hand and avoid scrapping the canal wall or puncturing the TM should the patient move.[6,15]** Even a very cooperative patient may move due to an involuntary reflex cough.[18]

IRRIGATION

Irrigation is the safest and easiest method of removing cerumen, and is usually successful.[2,4,6,10,15] It is less likely to lacerate or damage the EAC or TM than other techniques. It is also the technique most commonly used by nonotolaryngologists.

Place a kidney basin under the affected ear and against the patient's cheek to catch the exiting irrigation solution and cerumen. Instruct the patient or an assistant to hold the basin in place. This author's favorite device for irrigating is to cut the needle and most of the tubing off a butterfly needle, leaving only 1 to 2 cm of tubing (**Figure 166-5**).[13] This remaining tubing will usually be curved, which is optimal for precisely directing the irrigation stream. Others use a 14 or 16 gauge plastic angiocatheter.[12] It is important to remember that wider diameter instruments deliver fewer pounds per square inch of pressure with reduced chance of injury.[12] Attach the irrigation tubing or angiocatheter onto a 10 or 20 mL syringe. Draw up body temperature normal saline or tap water into the

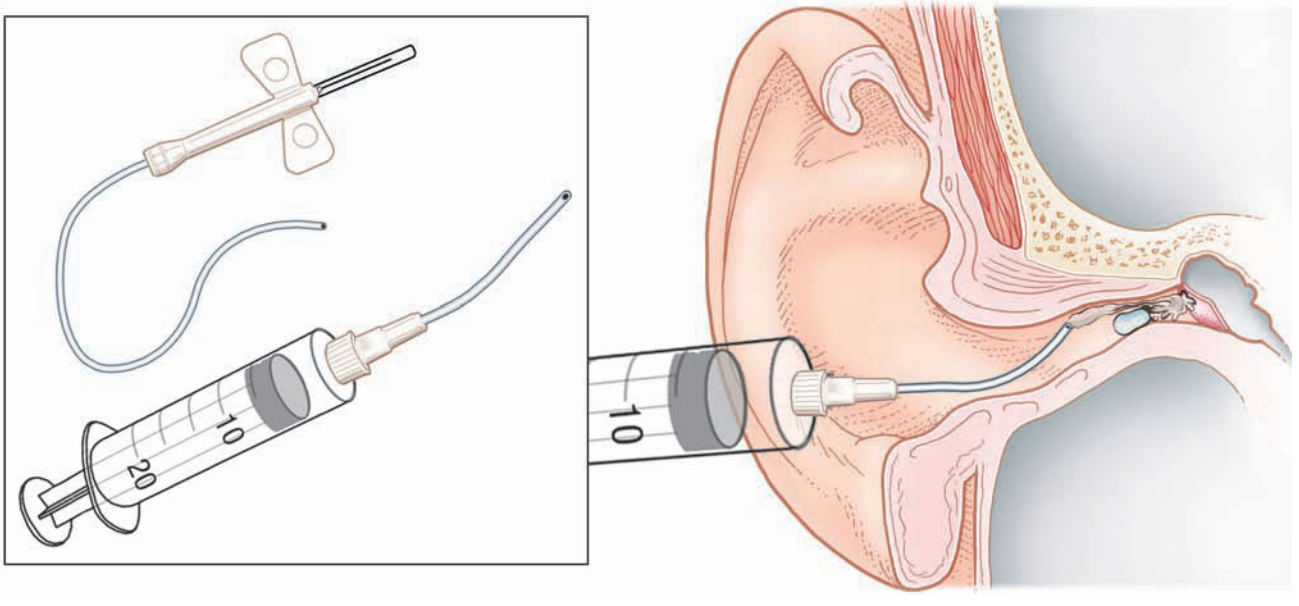


FIGURE 166-5. Irrigation with butterfly catheter tubing attached to a syringe. The stream of fluid is aimed toward the top of the external auditory canal and above the cerumen.

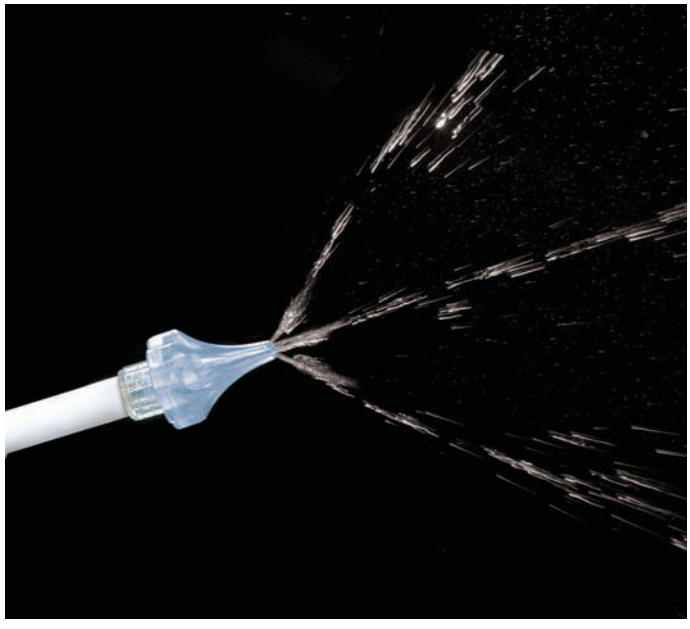


FIGURE 166-6. The OtoClear Ear Irrigation Tip. (Photo courtesy of Bionix Medical Technologies, Toledo, OH.)

syringe. Insert the butterfly tubing or angiocatheter 1 cm into the EAC with the tip aimed in a direction opposite to the location of the cerumen[8] (**Figure 166-5**). This will cause the water to shoot past the cerumen, bounce off the TM, and force the cerumen out of the EAC along with the irrigating solution.[10] If there is no obvious break in the cerumen, direct the stream superiorly or slightly anterior and superiorly.[4,10]

Care must be taken to make sure that the irrigation stream can easily exit the EAC, to prevent an increase in hydrostatic pressure, which could damage the TM.[9] **Use only body temperature, or slightly warmer, fluid to avoid caloric stimulation symptoms.**[4] Irrigation will often have to be repeated numerous times, but persistence is usually rewarded with success.[6] Irrigation will sometimes have to be combined with either cerumen softening agents, manual separation of cerumen from the EAC wall, or direct grasping of a partially dislodged cerumen plug.[4,6]

Many physicians have used mechanical dental irrigation devices (e.g., Water-Pik) to irrigate the EAC and remove cerumen. These devices shoot a stream of fluid from its tip. While they will often remove the cerumen, the direct fluid stream can rupture a TM.[3,4,12,20]

The OtoClear Ear Irrigation Tip (Bionix Medical Technologies, Toledo, OH) is an improvement for EAC irrigation (**Figure 166-6**). This device is designed as disposable and single patient use. It attaches to the Luer hub of a syringe. The OtoClear tip can also be attached to a spray bottle or dental irrigating device, allowing these devices to be safely used. When inserted into the EAC, its flared base fits snugly and prevents it from being inserted too far. Holes in the base allow for the egress of irrigation fluid and cerumen into the kidney basin held against the skin. The OtoClear tip directs fluid toward the walls of the EAC (**Figure 166-6**). This prevents damage to the TM.

INSTRUMENT REMOVAL: SEPARATION OF CERUMEN FROM THE EAC WALL

This technique is a useful adjunct to irrigation and/or instrument removal.[15] Sometimes the cerumen is firmly pressed against the EAC wall in all visible directions. Irrigation will not work or may even worsen the situation by pushing the cerumen further into the EAC. Use either cerumen curettes (**Figures 166-2 to 4**), loops (**Figure 166-1A**), right-angle hooks (**Figure 166-1B**), or wires to gently separate the cerumen from the EAC wall and compress it into the center of the lumen.[9]

The EasiEar Disposable Comfort Curette (Splash Medical Devices LLC, Atlanta, GA) is an improvement to the standard disposable plastic curette (**Figure 166-4**). It is a stainless steel, single patient use, and disposable curette. The rounded wire head is smooth. It lacks the jagged and sharp plastic edges that are often found on molded plastic curettes. The EasiEar has no abrasive edges, seams, or surfaces to potentially abrade the EAC. This design may prevent painful cerumen removal, EAC abrasions and lacerations, and procedure-related bleeding. The spring wire shaft provides some flexibility and enhanced maneuverability when compared to molded plastic curettes, making the cerumen removal process easier.

The best place to start is superiorly. **The cerumen should not be pulled out with the same movement, as this can abrade the EAC.**[15] Once there is a visible passage to the TM, irrigation as described above is highly successful and safe. Alternatively, separation of the cerumen from the EAC wall can be performed circumferentially, all the way around the cerumen plug. This results in a cerumen plug freely suspended in the EAC, which can easily be removed by irrigation, pulled out with a right-angle hook, or grasped with forceps.[15]

INSTRUMENT REMOVAL: SLIDING CERUMEN OUT WITH INSTRUMENTS FROM BEHIND

This technique requires either a cerumen spoon (**Figure 166-1A**), a wire loop for small cerumen particles, a right-angle hook (**Figure 166-1B**) for larger quantities, or an EasiEar curette (**Figure 166-4**). Separate the cerumen from the EAC wall as described above. Position the instrument with the loop or hook in the same plane as the EAC wall. Insert the tip of the instrument into the EAC above and just beyond the cerumen to be removed. Rotate the instrument 90° to bring the loop or hook behind and directly in contact with the back (medial) side of the cerumen. Gently pull the instrument out of the EAC, pulling the cerumen out with it.[6] **Take care not to abrade the EAC wall with the instrument.**

INSTRUMENT REMOVAL: GRASPING CERUMEN WITH FORCEPS FOR REMOVAL

To be successful, there must be sufficient space for the jaws of the forceps on both sides between the EAC wall and the cerumen, or a lateral leading edge that can be grasped. Separate the cerumen from the EAC wall as described above. Insert the forceps into the EAC. Grasp the cerumen with the jaws of the Hartman (**Figure 166-7A**) or alligator forceps (**Figure 166-7B**). Gently withdraw the forceps, taking care not to abrade the EAC wall. If the cerumen is located too far medially or instrumentation would cause pain or damage to the TM, irrigation can move the cerumen plug laterally for subsequent grasping with a forceps.

For an optimal outcome, one may need to alternate irrigation and instrument removal to remove all of the cerumen plug safely and completely.[4,6] For example, irrigation may gently soften or loosen the plug. A cerumen loop or curette can then be used to separate it from the EAC wall. Irrigation can be used again to move it more laterally. Finally, a forceps or hook can be used to remove the cerumen plug from the EAC.

SUCTION REMOVAL

This technique requires soft cerumen or multiple small flakes.[9] Use the same preparations and precautions described above. Attach the

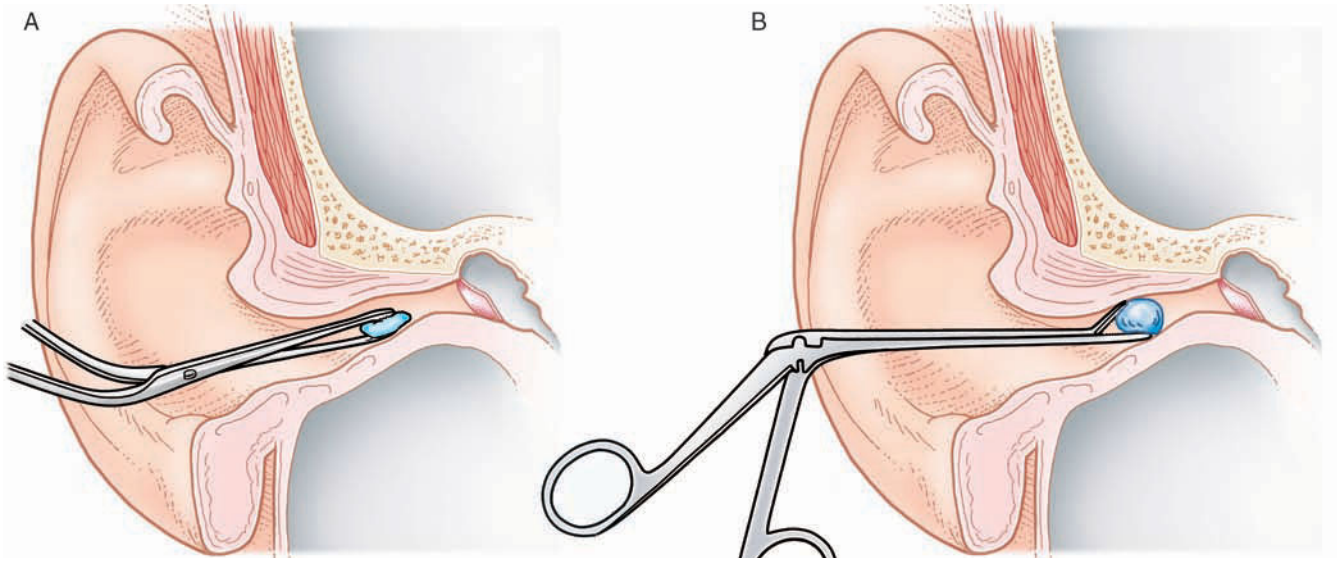


FIGURE 166-7. Forceps removal of cerumen. **A.** Hartman forceps. **B.** Alligator forceps.

Frazier suction catheter or suction tubing to the suction source. Turn on the suction source. Insert the suction catheter into the EAC. Gently advance the suction catheter until the tip is in contact with the cerumen (**Figure 166-8**). If using a Frazier suction catheter, place the thumb over the hole on the catheter shaft to direct the suction through the tip of the Frazier catheter. Gently advance the Frazier catheter until its tip is in contact with the cerumen. Withdraw the suction catheter or Frazier catheter and cerumen from the EAC. Usually the tip must be withdrawn and cleaned continuously, because most cerumen will plug the suction tip. For additional safety, insert the suction catheter through a plastic otoscope speculum and withdraw both together.

CERUMEN SOFTENING AGENTS

If the cerumen is so impacted and hard that the above techniques are likely to cause pain and/or injury or if the cerumen cannot be removed, apply a "cerumenolytic" or cerumen softening agent. After the cerumen has softened, it can be removed using the techniques described above. Many studies have compared different agents and most are surprisingly comparable in their effectiveness.[1,4,7,14] In fact, even water or saline is effective for cerumen softening and disintegration.[1,4,7,14] This may explain why persistent irrigation is so frequently successful. The more commonly available agents in the Emergency Department are listed in the "Equipment" section.

Fill the EAC with one of the cerumen softening agents. Insert a cotton ball into the opening of the EAC to prevent the agent from leaking out. Apply the agent to the contralateral EAC if indicated. An alternative is to place the patient lying on their side with the affected ear facing upward. Insert the agent into the EAC. The agent will not leak out if the patient remains in this position. The disadvantage of placing the patient on their side is that only one ear can be worked on at a time.

Most authors recommend waiting 15 to 30 minutes after the application of the cerumen softening agent before attempting to remove the cerumen.[8] Some recommend using the agents at home for up to a week before further removal attempts.[8,9] Prolonged exposure to these agents can precipitate an otitis externa, allergic reactions, or a contact dermatitis in the EAC. These agents must be removed and the canal thoroughly dried after their use.[4,6]

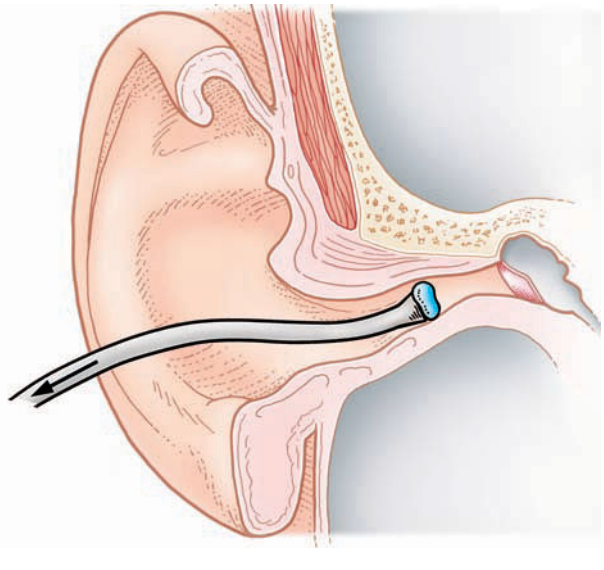


FIGURE 166-8. Suction removal of cerumen.

ASSESSMENT

After cerumen has been removed, it is critical to reexamine the ear to confirm that the EAC, TM, and hearing are all normal.[2,4] Remove all remaining water and softening agents to prevent an otitis externa.[4,6]

AFTERCARE

Many authors recommend prescribing several days of topical otic drops to prevent or treat subclinical otitis externa, which is frequently present in these patients. Often recommended are topical combinations of antibiotics and steroids in solution or suspensions. Commonly prescribed agents include otic quinolones, Corticosporin Otic, Otic Domeboro, Otobiotic, Pediotic suspension, and VoSol to name a few. Consult an Otolaryngologist for patients with injuries, hearing deficits, severe otitis externa, or in whom cerumen removal was unsuccessful. Otherwise, the patient

can receive follow-up with their Primary Care Physician in 48 to 72 hours. Instruct the patient in the proper application of ear drops. They should return to the Emergency Department if they develop ear pain, ear discharge, fever, decreased hearing, vertigo, headache, or a stiff neck. They should also be cautioned against future use of cotton swabs or other instruments in the EAC.

COMPLICATIONS

Numerous complications can result from the removal of cerumen from the EAC.[2,3,4,7,9,12,13,19,20] The complication rate for irrigation is 1 per 1000 cases.[2,4,7] It is higher for all other techniques. Irrigation can push cerumen further into the EAC. Irrigation fluid must be body temperature or slightly warmer. Cold fluid can cause caloric stimulation resulting in vertigo, vomiting, bradycardia, or syncope. Middle ear debris can be forced through a preexisting or iatrogenic TM defect, resulting in an otitis media, ossicle damage, labyrinthitis, mastoiditis, loss of hearing and balance, or a central nervous system infection. Otitis externa can result from abrasions to the EAC or retained fluids. Butterfly tubing is less likely than an angiocatheter to damage the EAC or TM because of its more pliable nature, larger diameter, and curved tip.

It is known that mechanical dental irrigation devices, even at low pressures, can rupture the TM. For this reason, they are not recommended for cerumen removal.[3,4,12,20]

Instrumentation and suction should be used with caution to prevent secondary injury. This includes lacerations or abrasions of the EAC, rupture of the TM, pushing foreign bodies further into the EAC, and disruption or removal of the ossicles. Abrasions or lacerations to the EAC can result in an otitis externa.

Cerumen softening agents can cause a contact dermatitis in the EAC, which may lead to an otitis externa. If the TM is not intact, these agents may cause permanent middle ear damage. Do not use these agents if the TM is ruptured acutely or the history suggests a potential defect.

SUMMARY

Successful cerumen removal will often require using multiple techniques in sequence, adapted to the individual patient's situation. With adequate anesthesia, careful planning of the procedural sequence, and gentle handling, those who have been relieved of cerumen impaction will be among your most grateful patients.

167 Tympanocentesis

Paul J. Jones

INTRODUCTION

Tympanocentesis, first described in 1768, is a diagnostic and therapeutic procedure in which a needle is inserted through the tympanic membrane to aspirate fluid from the middle ear space (**Figure 167-1**). The procedure is considered diagnostic when the material obtained is sent for laboratory and/or microbiological analysis. It is considered therapeutic in most instances because it relieves pressure, thereby reducing pain and many times shortens the course of an acute otitis media (AOM).

The procedure is quick, simple, and not as frequently performed as it should be. In the preantibiotic era, general practitioners and pediatricians would frequently perform the procedure for the relief of pain. Tympanocentesis is making a resurgence. It should be considered when a patient presents to the Emergency Department seeking treatment for a painful AOM. The American Academy of Family Physicians, American Academy of Pediatrics, and the Centers for Disease Control all include tympanocentesis in their practice guidelines for AOM. Many authors are calling for culture-directed antibiotic therapy for otitis media to reduce the need for broad-spectrum antibiotics and prevent, as much as possible, the emergence of multiresistant organisms.[1–6]

ANATOMY AND PATHOPHYSIOLOGY

The ear is divided into the external, middle, and inner parts. The external ear is comprised of the auricle, the external auditory canal, and the external auditory meatus. The middle ear contains an air space and mastoid cells ventilated by the eustachian tube, the tympanic membrane, and the three ossicles. The inner ear is comprised of the cochlea, semicircular canals, fluids, and cranial verve VIII. The facial nerve courses through the middle ear space and mastoid process. It can be affected by a severe infection in these areas. Facial asymmetry during an acute ear infection is an indication of an unusually severe infection.

Inspection of the tympanic membrane will usually show it to be bulging during an acute infection with loss of mobility on

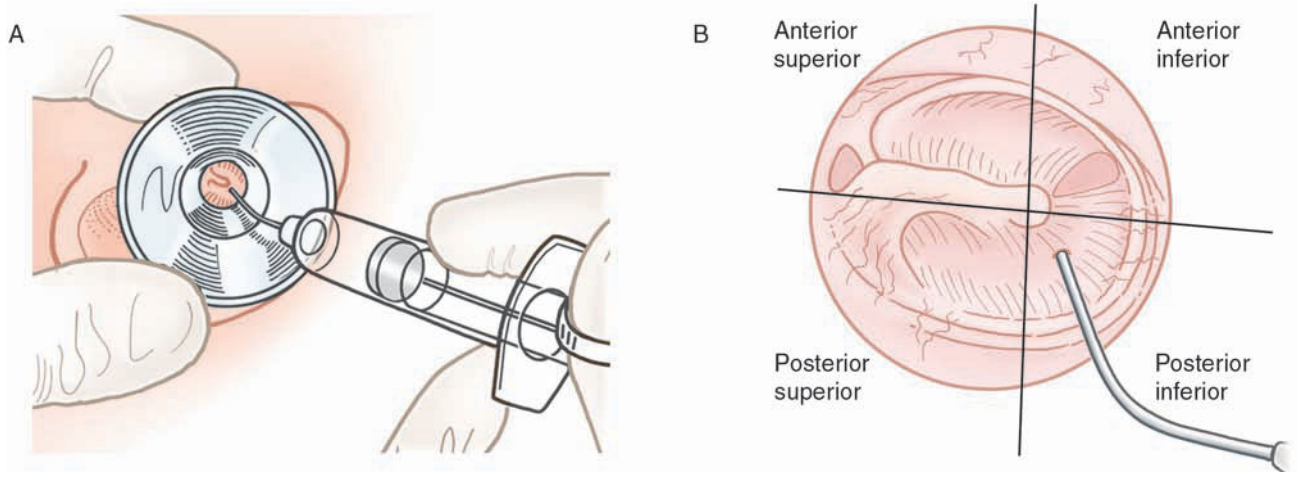


FIGURE 167-1. Tympanocentesis of the right ear. The patient is lying supine with their head directed to the left. **A.** An ear speculum is inserted into the external auditory canal. A needle is inserted through the posterior inferior quadrant of the tympanic membrane to aspirate middle ear fluid. **B.** Magnified view of the tympanic membrane.

pneumatic otoscopy. Conditions that are more chronic may show color changes of the tympanic membrane, with or without associated scarring and distortion.

INDICATIONS

Tympanocentesis is performed to obtain fluid for microbiological culture and antibiotic sensitivity testing to determine the infectious cause of a middle ear effusion. Tympanocentesis is warranted for patients with AOM that is severe, unresponsive to 48 to 72 hours of conventional antimicrobial therapy, or in a child less than 8 weeks of age to rule out gram-negative organisms. Tympanocentesis is warranted for patients with an AOM and either an acquired or congenital immunodeficiency as they will often require directed therapy. Patients who develop AOM while taking appropriate antimicrobial therapy should undergo tympanocentesis to be evaluated for the organism responsible and its sensitivity to antibiotics. Tympanocentesis is also performed when the patient has an AOM associated with unusually severe pain, signs of toxicity, or bullous myringitis. Tympanocentesis will provide immediate relief of pain, pressure, and/or hearing loss associated with AOM or a middle ear effusion. It may be performed in a patient with AOM and multiple antibiotic allergies to determine appropriate antibiotic selection and sensitivity. Finally, it can be performed in the patient with AOM prior to the 48 hour "watchful waiting" period to allow accurate antibiotic selection if the patient is still symptomatic after 48 hours.

CONTRAINDICATIONS

There are no absolute contraindications to tympanocentesis. It should not be performed in a patient who is uncooperative and cannot be restrained and/or sedated, as secondary injury may result. Uncooperative patients will require sedation to perform this procedure. Tympanocentesis should be performed by an Otolaryngologist if the landmarks on the tympanic membrane are unable to be absolutely identified or are obscured. Consult an Otolaryngologist prior to performing a tympanocentesis if an AOM is associated with a facial nerve palsy, mastoiditis, meningitis, encephalitis, brain abscess, or dural sinus thrombosis. Do not perform a tympanocentesis if the patient has an otitis externa.

EQUIPMENT

- Topical otic anesthetic solution
- 21 gauge spinal needle, 2.5 or 3 inches long
- 3 mL aspirating syringe
- Ear speculum
- Ear wax curette
- Culture swabs and media
- Laboratory tubes for fluid cell count and differential
- Intravenous extension tubing
- Otoscope
- Headlamp or overhead surgical light source
- Frazier suction catheters
- Suction tubing
- Suction source
- CDT Speculum, optional

The Channel Directed Tympanocentesis or CDT Speculum (Walls Precision Instruments LLC, Baker City, OR) is a single patient use, disposable, easy to use, and sterile device with built-in safety features. It was designed for use by Primary Care Physicians in the outpatient setting. The CDT Speculum attaches to most commonly available otoscopes (**Figure 167-2**). The device allows tympanocentesis and the aspiration of middle ear effusions.



FIGURE 167-2. The CDT Speculum attached to an otoscope. (Photo courtesy of Walls Precision Instruments LLC.)

There are several advantages to this device over the traditional spinal needle on a syringe. The ensheathed needle protects the Emergency Physician as well as the patient from accidental needle sticks. The needle is incorporated into a speculum to prevent it from contacting the external auditory canal. The needle is automatically retracted by a spring into a protected position when not being used. A safety latch prevents accidental needle extension. Needle extension is limited and prevents it from being inserted too far into the middle ear cavity.

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The postprocedural care should also be discussed. Obtain a signed consent for the procedure.

Place the patient supine on a locked gurney. View the tympanic membrane with an otoscope. Remove any cerumen from the external auditory canal using a curette. The cerumen may also be flushed from the external auditory canal. Refer to Chapter 166 for the complete details regarding cerumen removal. Again, view the tympanic membrane with an otoscope.

Administer analgesic medicine in advance of the procedure. Topical anesthetic solutions include benzocaine–antipyrine (e.g., Auralgan), viscous 4% lidocaine, 8% tetracaine, and cocaine. The administration of topical or local anesthesia is often not helpful in the presence of an acute infection. Topical anesthetics can potentially affect culture results due to their antimicrobial activity. If culture results are not a concern, apply a topical anesthetic solution into the external auditory canal followed by a cotton ball. Allow the solution to remain for 5 to 10 minutes. Use a wick to absorb the topical anesthetic solution and dry the external auditory canal. Refer to Chapters 126 and 168 for the details regarding regional anesthesia of the ear.

Children and uncooperative patients must be restrained and/or sedated so that the head is immobile. A papoose is effective for young children. Some practitioners use intravenous sedation. Only rarely is procedural sedation or general anesthesia required.

TECHNIQUES

TRADITIONAL NEEDLE-BASED TECHNIQUE

Bend a 21 gauge spinal needle at the hub to approximately 60°. Attach the spinal needle to a 3 mL aspirating syringe. Insert the ear speculum into the external auditory canal (**Figure 167-1A**). View the tympanic membrane through the ear speculum using a headlight or overhead surgical light source for illumination or an operating otoscope.

Insert the spinal needle through the speculum. Advance the needle and penetrate just into the inferior half of the tympanic membrane (**Figures 167-1A & B**). **Avoid inserting the needle through the posterior superior quadrant of the tympanic membrane. This location is near the ossicles. Any movement of the needle near the ossicles could result in disarticulation of the ossicles requiring surgical repair.** Aspirate the middle ear fluid into the syringe (**Figure 167-1A**). Simultaneously withdraw the syringe and ear speculum.

CHANNEL DIRECTED TYMPANOCENTESIS (CDT) SPECULUM

Remove the sterile CDT Speculum from the package. Attach the aspirator bulb and tubing to the CDT Speculum. Attach the CDT Speculum to the otoscope. Align the arm of the CDT Speculum with the insufflator port of the side of the otoscope head. Firmly attach the CDT Speculum onto the otoscope. Rotate the CDT Speculum 90° clockwise so that the arm is aligned with the seam on the top of the otoscope head. Disengage the safety latch.

Grasp the CDT Speculum with the dominant hand while simultaneously holding the otoscope and aspiration bulb with the nondominant hand (**Figure 167-3**). Compress the aspirator bulb. Insert the CDT Speculum into the external auditory canal. Visualize the tympanic membrane through the CDT Speculum. While looking through the CDT Speculum, press the actuator with the dominant thumb to extend the needle toward the inferior portion of the tympanic membrane (**Figure 167-3**). Continue to press the actuator to keep advancing the needle through the tympanic membrane and no more than 1 to 2 mm into the middle ear cavity. Release the compression on the aspirator bulb to aspirate the middle ear fluid. Release the pressure on the actuator to retract the needle. Withdraw the CDT Speculum from the external auditory canal.



FIGURE 167-3. Proper grasping of the CDT Speculum attached to an otoscope. Note that the dominant thumb is placed on the actuator. (Photo courtesy of Walls Precision Instruments LLC.)

Place the tip of the CDT Speculum over the culture swab or medium. Compress the aspirator bulb to expel the middle ear fluid sample. Discard the CDT Speculum.

ALTERNATIVE TECHNIQUE

An alternative method involves attaching intravenous extension tubing between the spinal needle and the syringe. The Emergency Physician can observe the tympanic membrane, insert the spinal needle, leaving a hand available for manipulation of the ear speculum or a suction catheter. An assistant is required to hold the syringe and aspirate the middle ear fluid. The remainder of the technique is as described previously.

ASSESSMENT

Tympanocentesis will decompress the middle ear pressure and provide the patient significant symptom relief. Transfer the fluid into appropriate laboratory medium and containers as quickly as possible. Label the containers and have them transported to the laboratory for a Gram's stain, culture and sensitivities, cell count, and differential of the cells present.

AFTERCARE

Since most of the distress associated with the procedure in small children is due to immobilization, immediately release the child from the papoose or restraining device. Most patients will have immediate improvement in their pain and, in many cases, their hearing. Some Otolaryngologists will rinse the external auditory canal after a tympanocentesis with a 3% peroxide solution then absorb the solution with a wick. This is optional and at the discretion of the treating Emergency Physician. Because there is a small opening in the tympanic membrane, further drainage including bleeding may occur and should be expected for 48 to 72 hours. Instruct the patient and/or their caregivers to keep the ear dry for 2 to 3 days. This is especially true during bathing or hair washing. A cotton earplug coated with a thin film of petrolatum jelly (e.g., Vaseline) works well. The tympanic membrane usually spontaneously heals within 48 to 72 hours, but can take up to 10 days. Follow-up for laboratory results and documentation of antimicrobial change or appropriateness is necessary in 48 to 72 hours.

COMPLICATIONS

Complications are uncommon. The most frequently cited complications include laceration of the ear canal, persistent perforation with or without otorrhea, development of a scar on the tympanic membrane, and an otitis externa. Pain and bleeding are usually minimal and self-limited. One of the most significant (but rare) complications is the disruption of the ossicles of the middle ear. **Disruption of the ossicles can be avoided by inserting the needles into the inferior half of the tympanic membrane and preventing patient movement during the procedure.** Injury to the chorda tympani, facial nerve, or internal carotid artery is theoretically possible, but virtually unheard of with this procedure.

SUMMARY

Acute otitis media is a common infection of childhood, but is also seen in adults. Most episodes respond quickly, with or without antimicrobial therapy. Tympanocentesis can be used to direct antimicrobial therapy in patients when a clinical response is delayed, host immunosuppression exists, or unusual organisms are suspected. Tympanocentesis can be used to provide immediate

pain relief from a severe middle earache. The procedure is quick and simple to perform in the Emergency Department.

168 Auricular Hematoma Evacuation

Eric F. Reichman

INTRODUCTION

Blunt trauma to the auricle can cause abrasions, ecchymosis, hematoma formation, and lacerations. Abrasions and ecchymosis of the auricle require no therapy other than oral analgesics and observation for infection.[1] Some authors recommend the application of topical antibiotics to all abrasions as prophylaxis for infection.[2] Lacerations to the auricle are addressed in Chapter 96. This chapter addresses the management of an auricular hematoma.

Injuries to the auricle are common due to its exposed position and lack of protection from surrounding structures.[3] The most common cause for an auricular hematoma formation is blunt trauma while participating in the contact sports of wrestling or boxing.[1,2,4–6] Such trauma may occur in other situations, including assaults, falls, fights, and motor vehicle crashes. Auricular trauma and hematomas are common in children due to the high incidence of head injuries during playtime.[2,4] Blood dyscrasias may also cause an auricular hematoma.

An auricular hematoma presents as a firm and painful swelling that obscures the normal convolutions on the lateral aspect of the auricle. It can develop within minutes to hours of the blunt trauma. **An auricular hematoma must be evacuated to prevent the cosmetic disfigurement known as cauliflower ear. The sooner it is evacuated, the less chance of permanent disfigurement.**[4,5] After evacuation, the patient requires a pressure dressing to the auricle, oral antibiotics, and close follow-up to prevent complications.[2,5,7,8]

ANATOMY AND PATHOPHYSIOLOGY

The auricle is that portion of the external ear that projects from the side of the head. It functions to augment sound delivery to the tympanic membrane and assist in sound localization. It is fixed in position by both ligaments and muscles.[9] It has an underlying cartilaginous framework that is 0.5 to 1.0 mm thick and provides the auricle with its unique shape. The cartilage is a single, thin sheet of flexible yellow elastic cartilage with many convolutions on the lateral surface.[10] The only portion of the auricle without cartilage is the lobule in which fibrofatty tissue replaces the cartilage.[9] **The cartilage is avascular and derives its blood supply and nutrients from the adjacent perichondrium.**[11]

The skin covering the auricle is similar to that elsewhere on the body.[12] It contains sebaceous glands and a varying number of hair follicles. The skin on the lateral surface of the auricle is tightly adherent to the perichondrium and lacks a subcutaneous layer (**Figure 168-1**). The skin on the medial surface of the auricle is loosely attached and has a layer of subcuticular tissue between the skin and perichondrium.

Trauma may cause the perichondrium to be torn off the underlying cartilage due to the tight attachment of the skin to the perichondrium on the lateral surface of the auricle. This traumatic avulsion of the perichondrium causes hemorrhage into the space between it and the cartilage, allowing a hematoma to form (**Figure 168-2**). Bleeding into this potential subperichondral space causes dissection

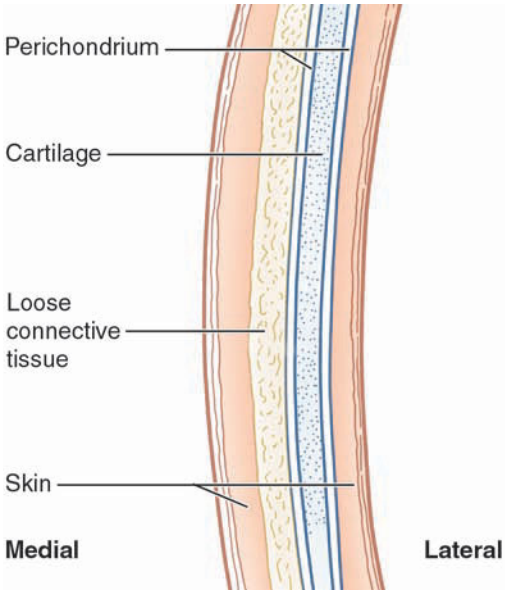


FIGURE 168-1. Cross section of the auricle. The skin on the medial surface has a layer of loose connective tissue that is lacking on the lateral surface.

of the perichondrium from the underlying cartilage. Auricular hematomas can be painful due to the rich sensory innervation to the area and the accumulation of blood in this relatively closed space.[11] **Failure to adequately evacuate a hematoma may lead to cartilage necrosis and a deformed ear.** The necrosis is due to a combination of separating the cartilage from its blood supply and direct pressure effects from the hematoma.

The cauliflower ear is a purely cosmetic deformity that results from an auricular hematoma not being evacuated and allowing the auricle to spontaneously heal. The hematoma is invaded by fibroblasts and slowly replaced by fibrous tissue. This organization of the hematoma causes irregular thickening of the auricle. The perichondrium, elevated from the cartilage by the hematoma, senses the

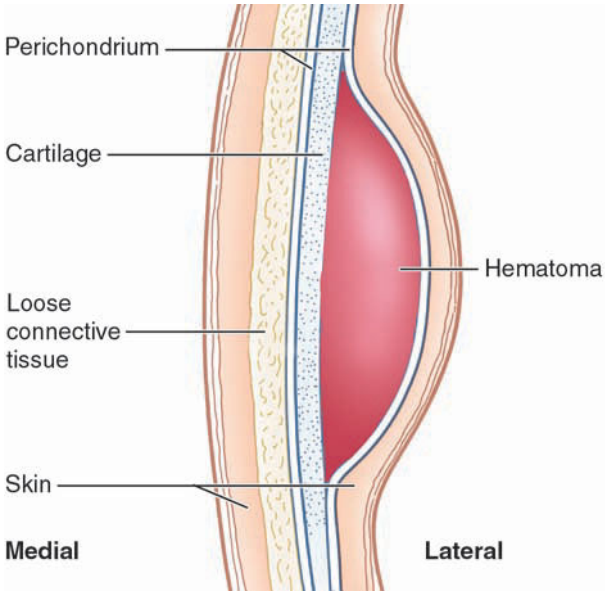


FIGURE 168-2. An auricular hematoma. The blood collects between the perichondrium and the cartilage.

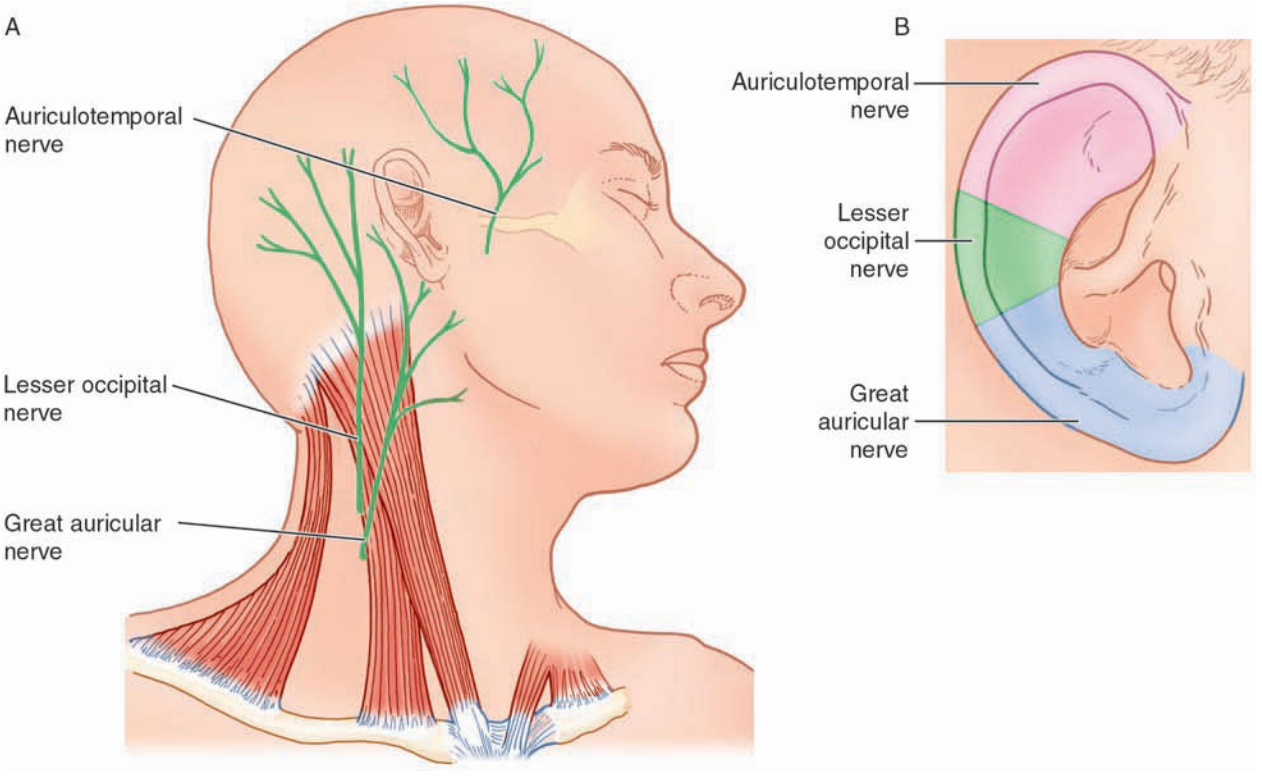


FIGURE 168-3. The sensory innervation of the auricle. **A.** The distribution of cutaneous nerves surrounding the auricle. **B.** An enlarged view of the auricle demonstrating the cutaneous innervation.

lack of adjacent cartilage and activates chondroblasts. New cartilage is deposited on the surface of the hematoma causing further thickening and deformity of the auricle.

INNERVATION OF THE AURICLE

A brief review of the innervation of the auricle will later aid in understanding the technique of regional anesthesia. Three nerves contribute to the sensory enervation of the auricle (**Figure 168-3**).[8,11–15] The auriculotemporal branch of the mandibular division of the trigeminal nerve supplies sensation to the upper, lateral surface of the auricle. This nerve emerges subcutaneously just anterior to the auricle at the level of the external auditory canal. Two branches of the cervical plexus become subcutaneous at the posterior border of the midportion of the sternocleidomastoid muscle and ascend to the auricle. The lesser occipital nerve provides sensory innervation to the upper medial surface of the auricle. The great auricular nerve provides sensory innervation to most of the medial surface and the lower half of the lateral auricular surface.

INDICATIONS

An auricular hematoma must be evacuated. The indication for evacuation is to prevent the cosmetic deformity known as the cauliflower ear.[7] It is preferable to evacuate the hematoma within 12 to 24 hours after its occurrence. Although there is no urgency to immediately evacuate the hematoma, the longer it remains the higher the chance of clot organization and new cartilage deposition.[7,16]

CONTRAINDICATIONS

There are no absolute contraindications to the evacuation of an auricular hematoma. If the skin overlying the hematoma is cellulitic, or if purulent material is drained from the hematoma, the patient will require hospital admission and intravenous antibiotics.[1,8] An Otolaryngologist or Plastic Surgeon should be immediately consulted on these patients. The auricular hematoma should be evacuated by a consultant if it has been present for more than 5 to 7 days. These hematomas have already begun organization and new cartilage has developed requiring curettage associated with the evacuation.[7,16,21,23] An uncooperative patient (e.g., young child or due to altered mental status) may require evacuation under procedural sedation or in the operating room.

EQUIPMENT

Auricular Anesthesia

- Povidone iodine or chlorhexidine solution
- 1 mL syringe
- 10 mL syringe
- 25 to 30 gauge needles, 2 inches long
- 10 to 20 mL of local anesthetic solution without epinephrine

Auricular Hematoma Aspiration

- Povidone iodine or chlorhexidine solution
- Tuberculin or insulin syringe
- 0.25 mL of local anesthetic solution without epinephrine
- 10 mL syringe
- 18 gauge needle
- Topical antibiotic ointment

Auricular Hematoma Incision and Drainage

- Auricular anesthesia as above
- #15 surgical scalpel blade on a handle
- Curved hemostat
- Sterile drain (optional)

- 10 mL syringe
- 18 gauge angiocatheter without the needle
- Sterile saline
- Topical antibiotic ointment
- Forceps

Mastoid Pressure Dressing

- Petrolatum gauze
- Cotton balls soaked in sterile saline
- Dry cotton balls
- 4 × 4 gauze squares
- 4 inch elastic bandage
- Scissors

Surgical Pressure Dressing

- Cotton bolsters or dental rolls
- Needle driver
- 4-0 monofilament nylon suture

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. The postprocedural care should also be discussed. Obtain a signed consent for the procedure. Some Emergency Physicians omit the signed consent and place the following statement in the procedure note: "The risks, benefits, and complications were described and discussed with the patient. They understood this and gave verbal consent for the procedure." This decision must be based on physician preference, hospital guidelines, and state guidelines for documentation requirements.

Remove any dirt and debris from the auricle and surrounding skin. Apply povidone iodine or chlorhexidine solution to the same areas. Follow aseptic technique for the remainder of the procedure.[4] In patients who are anxious and without other associated injuries, the administration of intramuscular, intravenous, or oral benzodiazepines may be beneficial.[15]

AURICULAR ANESTHESIA

The local anesthetic solution used for auricular anesthesia should contain no epinephrine.[2,13,14,17] Epinephrine is not used for fear of intense vasoconstriction of end arterioles resulting in decreased perfusion with possible ischemia and necrosis of the auricle. Some authors recommend the use of 1/100,000 epinephrine mixed with the local anesthetic solution.[1,15,16] The epinephrine may decrease bleeding by its vasoconstrictive action. It may also prevent reaccumulation of the hematoma after it has been evacuated. Authors who advocate using epinephrine state that the auricle has a rich blood supply and that, based on anecdotal evidence, there is no danger of ischemia or necrosis from the use of epinephrine in healthy patients without evidence of traumatized vascularity. **Although many physicians will use epinephrine, it has not been proven safe to use or proven to prevent reaccumulation of the hematoma.** It may be wiser to be conservative and not use epinephrine than to use it and have to deal with the complications to the patient and potential litigation.

The choice of which local anesthetic to use is physician-dependent. Lidocaine (1%) is the most commonly used local anesthetic. Long-acting local anesthetic solutions, such as bupivacaine (Marcaine) or etidocaine (Duranest), may be used to provide analgesia for several hours after the procedure is completed.[14]

The methods of anesthesia for evacuation of an auricular hematoma range from none to a superficial skin wheal to a regional block. Some authors advocate using no anesthesia if needle aspiration of a small and fresh hematoma is performed.[2] This is not generally recommended as the pain from an 18 gauge needle aspiration is more uncomfortable than local anesthesia infiltration.

If using the aspiration technique to evacuate the hematoma, local anesthetic solution can be infiltrated directly over the hematoma. Apply a 25 to 30 gauge needle on a 1 mL syringe. Place a skin wheal, using 0.25 mL of local anesthetic solution without epinephrine, over the hematoma in the area of maximum fluctuance. **When placing the skin wheal, be careful not to inject the local anesthetic solution into the hematoma.** This will cause expansion of the hematoma and increase the separation of the perichondrium from the underlying cartilage.[17] It may also cause new bleeding, which can increase the possibility of hematoma reaccumulation.

A regional auricular block is the preferred method to obtain anesthesia.[13] It prevents distortion of the auricle from direct injection and further separation of the perichondrium from the underlying auricular cartilage.[17] Subcutaneous infiltration of the surrounding skin is less painful than injection directly into the sensitive auricular skin.[15] The landmarks for regional anesthesia are simple to locate, consistent, and predictable. The greatest reason for failure of an auricular block is incorrect needle placement.[14] A regional auricular block can be done prior to using the aspiration technique or the incision and drainage technique to evacuate the hematoma. If the aspiration technique fails (i.e., hematoma reaccumulates), then there is no need to reprep and perform an auricular block prior to performing the incision and drainage.

There are three methods to perform a regional auricular block (**Figures 168-4 & 168-5**). Each method blocks the lesser occipital, great auricular, and auriculotemporal nerves. Some Emergency Physicians prefer to subcutaneously inject local anesthetic solution circumferentially around the attachment of the auricle to the head (**Figure 168-4**).[2,11,13,17] An alternative method is based on blocking the sensory supply to the ear in a more anatomic distribution (**Figure 168-5**).[8,14] This latter method uses half the anesthetic



FIGURE 168-4. Regional anesthesia of the auricle. The technique of circumferential application of local anesthetic solution. Shaded areas represent subcutaneous infiltration of local anesthetic solution.

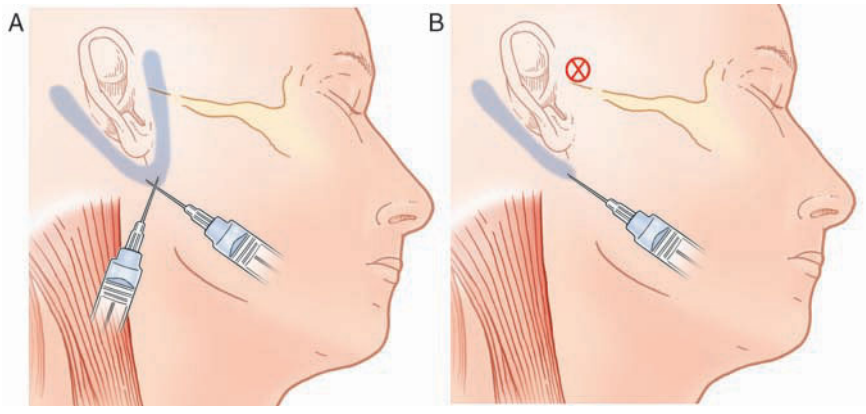


FIGURE 168-5. Regional anesthesia of the auricle. **A.** A more anatomical auricular block. **B.** An alternative regional block that anesthetizes the auriculotemporal nerve at its origin. Local anesthetic solution is injected at the ⊗ symbol. Shaded areas represent subcutaneous infiltration of local anesthetic solution.

and half the number of subcutaneous injections than the former method. For these reasons, this author prefers the second method, which is described in the following paragraph.

To perform a regional auricular block, first cleanse the auricle and surrounding skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution. Place a skin wheal of local anesthetic solution 0.5 cm below the pinna of the auricle (**Figure 168-5A**). Insert a 2 inch, 25 or 27 gauge needle through the skin wheal, aimed just posterior to the attachment of the auricle to the head. Infiltrate subcutaneously, in a superior direction, always remaining 0.5 to 1.0 cm posterior to the auricular attachment to the head. Stop infiltrating at the level of the superior attachment of the auricle to the head. This infiltration requires 4 to 7 mL of local anesthetic solution. Withdraw the needle almost completely. Redirect the needle through the skin wheal and aimed just anterior to the attachment of the auricle to the head. Infiltrate subcutaneously, in a superior direction, always remaining 0.5 to 1.0 cm anterior to the auricular attachment to the head. Stop infiltrating at the level of the superior attachment of the auricle to the head. This infiltration also requires 4 to 7 mL of local anesthetic solution. Care must be taken not to inject too deeply anterior to the auricle as it can cause temporary paralysis of the facial nerve. An alternative to the anterior infiltration is the injection of 3 to 4 mL of local anesthetic solution just superior and anterior to the tragus (**Figure 168-5B**).[1,18] This injection blocks the auriculotemporal nerve at its origin. **Allow 10 to 15 minutes for the full anesthetic effect prior to beginning the procedure.**[17]

TECHNIQUES

The methods for treating and managing an auricular hematoma require the evacuation of the hematoma and replacing the perichondrium onto the underlying cartilage. The techniques include aspiration, incision and drainage, and closed suction drainage. The first two techniques will be described in detail. The closed suction technique requires inpatient admission and is not a procedure to be performed in the Emergency Department. It will therefore not be described here.

ASPIRATION

Some consider the aspiration technique to be the primary method to evacuate an auricular hematoma.[2,3,5,6] They reserve the incision and drainage technique for incomplete aspiration or recurrence of the hematoma. Unfortunately, the hematoma frequently recurs after using the aspiration technique and the patient requires a second procedure to evacuate the hematoma.[1,3,6,19] Because of the high rate of recurrence, this author and others prefer to use the incision and drainage technique as the primary procedure.[16]

Clean and prep the skin. Anesthesia is achieved by performing a regional auricular block or by placing a skin wheal of local anesthetic over the hematoma. Attach an 18 gauge needle onto a 10 mL syringe. Insert the needle into the area of maximum fluctuance (**Figure 168-6**). Apply negative pressure to the syringe, by withdrawing the plunger, to evacuate the hematoma. Express or "milk" the hematoma between the thumb and index finger of the nondominant hand while applying negative pressure with the syringe to ensure complete evacuation of the hematoma (**Figure 168-6**).

Remove the needle and apply manual pressure to the area of the former hematoma for 3 to 5 minutes. If the hematoma recurs or if complete aspiration is not possible, perform the incision and drainage technique. If the hematoma is completely evacuated and does not recur, apply topical antibiotic ointment and a pressure dressing.

There are several disadvantages to this technique. First, the hematoma frequently recurs.[1,3,6,19] This means that the patient often needs a second drainage procedure. Even if the hematoma is adequately evacuated, the elimination of the dead space is problematic.[19] The dead space may fill with blood or serous fluid requiring a second procedure. A surgically applied pressure dressing may alleviate the dead space and make the aspiration technique more successful. Finally, the aspiration technique may not remove all of the hematoma.[1] Again, the patient will need a second procedure.

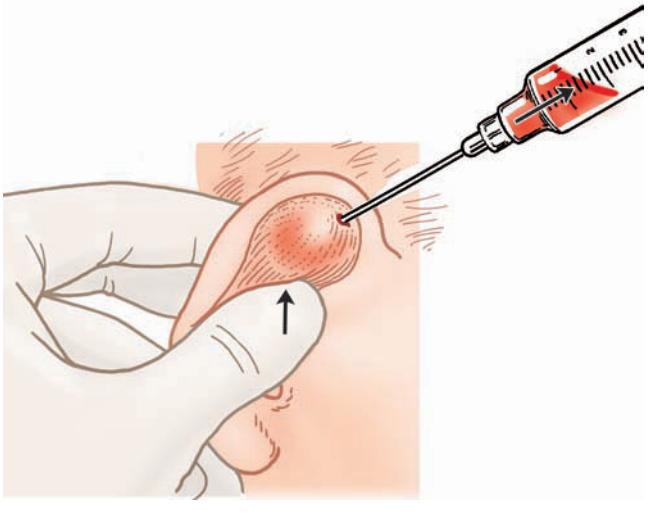


FIGURE 168-6. The aspiration of an auricular hematoma. The hematoma is expressed with the thumb and index finger as negative pressure is applied to the syringe.

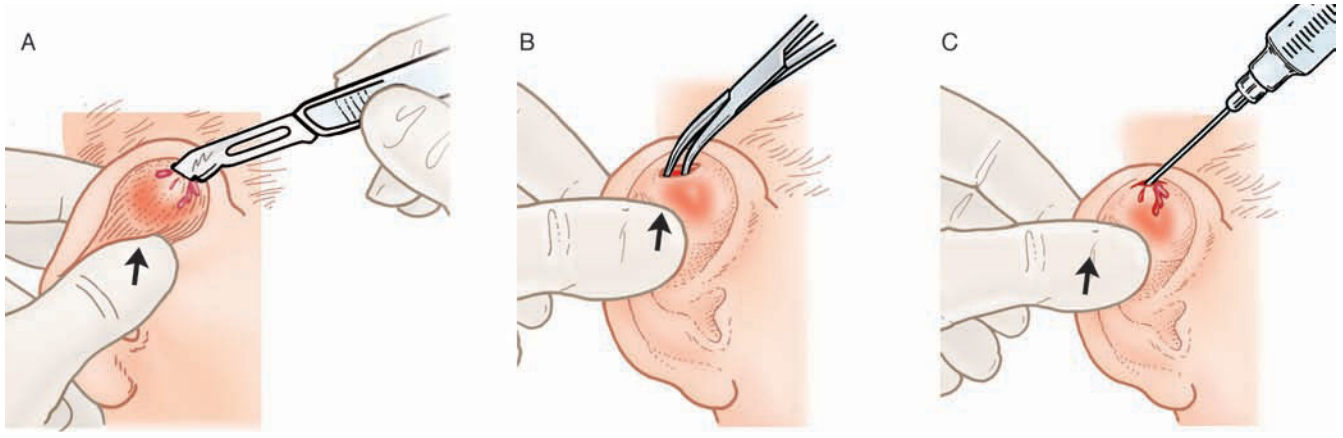


FIGURE 168-7. Incision and drainage of an auricular hematoma. **A.** An incision is made along the helical rim. **B.** The hematoma is evacuated with the aid of a hemostat. The thumb and index finger express the hematoma from the subperichondral space. **C.** The subperichondral pocket is flushed with normal saline to remove any residual blood and clot.

For these above stated reasons, the aspiration technique is not the preferred method to drain an auricular hematoma.

INCISION AND DRAINAGE

This is the preferred technique to evacuate an auricular hematoma.[16] It requires a regional auricular block for anesthesia. This technique takes more time to perform than the aspiration technique.

As noted previously, the skin should be cleaned and prepped in the usual manner. Perform a regional auricular block to provide adequate analgesia. Allow the block 10 to 15 minutes to achieve maximal effect.[17] Incise the auricular skin with a #15 surgical scalpel blade at the edge of the hematoma (**Figure 168-7A**). **When making the incision, it should follow the curvature of the pinna and be no longer than 1 cm.** Gently peel this skin and attached perichondrium off the hematoma using forceps. Express or "milk" the hematoma with the thumb and index finger of the nondominant hand. Insert a curved hemostat and gently loosen any remaining blood clot (**Figure 168-7B**). Fill a 10 mL syringe with sterile saline and attach a plastic 18 gauge angiocatheter. Gently flush out the area of the hematoma (**Figure 168-7C**).

Reapproximate the skin and perichondrium on the cartilage. Compress the tissue to eliminate any fluid and dead space. Some authors apply a small rubber drain through the incision to prevent accumulation of blood or serous fluid.[4,8] The use of a drain is optional. A drain can be made by cutting a small strip from a sterile Penrose drain.

Apply manual pressure to the area of the former hematoma for 3 to 5 minutes. If the hematoma or serous fluid does not reaccumulate, apply topical antibiotic ointment and a pressure dressing as described below. If the hematoma or serous fluid does reaccumulate, consider inserting a rubber drain or applying a surgical pressure dressing.

PRESSURE DRESSINGS

A pressure dressing must be applied to the auricle after the successful drainage of an auricular hematoma. It prevents reaccumulation of the hematoma or serous fluid, and supports the auricle while the perichondrium reattaches to the cartilage.[3,6,10] The pressure dressing must be applied for at least 48 hours.[4] The pressure dressing can be the traditional mastoid dressing or a surgically applied dressing.[16,17,19,20] These pressure dressings apply even pressure over the entire auricle without compromising the blood flow while simultaneously eliminating the dead space within the wound.[17]

MASTOID PRESSURE DRESSING

The most commonly applied dressing is the mastoid pressure dressing (**Figure 168-8**). Although simple to place, it has many

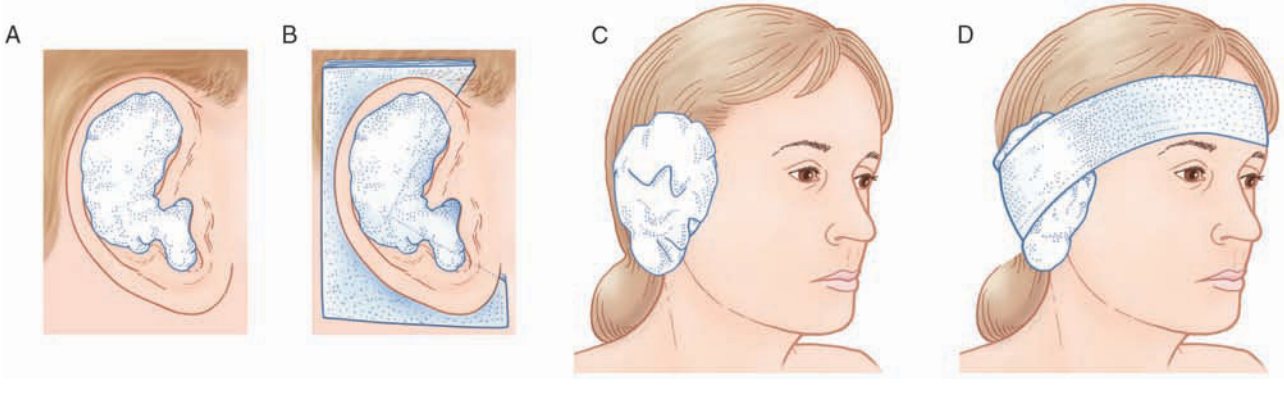


FIGURE 168-8. The traditional mastoid dressing. The convolutions are covered with a layer of petrolatum gauze. **A.** Saline-soaked cotton balls are packed over the convolutions, level with the helical rim. **B.** Trimmed gauze squares are placed between the auricle and the head. **C.** Fluffed gauze is placed over the auricle. **D.** The circumferential application of an elastic gauze bandage to the head. The bandage should cover the injured auricle and not the contralateral auricle.

disadvantages when compared to the surgically applied pressure dressing. It is bulky and hard to keep in place. It is very conspicuous. Patients must keep it dry and remain relatively inactive to prevent it from coming off.

Place a piece of sterile dry cotton in the external auditory canal and level with the base of the auricular cartilage. Mold a sterile material that conforms easily onto all the convolutions of the auricle until it is level with the lateral helical rim (**Figure 168-8A**). The choices of material include cotton balls soaked in mineral oil, cotton balls soaked in saline, or petrolatum gauze. The material chosen is left to Emergency Physician preference and what is available in the Emergency Department. This author prefers to use petrolatum gauze. The petrolatum gauze allows the dressing to be removed with minimal trauma to the ear. Pack the auricle with saline-soaked cotton balls. **All the convolutions of the auricle must be thoroughly packed. The packing of the auricular convolutions assures even application of pressure to all portions of the auricle.**

Cut out and discard a semicircle or a V-shaped section from a pile of gauze squares. Place the remaining C-shaped gauze pads behind the auricle (**Figure 168-8B**). The gauze pads should be built up until they completely fill the area between the auricle and the head. This padding is used to support the auricle as well as prevent undue contortion or uneven pressure from the compression dressing.[2]

Unfold and fluff several gauze squares or open a roll of gauze. Place the fluffed gauze over the lateral surface of the auricle (**Figure 168-8C**). Wrap an elastic bandage snugly over the auricle and around the head to hold the dressing in place (**Figure 168-8D**). The circumferential head dressing should not encompass the opposite auricle. The elastic bandage is used to compress the auricle between the two layers of gauze padding.

SURGICAL PRESSURE DRESSING

A surgically applied pressure dressing may be used instead of the traditional mastoid dressing (**Figure 168-9**).[1,7,16,19] This dressing applies even pressure over the former hematoma site to prevent reaccumulation. It takes more skill to apply than the traditional mastoid dressing. Aseptic technique is mandatory to prevent infection and perichondritis. This dressing requires a skin prep of a much wider area to include the entire medial and lateral surface of the ear, and the surrounding skin.

The surgically applied pressure dressing has many advantages over the traditional mastoid dressing. It produces pressure exactly where it is needed. The wound is not obscured with a bulky dressing. This allows the patient to easily observe and monitor the site for reaccumulation of fluid and possible infection. This dressing is comfortable and well tolerated by the patient. It is unlike the bulky and conspicuous mastoid dressing that is difficult to keep in place, especially when sleeping. The dressing can remain in place while monitoring the auricle, unlike the mastoid dressing that must be removed and replaced daily. The patient can remain active, including taking a shower, without fear of the dressing coming undone. The surgical pressure dressing is adaptable to any location or a variety of hematomas.

Trim a cotton dental bolster or cotton roll to fit the convolution of the auricle over the site of the drained hematoma. Place the cotton roll over the site of the former hematoma (**Figure 168-9A**). Place a second dental roll on the medial surface of the auricle opposite the first dental roll (**Figures 168-9A & B**). Place the needle of a 4-0 monofilament nylon suture immediately adjacent to the first cotton bolster. Pass the suture through the entire thickness of the auricle and out the medial surface. Pass the needle over the second cotton bolster and back through the auricle. Snugly tie the suture over the anterior cotton bolster (**Figure 168-9B**). The suture should be snug enough to allow the cotton bolsters to firmly hold the perichondrium to the cartilage without causing vascular compromise. Apply additional sutures using the same technique until the cotton bolsters are firmly attached and any dead space is eliminated. Depending upon the location of the hematoma, it may require a minimum of two to a maximum of four bolsters to reapproximate the skin and perichondrium and to eliminate all of the dead space.

Monofilament nylon is the preferred suture material for this procedure.[7] It causes less tissue reaction than silk, cotton, gut, or absorbable sutures. It has less of a tendency to cut the ear tissues when tied over the cotton bolsters. Monofilament nylon is less likely to wick bacteria into the auricle and cause an infection than multifilament nylon. The suture may be safely left in place for up to 3 weeks without any complications.

ALTERNATIVE TECHNIQUES

An alternative to packing the pinna with petrolatum gauze is to use either ENT silicone putty or dental impression material.[22,25]

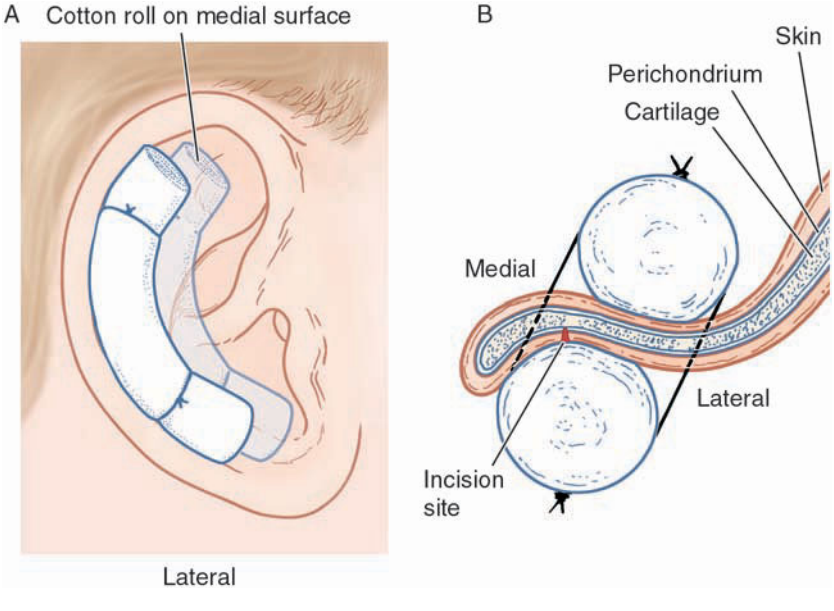


FIGURE 168-9. A surgically applied pressure bandage. **A.** A cotton roll is applied to the lateral surface of the auricle, over the site of the evacuated hematoma. A second cotton roll is applied on the medial surface of the auricle directly beneath the first cotton roll. The cotton rolls are secured with 4-0 monofilament nylon suture. **B.** Cross-sectional illustration of the surgical pressure dressing. The position of the cotton rolls and suture is seen in relation to the incision site. Note that the perichondrium is apposed to the cartilage and the dead space is eliminated.

Evacuate the hematoma as described previously. Mix the chosen material to form a uniform composite and activate it. Mold it to fill the pinna, wrapping over the pinna and filling the space between the medial surface of the ear and the head. The putty or impression material will solidify in a few minutes after mixing it and the application. Apply an elastic bandage as described previously. Unfortunately, ENT silicone putty and dental impression material is not often available in the Emergency Department.

The placement of cotton bolsters is often cumbersome and difficult if the Emergency Physician has little experience with this technique. An alternative is to use thermoplastic splinting material.[24] Trim a sheet of thermoplastic splinting material to form a lateral and medial splint of an appropriate size to conform to the lateral and medial surfaces of the ear, respectively. Place the splints in warm water to soften them. Apply the splints to the surfaces of the ear, mold them to the contours of the ear, and apply pressure until they cool and become rigid again. Suture the rigid splints through the ear as described previously.

A second surgical alternative to the use of bolsters is to apply running mattress sutures through the ear to reapproximate the skin and perichondrium.[26–28] Begin posteriorly and weave 4-0 Vicryl or chromic gut suture through-and-through the ear in a running pattern to reapproximate the soft tissues and repair the ear contours. The main advantages of this technique include eliminating bolsters, eliminating the bulky dressing, and the comparable success rates while minimizing the reaccumulation of blood or fluid.

AFTERCARE

The postprocedural care of the auricle is as important as the initial hematoma evacuation. Proper follow-up and care can minimize or prevent any cosmetic deformities. All patients should be seen within 12 to 24 hours to reevaluate the auricle for infection or reaccumulation of the hematoma or serous fluid. Analgesia can be provided by the use of nonsteroidal anti-inflammatory agents. Determine the patient's tetanus immune status and provide prophylaxis as required.

Provide all patients with oral and written instructions regarding the signs and symptoms of cellulitis and perichondritis. This includes the immediate return to the Emergency Department for increasing pain, progressive swelling, redness, tenderness, and warmth. Prophylaxis with oral antibiotics is indicated with any laceration, incision, or puncture of the auricular skin.[4] Prescribe antibiotics for 5 days.[4,5,16] Recommendations include a range of first-generation cephalosporins, antistaphylococcal antibiotics, or antipseudomonal antibiotics.[4,5,16]

Apply the pressure dressing for a minimum of 48 hours.[4] A pressure dressing is recommended for a total of 4 to 5 days. A mastoid dressing must be removed daily to evaluate the auricle, then reapplied. A surgically applied dressing will avoid daily visits to the physician.

Drain any residual clot or serous fluid at the follow-up visit. This can easily be accomplished by needle aspiration and replacement of the pressure dressing.[6,20] If necessary, a sterile drain can be inserted.[8] All drains must be removed within 48 hours of placement to decrease the risk of infection.

COMPLICATIONS

The complications are primarily related to incomplete evacuation of the hematoma or reaccumulation of the hematoma. Incomplete evacuation of the hematoma, if by the aspiration technique, requires an incision and drainage of the hematoma. If necessary, gentle curettage of the cartilage with a hemostat should dislodge the clot. Reaccumulation of the hematoma, or serous fluid, must be evacuated. Consider placing a sterile drain into the incision.[8] Another option is to place a surgical pressure dressing.[7] A hematoma located within the cartilage will result in a treatment failure and require operative management.[29]

Infection may complicate any surgical procedure. This may be due to reaccumulation or incomplete evacuation of the hematoma, which then becomes infected. Strict adherence to aseptic technique will usually prevent infection. Since patients are prophylactically placed on antibiotics, any cellulitis of the auricle at the follow-up visits requires hospital admission and intravenous antibiotics.

Perichondritis is the most feared complication. It is an aggressive and rapidly progressive infection. The auricle will become red, hot, and exquisitely tender if perichondritis develops. This is followed by diffuse swelling and abscess formation. This infection can lead to significant cartilage necrosis and a deformed ear if not promptly treated. *Pseudomonas aeruginosa* is isolated in 95% of patients with perichondritis.[1] Over 50% of cases are polymicrobial with *Staphylococcus aureus* associated with *P. aeruginosa*. These patients require Otolaryngology or Plastic Surgery consults for surgical debridement, broad spectrum intravenous antibiotics, and hospital admission.[1,8]

SUMMARY

An auricular hematoma forms in minutes to hours after blunt trauma to the ear. It presents as a firm and painful swelling that obscures the normal convolutions on the lateral aspect of the auricle. It requires drainage to restore the normal convolutions of the auricle and prevent future deformity. Complete evacuation can be accomplished by needle aspiration or by incision and drainage. After the procedure, prescribe oral antibiotics prophylactically to prevent infection. Follow-up is required within 12 to 24 hours of the procedure to evaluate the patient for reaccumulation of the hematoma and infection. Patients should be educated about the signs and symptoms of perichondritis. Frequent wound evaluation is required until the auricle is healed.

169 Nasal Foreign Body Removal

Raemma Paredes Luck

INTRODUCTION

Nasal foreign bodies are commonly seen in children, particularly those between 1 and 4 years of age. Adult patients with mental retardation or psychiatric illness can also present to the Emergency Department with a nasal foreign body. Young children are naturally curious and spend a great deal of time investigating themselves and the world around them. This involves handling, tasting, and smelling whatever they get their hands on. When these investigations go too far, the Emergency Physician is faced with a foreign body in a youngster's nose. The most common foreign bodies found are beads, food (e.g., corn, nuts, peas, and popcorn), paper, rocks, and toy parts.[1,2] Nasal foreign bodies also result from attempts to clean the nose and to control bleeding. In these cases, most of the foreign bodies retrieved consist of cotton swabs, paper, or sponge material.

Children may present with a known nasal foreign body. However, other presentations are common and may be subtle. This includes body odor, halitosis, persistent unilateral nasal discharge, or recurrent epistaxis. Foreign bodies can be found during a routine examination or as an incidental finding on radiographs in the asymptomatic child.[1,3,4]

The task of the Emergency Physician in these cases is fourfold. First is to suspect the presence of a nasal foreign body. Second is to perform a thorough physical examination, including a search for the foreign body. Next is to visualize the foreign body. Finally, remove the foreign body efficiently and with minimal trauma.

ANATOMY AND PATHOPHYSIOLOGY

The nasal cavity consists of two passages on either side of the nasal septum. The superior, middle, and inferior bony turbinates project medially into each passage and are covered by a mucous membrane overlying a venous plexus. Although foreign bodies can be located anywhere in the nose, most foreign bodies are found on the floor of the inferior turbinate or anterior to the middle turbinate.[5] The cartilaginous septum is covered by a thin mucosa and receives its blood supply from the mucoperichondrium. Sensory nerves of the nasal cavity are branches of the greater palatine nerve and sphenopalatine ganglion.[6] These nerves are easily anesthetized with topical anesthetics. The nasal cavity is separated from the orbit by the thin lamina papyracea and from the anterior cranial fossa by the cribriform plate of the ethmoid bone.

A foreign body in the nasal cavity sets off an inflammatory response and the venous plexus becomes congested. This swelling may eventually obscure the foreign body from view. The longer the foreign body remains in the nasal cavity, the more likely the patient is to develop pressure necrosis, granulation tissue, infection, and a purulent discharge. The foreign body can erode into the surrounding areas over time if it is not removed. A unilateral malodorous discharge and/or epistaxis from a child's nose is the hallmark of a foreign body.

The presence of a disk or button battery in the nasal cavity requires urgent removal. These batteries contain a strong alkali, usually potassium hydroxide or sodium hydroxide. The moisture in the nasal cavity may cause corrosion of the battery, leakage of the battery contents, and a low-voltage direct current between the anode and cathode. This may cause liquefaction necrosis, tissue electrolysis, and tissue destruction (mucosa, cartilage, and bone) within hours.[6] These patients need to be seen and followed by an Otolaryngologist after the battery is removed. An electrical thermal burn may cause damage to the nasal tissues that is more extensive than is visible initially in the Emergency Department.[7,8] Patients may develop a delayed septal perforation and alar collapse from extensive tissue damage.[9]

Small magnets can produce pressure necrosis in the tissues, particularly when they span either side of the cartilaginous septum or a turbinate. These magnets are commonly used as beads, clasps for necklaces and bracelets, and in faux piercings.[10,11]

INDICATIONS

All nasal foreign bodies must be removed to prevent complications. The direct observation of a foreign body in one or both nostrils is an indication for its removal. The presence of signs or symptoms such as unilateral persistent nasal discharge, recurrent unilateral epistaxis, halitosis, or an unusual body odor should prompt a search for a nasal foreign body. More than 90% of nasal foreign bodies can be removed by the Emergency Physician with readily available equipment.[1,3]

CONTRAINDICATIONS

There are a few contraindications to the removal of a nasal foreign body in the Emergency Department. One contraindication is if the airway is in danger. **Do not attempt to retrieve a nasal foreign body if the patient is in distress or unstable.** This might be due to a posteriorly placed foreign body or an uncooperative patient. **Management of the airway in the Emergency Department or in the Operating Room must take priority to foreign body removal.**

An Otolaryngologist should be consulted in patients with nasal foreign bodies that are impacted, cause excessive bleeding, or have resulted in nasal perforation or penetration. Foreign bodies located posterior and superior to the middle turbinate pose a risk of being pushed back during retrieval and may perforate the cribriform plate. If a larger foreign body has entered the nose traumatically, it should be removed by an Otolaryngologist as it may have penetrated the cranial cavity, the orbit, or a sinus cavity.[12,13] Other indications to consult an Otolaryngologist include failure of the Emergency Physician to remove the foreign body after repeated attempts, failure to properly sedate the patient, or the inability to sedate the patient. All of these contraindications may require foreign body removal in the Operating Room under more controlled circumstances and with equipment not available in the Emergency Department.

EQUIPMENT

Nasal Anesthesia and Vasoconstriction

- 1% or 2% lidocaine solution
- 4% lidocaine solution with 0.25% phenylephrine
- 4% cocaine
- 0.25% phenylephrine (Neosynephrine)
- 5 mL syringe or cotton pledgets
- Atomizer device if available

Manual Removal of Foreign Body (Figure 169-1)

- Head light or head mirror, surgical lamp, or overhead light
- Nasal speculum
- Alligator forceps



FIGURE 169-1. Instruments used for the manual extraction of a nasal foreign body. Top row (from left to right): disposable medicine cup, pledgets, nasal decongestant spray. Bottom row (from left to right): zero-degree telescope, bayonet forceps, nasal speculum, 90° blunt-tipped ear pick or mastoid probe, small alligator (ear) forceps, and large alligator or Blakesley forceps.

- Hartman forceps
- Bayonet forceps
- Frazier suction catheter
- Ear curette
- Blunt mastoid hook
- Wire loop

Catheter Removal of a Foreign Body

- Fogarty vascular catheter, size #4 or #5
- Foley catheter, 5 to 6 French
- 5 mL syringe
- Katz Oto-Rhino Extractor (InHealth Technologies, Carpinteria, CA)

Positive Pressure

- Cooperative parent
- Bag-valve device
- Face mask, various sizes
- Male-male tube adapter

Cyanoacrylate Glue

- Cyanoacrylate tissue/wound glue or "superglue"
- Paper clip or cotton-tipped applicator
- Superglue removal equipment (Chapter 165)

Nasal Wash

- Bulb syringe
- Normal saline

Pediatric Immobilization

- Sheets
- Commercial immobilization device (e.g., Papoose board)

PATIENT PREPARATION

Discuss the risks, benefits, complications, and different techniques available with the patient and/or their representative. Include the possibility of using procedural sedation initially or if initial attempts at removal are unsuccessful. Obtain consent for the removal procedure and the procedural sedation. The type, shape, size, and location of the foreign body are important factors to consider in choosing the most appropriate technique. The patient's age, ability to cooperate during the examination and removal, and the experience and skill of the Emergency Physician can influence the choice of techniques.

The Emergency Physician should observe universal precautions, especially eye protection, while working in close proximity to the mucous secretions in the airway. It is recommended to wear a gown, gloves, and a face mask with an eye shield or goggles. Both nasal cavities should be carefully inspected for foreign bodies before and after the mucosa is decongested. A child will sometimes insert foreign bodies up both nostrils. A good light source is indispensable for examining the nasal cavity and removing the foreign body.

Preparation is important to ensure that the first attempt at retrieval is successful. A variety of equipment should be readily available at the bedside in the event that additional attempts and techniques are required. A Frasier suction catheter should be available to clear the nasal passages of blood and/or mucous. **A good light source, particularly a hands-free device (i.e., overhead light source or a head lamp) is important in directly visualizing the foreign body and facilitating its removal.**

Anesthesia of the nasal mucosa is obtained by the topical application of lidocaine (maximum 4 mg/kg) or cocaine (maximum 3 mg/kg). Cocaine has the added benefit of vasoconstriction and decongestion of the nasal mucosa. If lidocaine is used, a vasoconstrictive agent such as epinephrine or phenylephrine should be added. A syringe can be used as a dropper to apply the medication intranasally. This is best done by administering several drops at a time and then reassessing visibility before adding more. If the entire dose is added at one time, the child is more apt to blow the medication out their nose before it can take effect. An atomizer device may also be used. Commonly available are devices that attach to a syringe (e.g., Mucosal Atomizer Device, Wolfe-Tory Medical Inc., Salt Lake City, UT) or a nasal decongestant container. Allow 5 to 10 minutes for the medication to take effect.

If the patient is cooperative, it would be appropriate to have them attempt to blow the foreign body out of their nostril. Have the patient sit up and lean forward. Have the patient blow forcefully through their nose while covering the uninvolved nostril with a finger. Even if this has failed at home, it may work with the nasal mucosa swelling alleviated by the decongestants.[9]

Most children will need to be restrained while the foreign body is being removed. Even the child who appears cooperative and is adequately anesthetized may move suddenly while instruments are in the nasal cavity. One method is for the child to sit on their parent's lap (**Figure 169-2**). The adult should cross their legs over the child's



FIGURE 169-2. Method to properly restrain a child.

legs, using one arm to restrain the child's arms and trunk and the other arm to hold the child's forehead (**Figure 169-2**). Alternatively, instruct an assistant to hold the patient's head while the parent controls the body and limbs. Another alternative is to wrap the child in a sheet or use a commercial restrain device (e.g., papoose board).[9]

Severely uncooperative patients may require sedation, procedural sedation, or general anesthesia prior to removal of the foreign body. Procedural sedation may be used to facilitate removal, especially in the uncooperative or fearful patient. In one study, approximately 21% of pediatric patients with nasal foreign bodies required procedural sedation.[4] The nasal foreign body was successfully removed in 95% of these cases. Ketamine was the most commonly used agent.

TECHNIQUES

DIRECT INSTRUMENTATION OR MANUAL REMOVAL

The most straightforward and common method is to remove the anteriorly located nasal foreign body under direct vision. Instrument removal should not be attempted if the foreign body is located posteriorly. The instruments most often used include alligator forceps, bayonet forceps, straight forceps, or mosquito forceps. Hooked probes, such as right angles or curved hooks, ear curettes, wire loops, or mastoid hooks can also be utilized. In the absence of these, a paper clip can be fashioned into a hook. A novel device is the Lighted Forceps for Foreign Body Removal (Bionix Medical Technologies, Toledo, OH). It is a single patient use and disposable device that contains a light source and acts like a forceps (**Figure 169-3**).



FIGURE 169-3. The Lighted Forceps for foreign body removal. (Photo courtesy of Bionix Medical Technologies, Toledo, OH.)

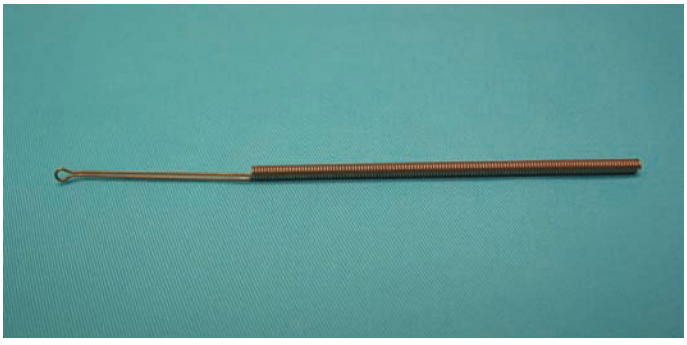


FIGURE 169-4. The EasiEar Metal Curette (Splash Medical Devices LLC, Atlanta, GA).

The EasiEar Disposable Comfort Curette (Splash Medical Devices LLC, Atlanta, GA) is an improvement to the standard disposable plastic curette (**Figure 169-4**). It is a stainless steel, single patient use, and disposable curette. The rounded wire head is smooth. It lacks the jagged and sharp plastic edges that are often found on molded plastic curettes. The EasiEar has no abrasive edges, seams, or surfaces to potentially abrade the nasal mucosa. This design may prevent abrasions, lacerations, and procedure-related bleeding. The spring wire shaft provides some flexibility and enhanced maneuverability when compared to molded plastic curettes, making the foreign body removal process easier. The angled head and flexible shaft allow it to be manipulated within the nasal cavity to remove a foreign body.

These instruments enable the Emergency Physician to grasp the foreign body directly or pull it out from behind. Anterior located foreign bodies are often easily removed with instrumentation. Forceps are better suited for soft and irregularly shaped foreign bodies (**Figure 169-5**).[5,14] Curettes and hooks are more effective



FIGURE 169-5. Using forceps to remove a thumb tack lodged in the nostril.

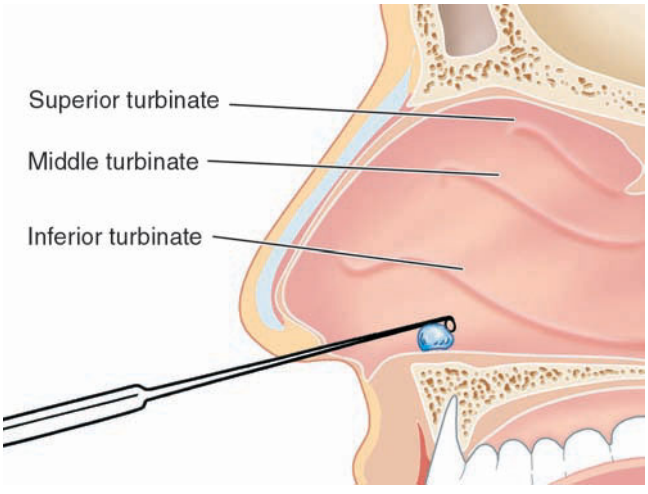


FIGURE 169-6. Removing a round, smooth foreign body from the nasal cavity. The curette, mastoid hook, or wire loop is passed through the nares and behind the foreign body. The hook is used to pull the foreign body out.

for hard and spherical foreign bodies.[5,14] Relative contraindications to instrumentation include posterior located foreign bodies, friable foreign bodies, and smooth or round foreign bodies. Potential complications include posterior displacement of the foreign body leading to nasal obstruction or even aspiration, mucosal abrasions and lacerations, and epistaxis.

Insert the nasal speculum to hold the nostril open. Adjust the headlight or head mirror to illuminate the nasal cavity. **It cannot be overemphasized how crucial adequate light and visibility are to successfully remove the foreign body.** Remove any mucus or blood with the Frazier suction catheter. Grasp an irregularly shaped foreign body with a type of forceps. Forceps may cause a round or smooth foreign body to slip farther posteriorly when the jaws close. In these cases, pass a curette, wire loop, or mastoid hook behind the foreign body and pull it out (**Figure 169-6**).[9] If the foreign body is a bead and the opening is facing outward, the jaws of a small alligator forceps can be passed through the opening (**Figure 169-7**). Open the jaws when they are beyond the lumen of the bead and pull the bead from the nasal cavity.

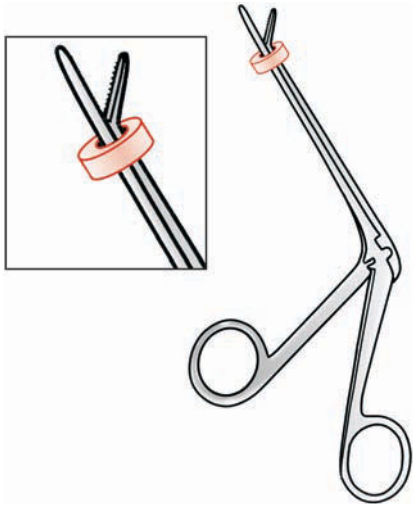


FIGURE 169-7. An alligator forceps is used to remove a bead or other foreign body with a hollow center.

BALLOON CATHETER EXTRACTION

Some Emergency Physicians prefer to use a catheter with a balloon to pull foreign bodies from the nasal cavity. This technique has a reported success rate of 90%, and is used most successfully for foreign bodies that are round, smooth, and cannot be grasped readily.[15] A balloon catheter does not work if the foreign body fully obstructs the nasal passage. Authors describe using a variety of catheters. This includes a #4 to 8 Fogarty vascular catheter, a #6 Fogarty biliary catheter, and a 5 to 6 French Foley balloon catheter.[3,9,16] Suction is relatively contraindicated if the foreign body is shaped so that the suction device cannot form a seal or if the foreign body is friable.

Inflate the balloon to ensure it has no leaks. Deflate the balloon. Lubricate the catheter. Insert the catheter until the balloon is beyond the foreign body. The catheter may be placed either above or below the foreign body.[9] Inflate the balloon with 2 to 3 mL of air. Gently pull the catheter. The balloon will push the foreign body out of the nostril. A balloon catheter can also be used to stabilize a foreign body from behind while it is removed with a forceps.

The disadvantage to this method is that it is more traumatic and epistaxis is more common.[2] If the catheter is not passed under direct vision or if it is too large to pass around the foreign body, the Emergency Physician risks pushing the foreign body posteriorly and impacting it, obstructing the nasal passage, or dislodging it into the airway.

KATZ EXTRACTOR

The Katz Extractor Oto-Rhino Foreign Body Remover (InHealth Technologies, Carpinteria, CA) is a device designed to extract foreign bodies from the nasal and auditory passages (**Figure 169-8**). It is a disposable single-use device consisting of a balloon-tipped catheter attached to a syringe. Always test the device before using it. Push the plunger to inflate the balloon and inspect it for any air leaks. Release the plunger to deflate the balloon.

Grasp the device with the dominant hand (**Figure 169-9**). Gently insert the catheter along the wall of the nasal activity until the balloon is just past the foreign body (**Figure 169-9A**). Inflate the balloon by depressing the plunger on the syringe (**Figure 169-9B**). Withdraw the catheter and foreign body from the nasal cavity while maintaining the balloon in the inflated state (**Figure 169-9C**). If the foreign body has a central hole (e.g., candy or bead), insert the catheter through the hole, rather than behind it, and inflate the balloon.

HOGNOSE OTOSCOPE TIP

The Hognose (IQDr. Incorporated, Manitou Springs, CO) is a disposable, latex free, and single-use device that attaches to a standard otoscope (**Figure 169-10**). It comes in three sizes (3, 4, and 5 mm), each with a color-coded tip. The size represents the cup size at the



FIGURE 169-8. The Katz Extractor. The balloon at the tip inflates and deflates by pushing and releasing the plunger, respectively. (Photo courtesy of InHealth Technologies, Carpinteria, CA.)

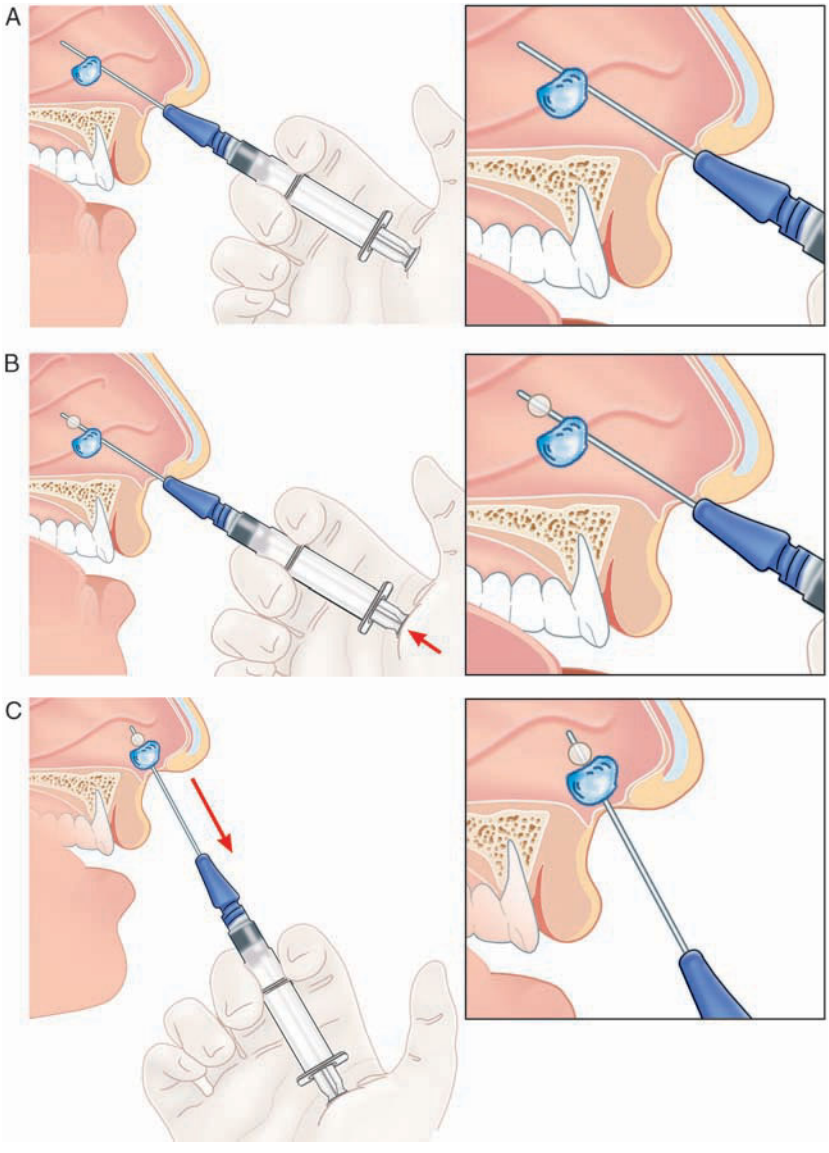


FIGURE 169-9. The Katz Extractor removing a nasal foreign body. **A.** The device is inserted until the balloon is just past the foreign body. **B.** The balloon is inflated. **C.** The Katz Extractor is removed with the balloon inflated and the foreign body is removed.



FIGURE 169-10. The Hognose otoscope tip attached to an otoscope. (Photo courtesy of IQDr. Incorporated, Manitou Springs, CO.)

tip of the device. The tip is soft, self-molding, and looks like the nose of a hog. It has an insufflation port and suction tubing attached to its side. The adapter on the suction tubing attaches to standard wall suction tubing.

Attach the Hognose to the otoscope similar to attaching a disposable speculum to an otoscope. Turn on the otoscope light source. Attach the hognose tubing to suction tubing and a suction source. Turn the suction source on to low or medium. Grasp the otoscope with the dominant hand. Insert the Hognose into the nasal cavity while visualizing the foreign body through the otoscope head. When the tip of the Hognose is just next to the foreign body, place an index finger over the insufflation port to engage the suction at the device tip. Gently advance the otoscope until the tip of the Hognose is against and attached to the foreign body. If you suddenly see black through the otoscope, the soft tip has collapsed on itself. Remove the finger over the insufflation port and reapproach the object. While maintaining suction, withdraw the Hognose with the foreign body attached.

GATORNOSE OTOSCOPE TIP

The Gatornose (IQDr. Incorporated, Manitou Springs, CO) is a disposable, latex free, and single-use device that attaches to a standard



FIGURE 169-11. The Gatornose otoscope tip attached to an otoscope. Note the three types of jaws that are available to snap onto the base of the device. (Photo courtesy of IQDr. Incorporated, Manitou Springs, CO.)

otoscope (**Figure 169-11**). It twists onto an otoscope like a speculum. It comes with three different jaw types that attach to the body of the device. These jaws are small flat jaws, large flat jaws, and open loop jaws. A trigger on the body of the device controls jaw opening and closing.

Attach the Gatornose to the otoscope similar to attaching a disposable speculum to an otoscope. Turn on the otoscope light source. Grasp the otoscope with your dominant hand. Insert the ring finger into the trigger. Pull the trigger to close the Gatornose jaws. Gently insert the Gatornose jaws just into the nasal cavity. Push the trigger to open the Gatornose jaws and be able to view through the otoscope. Gently advance the otoscope while visualizing the foreign body through the otoscope head. Position the jaws above and below or anterior and posterior to the foreign body. Pull the trigger to close the jaws onto the foreign body. Withdraw the otoscope with the foreign body in the jaws of the Gatornose.

SUCTION TECHNIQUE

Frazier suction catheters are most useful with small or round foreign bodies. Otherwise, this technique will be unsuccessful or will push the object farther into the nasal cavity. This technique is best reserved for large, round foreign bodies where suction can be maintained between the device and the foreign body. Complications include trauma to the surrounding tissues and epistaxis.[17]

Attach the Frazier suction catheter to the suction tubing. Turn on the suction source to at least 100 mmHg. Gently insert the catheter into the nasal cavity. Place a thumb over the hole in the catheter handle to direct the suction through the tip of the catheter. Gently advance the suction catheter until the tip is in contact with the foreign body. Withdraw the Frazier suction catheter and foreign body from the nasal cavity.

For impacted smooth, spherical objects, suction with plastic intravenous tubing can be used.[18,19] Cut a short length of plastic intravenous tubing and attach one end to the suction source. Fashion the other end into a small flange shape using a heat source and any metal object with a rounded end, such as the tip of a hemostat or larger clamp. Heat the jaws of the hemostat and insert them into the plastic tubing just enough to create a flange. Turn on the suction source. Place a hemostat onto the tubing to temporarily clamp the suction tubing. Gently advance the flange tip into the nasal cavity until it contacts the foreign body, taking care not to push it inward. Remove the hemostat from the tubing to activate the suction. Gently but quickly remove the tubing and attached foreign body from the nasal cavity.

POSITIVE PRESSURE

This technique is best utilized for foreign bodies that are large, posteriorly located, or occlude the nasal passage. It involves the generation of positive pressure in the nasopharynx behind the foreign body to force it out of the nostril. There are several ways to generate positive pressure within the nasal cavity. One is to simply ask the patient to occlude the unaffected nostril, take a deep breath through their mouth, close their mouth, and then forcefully exhale the air out through the nostril with the foreign body while keeping their mouth closed. This technique is most successful in older children and adults who are cooperative and can coordinate the movements. **The advantage to this technique, if it is successful, is that no instruments are placed into the nose. The disadvantage is that the foreign body becomes a flying body. Eye protection is advised.**

Other variants of this technique have been developed. The "big kiss," also known as the "parent's kiss" or "mouth-to-mouth" technique, involves asking the parent to blow into the child's mouth.[20] This is similar to rescue breaths during cardiopulmonary resuscitation (CPR). Explain the procedure to the child and the parent. Instruct the parent to open the child's mouth with one hand and stabilize the chin while occluding the unaffected nostril with a finger from their other hand. Instruct the parent to open their mouth, take a big breath, and then place their mouth over the child's open mouth. The child's mouth must be completely covered by their parents and a good seal formed. Instruct the parent to deliver a sudden and forceful breath into the child's mouth. This entire sequence of events should only take 3 to 4 seconds to complete.

This maneuver causes the child's glottis to close. If enough pressure is generated, the foreign body will be expelled from the affected nostril. This technique may be less traumatic to the child and involves no instrumentation or restraint.[20] High success rates have been reported.[21] However, this technique may be difficult for some parents to perform. A modified version of this technique involves using a drinking straw or small tube between the child's mouth and parent's mouths. The parent then gives a big puff of air through the straw while the child tries to make a tight seal between their mouth and the straw. This technique can also be performed by the Emergency Physician without placing their mouth on the child's mouth.

A bag-valve-mask device (i.e., the Ambu-bag) can also be used to blow the foreign body out the nostril.[22] Choose a face mask that is small enough so that it only covers the patient's open mouth. Cover the patient's mouth tightly with the mask. Close the unobstructed nostril with a finger (**Figure 169-12**). Squeeze the bag to force air into the mouth, lungs, and out the nose.[22] A variant of this method uses an anesthesia bag connected to high-flow oxygen (10 to 15 L/min). Cover the mouth with the mask, close the thumb hole, and allow the bag to expand and gradually increase the airway pressure. If this does not expel the foreign body, compress the bag.[3]

The "Beamsley Blaster" technique makes use of the positive pressure generated from the application of high flow (10 to 15 L/min) oxygen from tubing attached to an oxygen wall outlet.[23] The other end of the tubing is attached to a male-male



FIGURE 169-12. Bag-valve-mask method of removal. The child is restrained and the contralateral nostril is occluded. Bag-valve-mask is applied on the mouth to create a seal and a few breaths are delivered until foreign body is expelled.

adapter, which is then inserted into the unaffected nostril. The set-up generates enough pressure in the posterior nasopharynx to dislodge the foreign body from the nostril. The patient's mouth must be closed during the procedure to create a seal. Although there were no complications noted in the initial study, a subsequent case of barotrauma (subcutaneous orbital emphysema) was recently reported.[24]

If an SMR cabinet or other blower with a nasal tip is available, place the nasal tip in the unobstructed nasal cavity. This method is contraindicated if there are foreign bodies in both nasal passages. **It is important to be sure that the nasal tip is placed in the open nasal cavity or the foreign body could be blown into the trachea or esophagus.** Blow short puffs of air during the child's cries. The soft palate will close when the child is vocalizing and direct both the air and the foreign body out the other nostril.[2]

CYANOACRYLATE GLUE–ASSISTED REMOVAL

Cyanoacrylate glue can be used to extract spherical and other solid foreign bodies that are visible.[25] However, this technique can be fraught with complication. **There is a chance of gluing the foreign body to the nasal mucosa as well as creating a glue foreign body. The foreign body can be further impacted if pushed posteriorly or fall into the oropharynx and aspirated.**

Obtain a long, thin object (e.g., straightened paper clip or the stick end of a cotton-tipped applicator). Moisten the tip of the paper clip or applicator stick with a very tiny amount of cyanoacrylate glue. A larger amount can drop off into the nasal cavity. Insert the paper clip or applicator stick before the glue dries and until it just touches the foreign body. Maintain this position for 30 to 60 seconds to allow bonding of the glue to the foreign body. **Do not allow the drop of glue to fall from the stick, as it will bond to the nasal mucosa. Do not touch the tip of the wooden applicator stick to the nasal mucosa, as it will bond to the mucosa.** Remove the paper clip or applicator stick with the foreign body attached. The main disadvantages of this technique are potential bonding of the nasal mucosa and the time it takes for the glue to bond to the foreign body.

ALTERNATIVE TECHNIQUES

NASAL WASH

The nasal wash technique involves the introduction at high pressure normal saline through a bulb syringe into the unaffected nasal cavity. Place approximately 7 mL of normal saline into a bulb syringe. Insert the bulb syringe into the unaffected nostril. Advance it into the nostril until a seal is created. Forcefully squeeze the bulb syringe. The pressure generated is believed to expel the saline and the foreign body from the other nostril. The use of this technique carries a high risk of aspiration of saline and the foreign body, as well as concerns about reflux of the saline into the sinuses or eustachian tubes.[26] This technique should not be used in patients with a button battery or organic matter in their nasal passages. The increased moisture will hasten corrosion of the battery and cause swelling of the organic matter, making additional attempts at removal more difficult. This technique should also not be used in young infants and those with airway or neurologic abnormalities.

MAGNET REMOVAL

An occasional patient will present with a mini-magnet adhered to the nasal mucosa. The source of the magnets can be from their insertion in young children or nasal jewelry in older children, adolescents, and adults.[10] Adherence of magnets across the nasal septum creates the potential for septal necrosis and perforation.[11,27,28] They may be difficult to remove because of the attractive force they create across the nasal septum.

Numerous methods can be used to facilitate magnet removal. They may be grasped with a variety of forceps or hemostats. A hook can be made from nonferromagnetic blunt probe.[10] A magnet can be used to facilitate nasal magnet removal.[11,29,30] A pacemaker magnet is readily available in most Emergency Departments. A small and strong pocket magnet may also be available from the hospital maintenance department.

ASSESSMENT

Inspect the nasal cavity for any remaining fragments of the foreign body, ulcerations, bleeding, or a second foreign body. A gray precipitate may be noted if a disk battery has been removed. After a battery is removed, the nasal cavity should be irrigated with saline to remove any electrolyte solution or precipitate to prevent further damage.[12] Bleeding can be controlled with topical phenylephrine or epinephrine, pressure, or any of the methods described to control epistaxis (Chapter 172).

AFTERCARE

The patient can be discharged home with nasal saline spray to the affected nostril until secretions are clear of blood or pus. Oral antibiotics may be prescribed if the patient has developed sinusitis from a retained foreign body. Patients with ulcerations on opposing sides of the nasal cavity must be followed up to prevent obstructive synechiae or adhesions from forming. Patients with button batteries, mini-magnets in their nasal passages, or other injuries or complications should follow up with an Otolaryngologist. The caretakers should be educated to remove any small objects from the child's reach, supervise children when they have access to small objects, and childproof the house.

COMPLICATIONS

Complications can arise from the nasal foreign body itself or the removal technique. Foreign bodies can cause nasal obstruction, epistaxis, pressure on surrounding tissues, infection, ulceration, perforation, or aspiration.[5] The risk of complications increases the longer the foreign body is present. Otitis media, sinusitis, facial and orbital cellulitis, epiglottitis, and meningitis have been associated with retained nasal foreign bodies.[5,8]

The most significant complication would be to dislodge the foreign body into the airway. This is most likely to occur in an uncontrolled situation. Placing the patient supine and in the Trendelenburg position may prevent accidental aspiration of the foreign body.[31] Consider the use of sedation, procedural sedation, or general anesthesia if the patient is uncooperative.

Potential complications associated with each technique were described with each specific technique. Aspiration from posterior dislodgment of a nasal foreign body remains a serious potential complication for all the techniques described. Positive pressure techniques can result in barotrauma. Periorbital emphysema has been described in the "Beamsley Blaster" method.[24] Secondary infection may also result from the procedure. In most cases, once the foreign body has been removed antibiotics are generally not indicated. Complications related to manipulation within the nasal cavity include bleeding or subsequent infection. In rare instances, an anterior nasal pack may be required to tamponade bleeding. Toxic doses of cocaine and/or lidocaine may result in cardiac arrhythmias and seizures.

SUMMARY

The vast majority of nasal foreign bodies can be safely removed by the Emergency Physician with instruments that are readily available in the Emergency Department. There are multiple techniques for removing foreign bodies from the nasal cavity. Each has its own advantages and disadvantages. These methods include the use of forceps, balloon catheters, and positive pressure. The Emergency Physician should choose a method according to the shape and location of the foreign body, the tools available, the cooperativeness of the patient, and their experience with the different removal techniques.

170 Nasal Fracture Reduction

Eric F. Reichman

INTRODUCTION

Nasal fractures due to blunt trauma are a common occurrence. Fights, auto accidents, and sports accidents account for most fractures in an urban setting. Work, farm, sports, or leisure activity accidents account for most of these injuries in rural areas.[1] The majority of nasal fractures occur in males aged 15 to 25 years old, with fights being the major etiology.[2–5] Nasal fractures are often missed on initial evaluation, especially when there are many more urgent trauma concerns. It is best to perform closed or open reduction of a nasal fracture within the first 2 weeks, when it is easiest to avoid more elaborate operations later to correct the disfigurement and nasal airway obstruction. Perform the reduction in children within 3 to 7 days, as fracture fixation occurs faster than in adults.[6]

Suspect a nasal fracture in the blunt trauma patient with a history of epistaxis, new onset nasal blockage, or a change in nasal appearance. Determine whether the patient has a prior history of a nasal bone fracture, as repeat nasal bone fractures will be more difficult to reduce. An old photograph of the patient may aid this determination. One study revealed that 30% of injured noses had a preexisting nasal deformity.[7] At least 48% of the general population has a deviated nasal septum.[8] Physical examination may demonstrate skin lacerations, nasal tenderness and mobility, internal mucoperichondrial tears, ecchymosis, or a septal hematoma. A septal hematoma must be drained to avoid cartilage necrosis and the subsequent saddle nose deformity. Refer to Chapter 171 regarding the complete details of managing a nasal septal hematoma.

ANATOMY AND PATHOPHYSIOLOGY

The mechanism of injury, force of impact, direction of impact, and the history of any prior nasal deformity must be ascertained from the patient in order to understand the potential magnitude of the fracture. If possible, obtain photographic documentation before any attempts at nasal manipulation. The Waters and lateral nasal radiographs will often support the physical findings of a nasal fracture (**Figure 170-1**). Many Surgeons recommend radiographs as part of the medical legal documentation, although many do not agree. Plain radiographs can have a high false-negative rate due to the lack of fine resolution or a high false-positive rate from the misinterpretation of the normal bony sutures.[9,10] A CT scan is more sensitive and specific to identify a nasal bone fracture. Unfortunately, its cost and the radiation exposure are significant. A nasal fracture can often be diagnosed based upon the history and the physical examination. Reserve the CT scan for those patients with suspected nasal fractures that may have additional injuries requiring a CT scan.

The direction of the force to fracture the nasal bone is variable. There are several lateral and frontal force injury classifications, but no consensus exists.[5,11,12] One study demonstrated that 66% of nasal fractures were due to lateral forces, 13% from frontal forces, and 21% from mixed forces.[3] This predominance of lateral force fractures is due to several factors.[13] It takes more than twice the force, in cadavers, to cause a frontal impact fracture than to cause a lateral impact fracture.

Always rule out any associated maxillofacial injuries, especially when the patient presents with ocular hypertelorism and

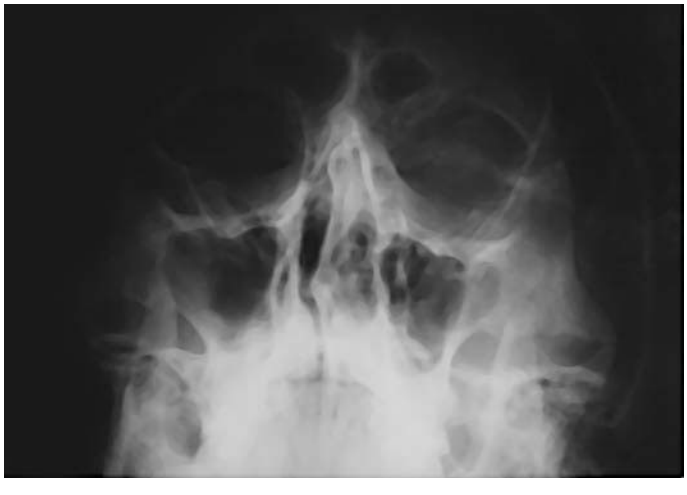


FIGURE 170-1. Radiograph demonstrating a Waters view of a deviated nasal septum and right nasal bone fracture.

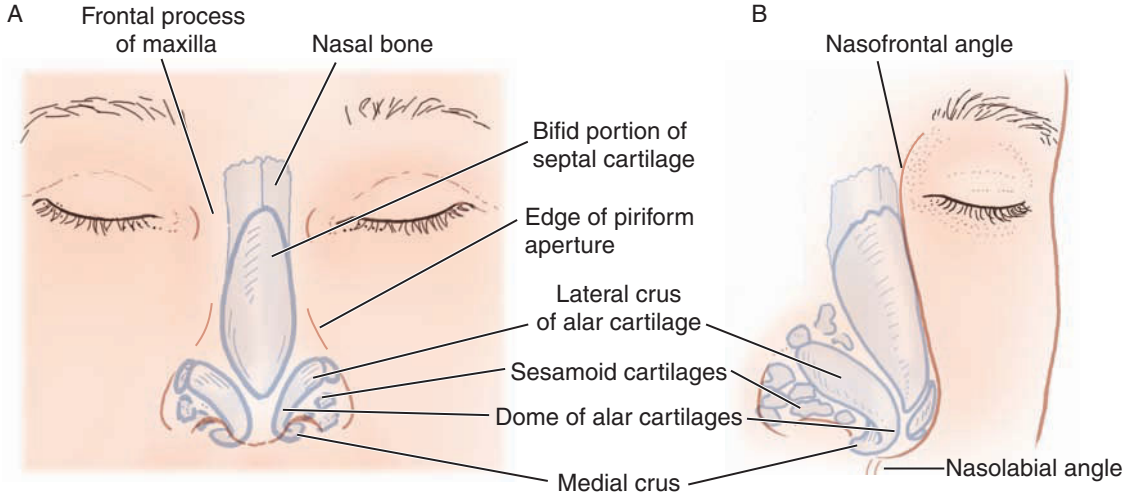


FIGURE 170-2. Anatomy of the external nasal cartilages. **A.** Frontal view. **B.** Lateral view.

lid lateral-pull laxity.[14] Thoroughly evaluate the patient for the presence of other head or neck injuries if they have a nasal fracture. Associated head and neck injuries take priority for management and evaluation as they can result in significant morbidity. Subcutaneous emphysema may be found in nasal trauma cases, as well as with simple lamina papyracea fractures, and nose blowing. Scleral chemosis, subconjunctival hemorrhage, eyelid edema, periorbital ecchymosis, or subconjunctival hemorrhage may all be associated with a complex facial fracture or an isolated nasal fracture. A history of anosmia indicates a possible cribriform plate fracture. Evaluate the patient for cerebrospinal fluid rhinorrhea and the presence of beta$_2$-transferrin.[1] Consider obtaining axial and coronal computed tomography scans of the paranasal sinuses with possible cisternography.

The nose consists of the external nose and the septum. The external nose consists of the bony upper third, the cartilaginous lower third, and the surrounding soft tissue and skin (**Figure 170-2**). The bony part consists of the paired nasal bones, the frontal processes of the maxillary bones, and the nasal processes of the frontal bones. The inferior nasal bones are thinner than the superior nasal bones. Thus, the lower bony portion is the most common area of the external nose to be fractured.

The cartilaginous components consist of the arched paired upper lateral cartilages and the horseshoe-shaped paired lower lateral cartilages. The former articulates with the cartilaginous septum and nasal bones, while the latter has ligamentous attachments to each other in front of the cartilaginous septum. The lower and upper lateral cartilages articulate with each other and form a crucial part of the nasal valve, the critical control point of nasal resistance, and obstruction. Any of these relationships can become dislocated from a traumatic impact and will require repair for an optimal functional and aesthetic outcome. The more lateral sesamoid cartilages are relatively unimportant in these regards.[15]

The bony nasal septum consists of the perpendicular plate of the ethmoid bone, the vomer, the anterior nasal spine, the maxillary crest, and the palatine bone (**Figure 170-3**). The perpendicular plate of the ethmoid bone is thin, except at its articulation with the vomer and cartilaginous septum. **The perpendicular plate of the**

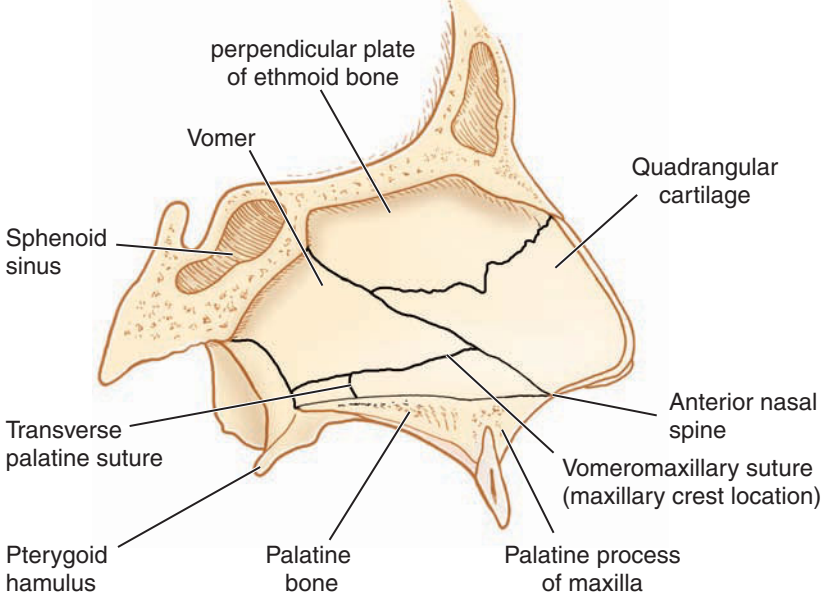


FIGURE 170-3. Anatomy of the nasal septum.

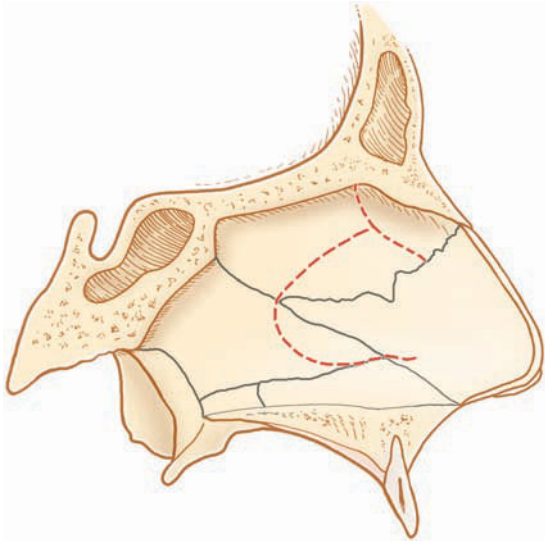


FIGURE 170-4. Schematic illustration of a common nasal septal fracture pattern. The fracture proceeds from the area of the maxillary crest, through the vomer, and up into the perpendicular plate of the ethmoid like a backward "C" going up into a "T".

ethmoid bone is the most common location for a septal fracture. The quadrangular cartilage of the septum is anteriorly located on the maxillary crest. It can be dislocated into either nostril with a significant force, especially from an inferior direction, and result in nasal airway obstruction.[5]

The bony nasal septal fracture is often similar, regardless of whether the etiology is a frontal or lateral impact (**Figure 170-4**). It usually begins just posterior to the nasal spine, at or just above the maxillary crest. The fracture can progress through this area and straight into the vomer where it curves like a "C," vertically upward and into the perpendicular plate of the ethmoid bone.[16]

Nasal fractures increase in severity from a unilateral depression without a septal fracture, to a nasal twist or deviation, to a significantly comminuted nasal fracture as the frontal or lateral force of impact increases (**Figure 170-5**). Between these extremes are the moderately severe bilateral fractures with the contralateral side being driven outward and more significantly impacted traumas, such as the previously described C-shaped septal fracture with overriding and interlocked fragments. This latter condition often appears as the classically shortened and twisted nose with tip ptosis from columellar retraction. There is often significant nasal airway obstruction as the quadrangular cartilage telescopes over the perpendicular plate of the ethmoid, causing thickening at this point and the appearance of a bilaterally deviated nasal septum.[17]

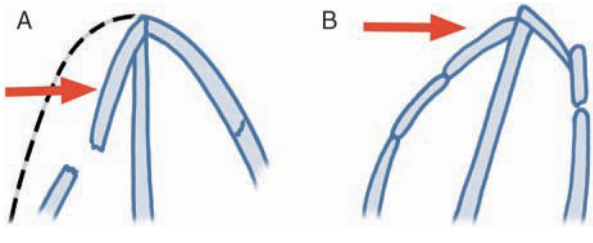


FIGURE 170-5. Nasal fractures resulting from lateral forces. **A.** Unilateral nasal fracture. **B.** Bilateral nasal fracture. The arrows depict the direction of the force of impact.

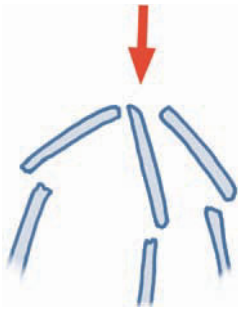


FIGURE 170-6. An "open book" nasal fracture resulting from a frontal impact.

The more common lateral force shifts the bony pyramid laterally (**Figure 170-5**), while a frontal impact broadens the nose. "Open book fractures" may occur in pediatric patients due to the open, midline suture of the nasal bones. This results in each of the nasal bones being shifted laterally (**Figure 170-6**). Children have fewer nasal fractures because of their smaller and more cartilaginous (i.e., more elastic) noses.[18,19] Greenstick fractures are more likely in children because of their resilient noses and can be present when it is not apparent externally.[20,21]

INDICATIONS

Attempt to reduce nasal fractures within the first 3 hours after the trauma, before significant edema develops. Otherwise, perform the reduction 3 to 10 days after the injury when the edema subsides. The indications for a closed nasal reduction include unilateral or bilateral nasal bone fractures, with or without a nasal septal fracture. Interestingly, one study found that 30% of nasal fractures that underwent closed nasal reduction were still malaligned postoperatively.[17] Strongly consider reduction under procedural sedation or general anesthesia for pediatric nasal fractures.

CONTRAINDICATIONS

There are no absolute contraindications to nasal fracture reduction as long as the timing, the patient's health status, and associated injuries are considered. The proper approach varies by the extensiveness of the fracture. Open nasal reduction is required for more severe nasal fractures, especially those with C-shaped septal fractures and cartilage telescoping over the perpendicular plate of the ethmoid bone.[3] Some authors have defined the indications for this more aggressive approach as being a nasal pyramid deviation exceeding one-half of the width of the nasal bridge.[17] Consider using an open approach, either during the same setting or within a few days, if deformities persist after closed reduction. Relative indications for the open approach include fracture-dislocations of the caudal septum, open septal fractures, septal hematomas, displaced fractures of the anterior nasal spine, associated alar cartilage deformities, or recent intranasal surgery. An open approach may be required if an extensive septal deformity exists.[2] Otherwise, the nasal deformity will be difficult to reduce against the interlocked forces.[2]

EQUIPMENT

- Headlight with light source, or overhead light
- 5 mL syringe
- 27 gauge needle, 1.5 inches long
- 25 gauge spinal needle
- Local anesthetic solution containing 1:100,000 epinephrine



FIGURE 170-7. Nasal fracture reduction instruments. From left to right: an elevator, a Walsham forceps, and an Asch forceps (with rubber tubing on one tong).

- Oxymetazoline nasal spray
- 4% cocaine, 4 mL
- Other nasal decongestants and anesthetics (Chapter 172 and **Table 172-1**)
- Surgical cotton paddies, 0.5 × 2 inches
- Bayonet forceps
- Walsham forceps (**Figure 170-7**)
- Asch forceps (**Figure 170-7**)
- Rubber tubing
- Boies nasal fracture elevator (**Figure 170-7**)
- Killian nasal speculum
- Silastic nasal splints or Goldsmith splints
- Antibiotic impregnated strip gauze or nasal tampon
- Plaster of Paris splinting/casting material
- 5-0 plain gut suture
- Paper tape, 1 inch wide
- Benzoin solution

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Significant complications include patient dissatisfaction, the possible need for open reduction within 2 weeks, and formal nasal reconstruction months later. Other potential complications (all of much lower probability) include adverse reactions to the local anesthetics, excessive bleeding, infection, saddle nose deformity, septal perforation, CSF rhinorrhea, and/or visual disturbances. Almost all of these complications can result from the reduction procedure, but also from the nasal fracture without and reduction attempts. Obtain an informed consent for the procedure.

Place the patient sitting upright in a multiposition procedure chair, or on a stretcher, with the head elevated to decrease blood flow and bleeding. Obtain an objective measure of the degree of lateral displacement. Draw a perpendicular line from the midpoint of the interpupillary line and extending downward to the base of the nasal columella. A point one-third of the way down from the cephalic end is the reference point for any deviation.[22] Consider the administration of parenteral analgesics, sedatives, or procedural sedation. Refer to Chapter 129 regarding the details of procedural sedation and analgesia. Obtain a prereduction photograph of the patient's face and nose, if possible.

NASAL ANESTHESIA

Anesthetize the nasal mucosa. Insert a nasal speculum. Apply oxymetazoline nasal spray bilaterally to decongest the nasal mucosa. Place 4 mL of 4% cocaine onto cotton pledgets. Cocaine is a vasoconstrictor, a decongestant, and an anesthetic. Insert the nasal speculum and pack the cocaine-soaked pledgets into the nose using a bayonet forceps (**Figures 170-8A, 9, & 10**). Ideally, place four

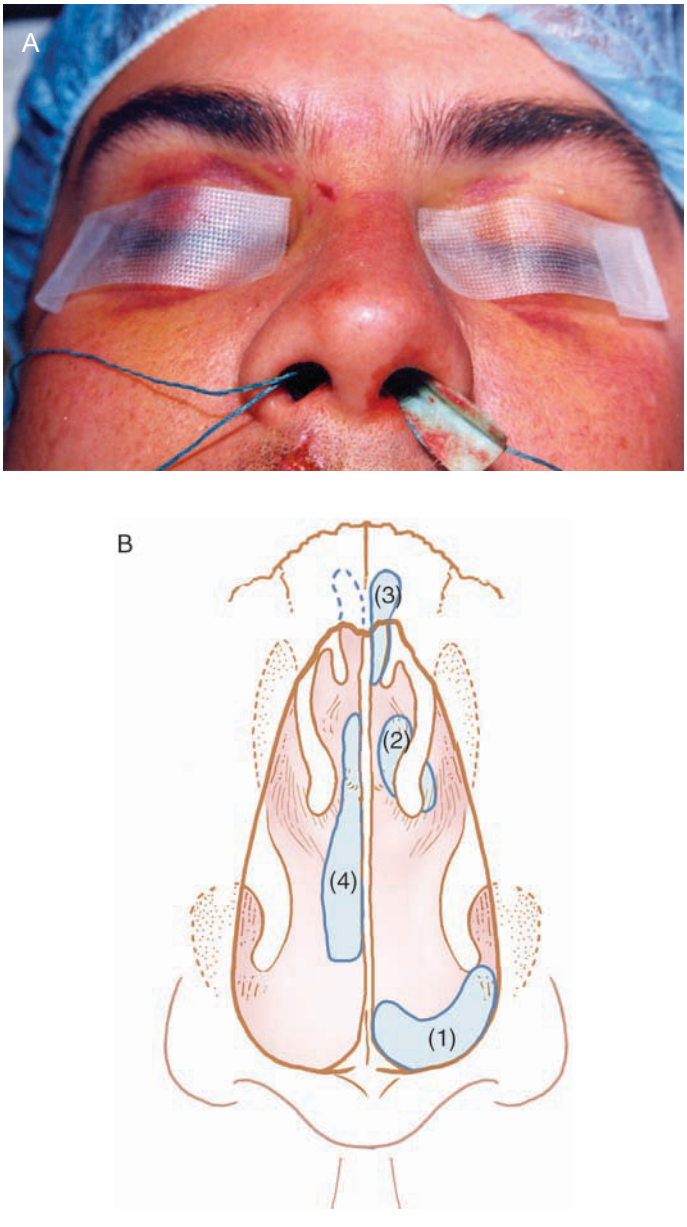


FIGURE 170-8. Topical anesthesia of the nasal mucosa. **A.** Surgical cotton pledgets soaked with cocaine placed in the nares. **B.** Typical sites for placement of the pledgets: (1) nasal floor, (2) posterior aspect of middle and inferior turbinate, (3) intranasal dorsum, and (4) along the nasal septum.

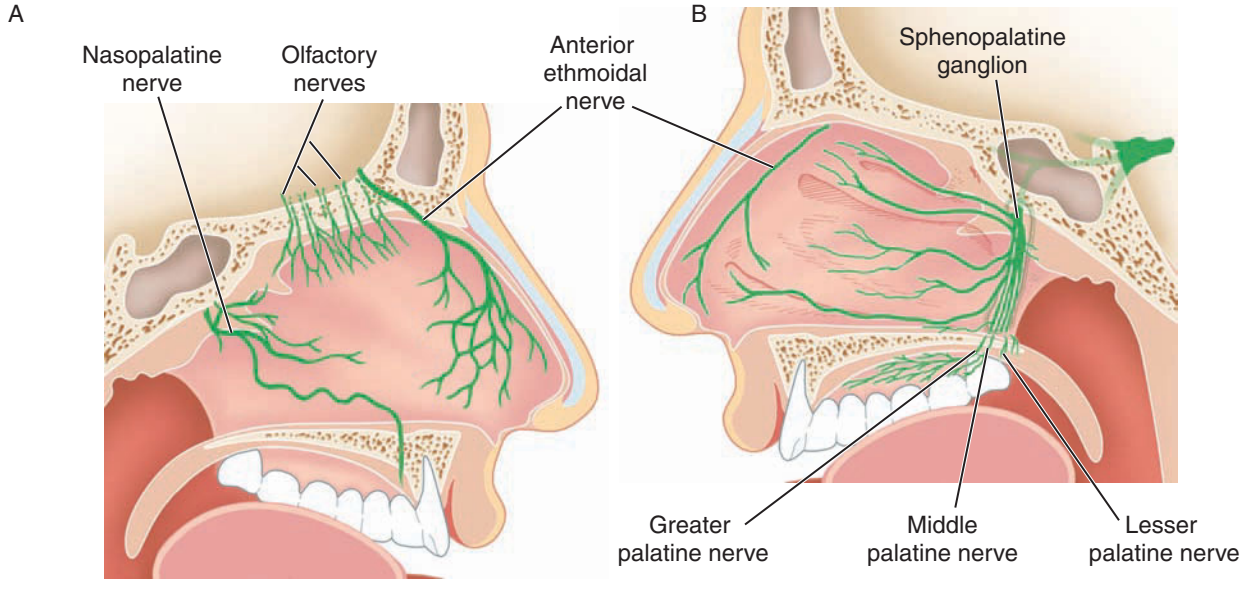


FIGURE 170-9. Nerve supply of the nasal mucosa. **A.** The nasal septum. **B.** The lateral nasal wall.

pledgets in each nostril at the strategic points of the neurovascular supply (**Figure 170-8B**). These areas include the posterior edge of the middle turbinate (sphenopalatine ganglion and artery), the anterior to middle turbinate and opposing septum (anterior ethmoid nerve and artery), the nasal floor (branches of both nerves and arteries), and the midseptum (branches of both nerves and arteries).[6,15] Allow the cocaine pledgets to remain in the nasal cavity for 10 minutes. Other anesthetics, decongestants, and anesthetic–decongestant combinations can be used depending upon availability. Refer to Chapter 172 for a more complete discussion of topical nasal anesthesia and decongestion.

Inject local anesthetic solution to anesthetize the remainder of the nose. The most commonly used agent is 1% or 2% lidocaine containing 1:100,000 epinephrine.[23] Acidosis from the injured tissues can make local anesthesia less effective. The addition of sodium bicarbonate, at a 1:10 dilution, will counteract the acidosis and lessen the discomfort from the injection.[24]

Perform the local anesthetic injections intranasally to avoid the added pain of puncturing through the skin (**Figures 170-11 & 12**). Infiltrate subcutaneously to anesthetize the external, nasal, infratrochlear, and infraorbital branches of the trigeminal nerve.[3,4] Insert the needle into the nasal cavity. Infiltrate along the nasal floor to anesthetize the superior alveolar nerve and ganglion. Infiltrate posterior to the inferior and middle turbinates to block the sphenopalatine nerve and ganglion. Allow 10 to 15 minutes for the local anesthetic agent to take effect. Assess the adequacy of the anesthesia using pinprick of the nasal mucosa. If intranasal injections are performed properly in a patient who is under procedural sedation and analgesia, the rare but potentially serious complications of using topical cocaine may be avoided. One

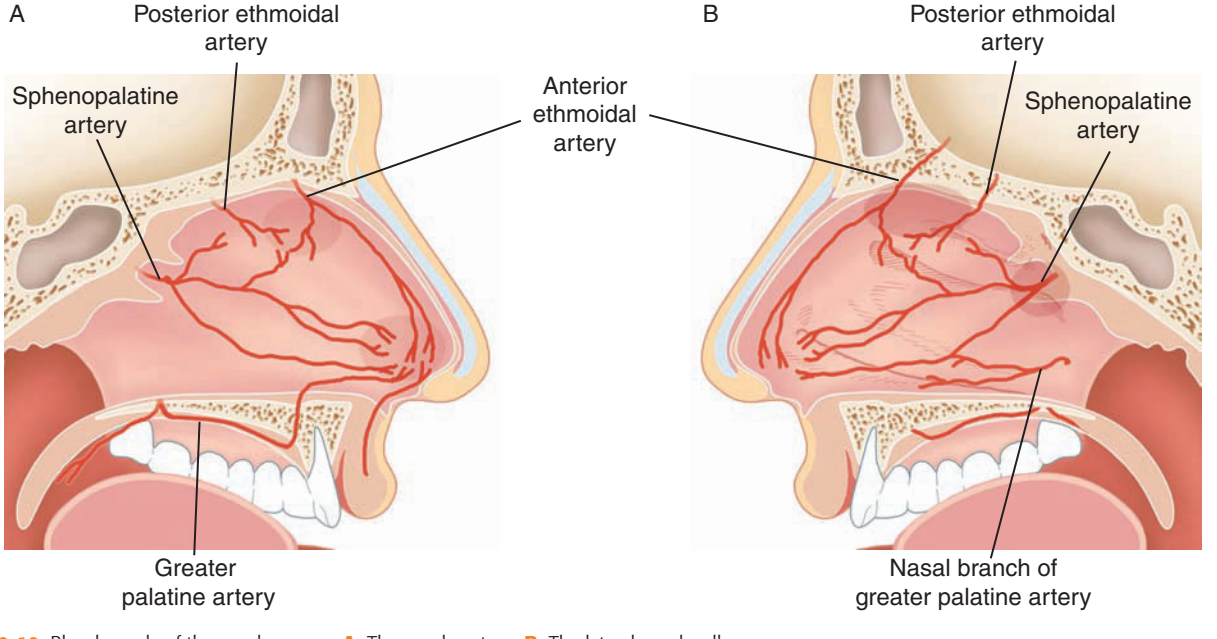


FIGURE 170-10. Blood supply of the nasal mucosa. **A.** The nasal septum. **B.** The lateral nasal wall.

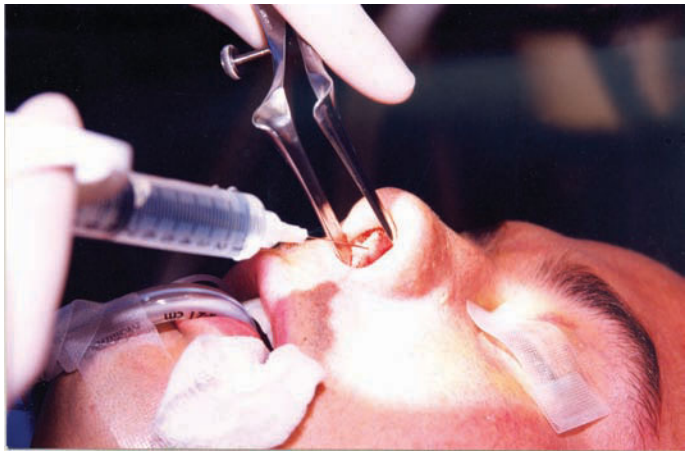


FIGURE 170-11. Intranasal injection with speculum exposure and a fine needle.

paper proposed using EMLA (eutectic mixture of local anesthetics) cream externally and cocaine intranasally.[25] This has yet to become a broadly accepted technique. The Emergency Physician may not feel comfortable with the technique of intranasal injection and the nerves may be anesthetized percutaneously as described in Chapter 126.

TECHNIQUES

NASAL BONE REDUCTION

Several studies have demonstrated that closed nasal reduction is 80% to 95% successful.[8,26] Measure the distance from the nostril rim to the nasofrontal angle in order to avoid putting the blade in too far (**Figure 170-13A**). Insert one blade of the Asch forceps, one blade of the Walsham forceps, or a Boies nasal fracture elevator into the nostril to the measured distance. Place the instrument against the depressed nasal bone. Apply a gentle upward and outward force while simultaneously applying digital counterpressure to guide the bone into reduction (**Figure 170-13B**). Alternatively, cover the other blade of the Asch or Walsham forceps with rubber tubing so that it can provide counterpressure to the intranasal blade during outward reduction (**Figure 170-14**).[6] Repeat the procedure on the contralateral side if there is a bilateral nasal bone fracture.

NASAL SEPTAL REDUCTION

A nasal septal fracture is often present if bilateral pyramidal fractures exist. **Always reduce the nasal bone fracture(s) before manipulating the septum.** Insert a nasal speculum and determine whether the reduction of the nasal bones results in a straightening of the septum. If not, withdraw the nasal speculum and reduce the septum with the Asch or Walsham forceps (**Figure 170-15**). Insert the forceps with one blade in each nostril. Gently close the blades of the forceps to grasp the septum. Elevate the septum upward and anteriorly to disimpact any interlocked fragments. Reinsert the nasal speculum and visualize the nasal septum. Insert a Boies or Freer elevator under direct visualization and straighten the septum more precisely.

ASSESSMENT

Thoroughly evaluate the nasal cavity and nose. Determine the adequacy of the reduction procedure. Determine visually whether the nasal bones and the nasal septum are reduced. Consult an Otolaryngologist if the manipulations fail to provide a satisfactory reduction, if the fracture appears too comminuted, or if the nose or septum is too deviated for a closed approach. The patient may require open reduction 2 weeks from the day of the trauma. **Perform a thorough examination to rule out an associated septal hematoma. This must be evacuated and managed to prevent complications.** Refer to Chapter 171 regarding the details of managing a nasal septal hematoma. Attempt to suture any nasal septal mucosal tears that exist from the fracture or the reduction procedure using 5-0 plain gut suture. Warn the patient of the potential for a septal perforation that can lead to chronic crusting, bleeding, or an audible whistling. Obtain postreduction photographs of the nose, if possible. Place the prereduction and postreduction photographs in the patient's medical record.

AFTERCARE

Brace the septum for stability with bilateral Silastic splints for 5 to 10 days. This also helps to prevent the formation of a nasal septal hematoma. Doyle or Goldsmith septal splints have lumens that

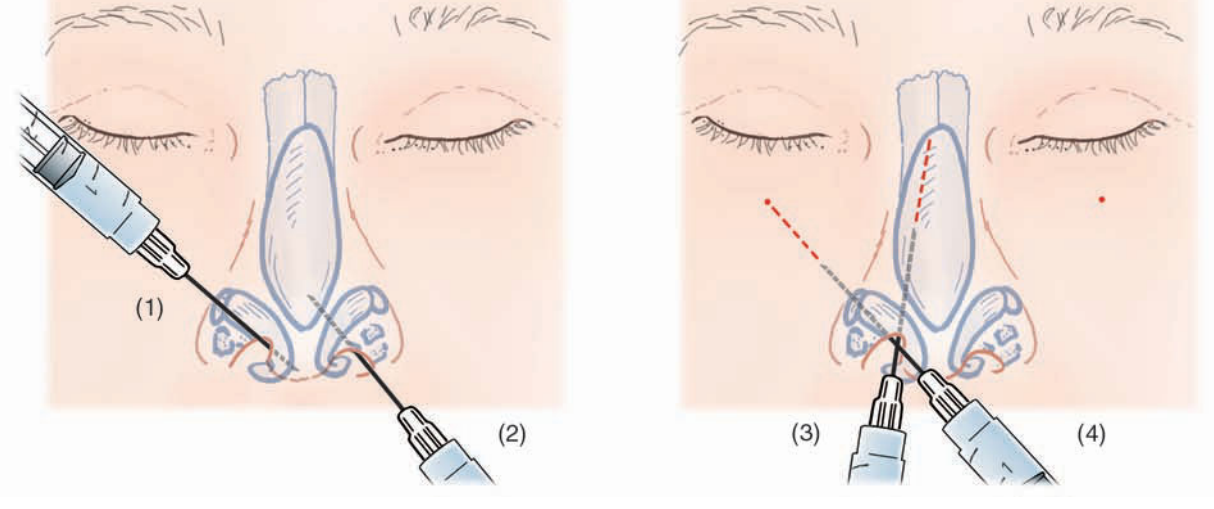


FIGURE 170-12. Intranasal injection of local anesthetic solution: (1) the nasal spine, (2) the nasal tip, (3) the nasal dorsum along the outside of the nasal bones, and (4) the infraorbital nerve.

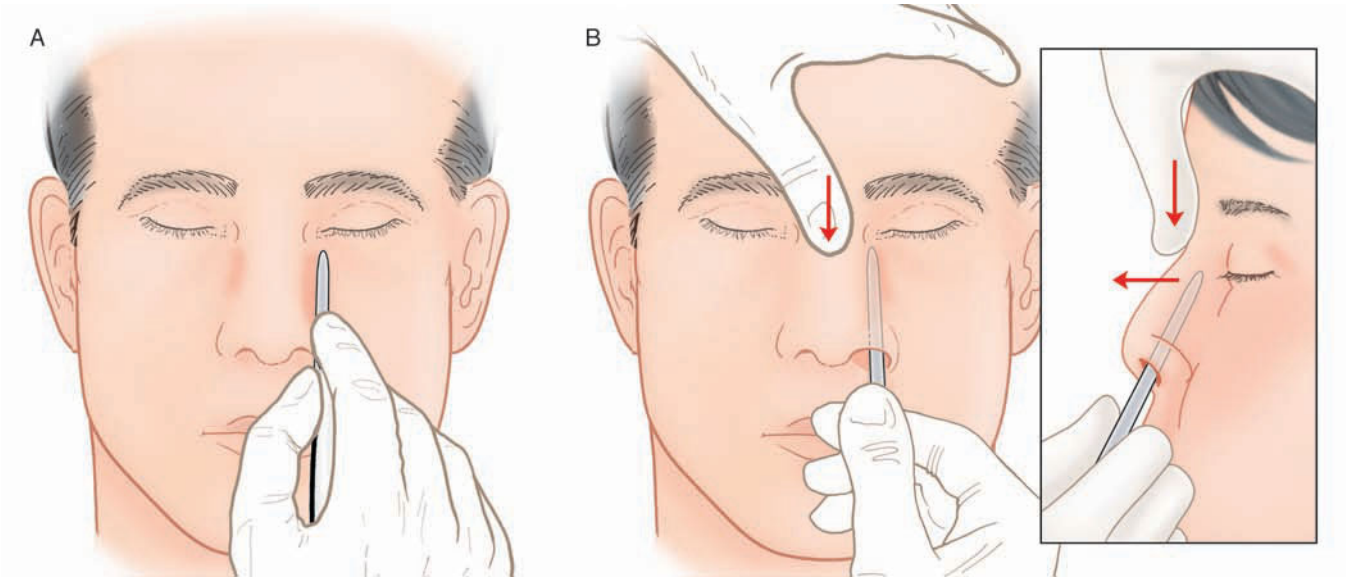


FIGURE 170-13. Closed reduction of a nasal fracture. **A.** Measure the nostril to nasofrontal angle (N-NFA) distance with the Boies elevator or another instrument. **B.** Place the elevator or forceps intranasally, just less than the N-NFA distance, and elevate the depressed bone. Simultaneously reduce the contralateral nasal bone downward.

allow the patient to nasally breathe in the postoperative period. These splints must be kept open by the patient applying six drops of hydrogen peroxide to each nostril three times a day, while avoiding swallowing this solution. A simpler and more convenient alternative is bilateral anterior nasal packing. The equipment is readily available in every Emergency Department. This is especially useful in cases of epistaxis. Apply bilateral petrolatum impregnated gauze ribbon, iodinated gauze ribbon, nasal sponges/tampons, or balloon catheters. **Avoid overpacking the nasal cavity as this can splay out the fractured nasal bones.**[6]

All patients with nasal packing must be placed on oral antibiotics with gram-positive and gram-negative coverage, such as cefazolin (Keflex), for the duration of the packing. This will aid in the prevention of a sinusitis or toxic shock syndrome. Leave the nasal packing in place for 1 to 7 days depending upon the amount of manipulation, the amount of bleeding, and Emergency Physician preference. Avoid nasal splinting and packing in patients with nasal fractures requiring a minor degree of manipulation, especially when patients are assessed to have a low probability of follow-up and compliance.

Consider applying an external splint in addition to the internal splint or nasal packing. Some authors do not advocate external splinting and its use is based on Emergency Physician preference. The splint serves to support the healing fracture and to remind the patient to keep their nose protected. Cleanse the skin of the nose and the surrounding area with alcohol. Apply benzoin solution to the nose and surrounding area. Allow the benzoin to dry and become tacky. Apply 1 inch wide paper tape in horizontal strips,

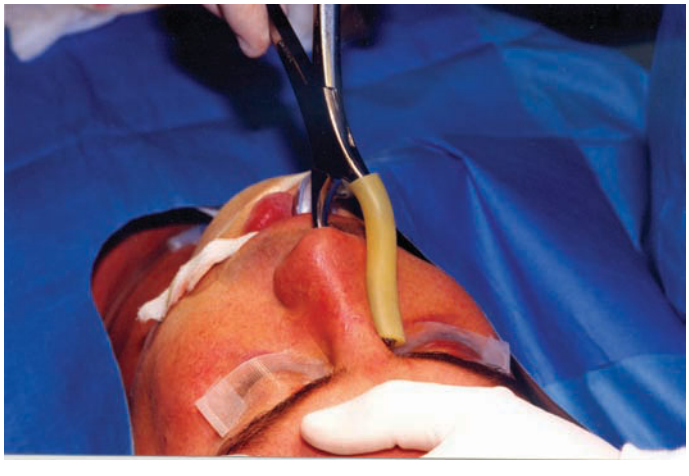


FIGURE 170-14. Placement of nasal reduction forceps. Note the rubber tubing over the outer tong to protect the skin.

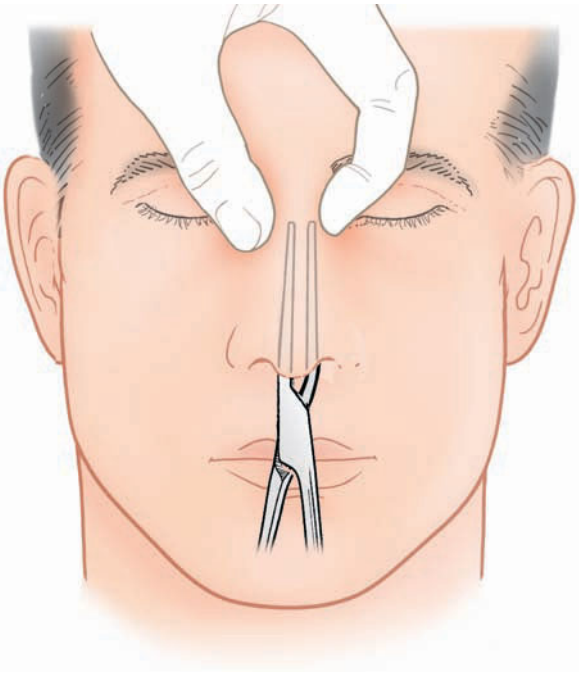


FIGURE 170-15. The Asch forceps to elevate a frontal/inferior force fracture and straighten the associated deviated nasal septum.



FIGURE 170-16. Postreduction Denver splint applied after appropriate taping and midline vertical foam rubber placement.

layered downward from the nasofrontal angle to the tip of the nose. Apply benzoin solution over the tape. Allow the benzoin to dry and become tacky. Apply three to five layers of 2 inch wide orthopedic plaster of Paris over the tape. Alternatively, apply an appropriately sized Denver aluminum or Thermoplast splint over the tape (**Figure 170-16**). Ensure that the foam rubber strut is placed vertically over the midline length of the nose to prevent any skin necrosis. Place tape over the splint to secure it.

Instruct the patient to return to the Emergency Department for excessive bleeding, increased pain, a purulent or foul nasal discharge, or a fever. Prescribe acetaminophen supplemented with narcotic analgesics as needed. Instruct the patient to avoid aspirin containing products and nonsteroidal anti-inflammatory drugs as they can increase the risk of bleeding. Arrange follow-up with an Otolaryngologist or Plastic Surgeon within 24 to 48 hours to assess the reduction and the need for further management.

COMPLICATIONS

Pack (or repack) the nasal cavity, after providing adequate local anesthesia, if bleeding occurs. A septal hematoma is likely if a patient complains of persistent or excessive pain, has noticeable nasal widening, and has an ecchymotic septum. This must be evacuated as described in Chapter 171. Infection, cartilage necrosis, and disfiguring nasal dorsal saddling may occur if the septal hematoma is not evacuated. A nasal dorsal hematoma can occur as well and must be recognized and evacuated. Cerebrospinal fluid rhinorrhea and visual impairment are rare complications of the nasal manipulation, but more likely complications of the original trauma. Cerebrospinal fluid rhinorrhea can be delayed from the initial trauma until the edema has subsided. The reduction may be inadequate and require further closed or open reduction.

SUMMARY

Nasal fractures may be reduced and repaired in the Emergency Department using a closed technique. Perform the reduction, ideally within 3 hours of the injury, before significant edema occurs. It is otherwise best to wait until the swelling subsides in approximately 1 week. Repair nasal septal fractures at the same time as the nasal reduction. Severe fractures sometimes require an open reduction. Photographic and radiographic documentation can be important medicolegally as part of the preoperative evaluation. Drain any septal or nasal dorsal hematomas. Internal and external splinting is useful to help insure good postoperative healing. Antibiotics are essential if nasal packing is applied.

171 Nasal Septal Hematoma Evacuation

Michael Friedman, Meghan Wilson, and George Chiampas

INTRODUCTION

Soft tissue and bony injuries of the nose are common because the nose is centrally located and the most anteriorly protruding structure of the face.[1] **Suspect a nasal septal hematoma, although an uncommon complication of nasal trauma, in any individual who has sustained a nasal injury.[2,3] All individuals who have sustained nasal trauma must undergo a careful examination of the septum and nasal passages, regardless of the mechanism of injury or the findings on external examination.[2]**

Blunt trauma, either intentional or unintentional, is the most common cause of a nasal septal hematoma. Consider a bleeding diathesis if the hematoma develops after a seemingly trivial injury.[2,4,5] Other etiologies include sports injuries and child abuse.[5,6] Iatrogenic nasal septal hematomas following nasal septal surgery are probably more common than reported in the literature. Evaluate patients who have had recent nasal surgery and present with complaints of pain and nasal obstruction for a possible nasal septal hematoma.

Nasal septal hematomas are characterized by severe localized nasal pain, tenderness on palpation of the nasal tip, and a cherry-like swelling or bluish discoloration of the nasal mucosa emanating from the septum that obstructs all or a portion of the nasal passage[1–3,7] (**Figures 171-1 & 2**). Evacuation must be performed to prevent complications.[1,2,4,5] Patients require bilateral nasal packing, oral antibiotics, and close follow-up with an Otolaryngologist to prevent complications following the evacuation of the hematoma.[2,4,8]

Distinguishing an uncomplicated nasal septal hematoma from one that has become infected is difficult, particularly if there has been a delay of several days in seeking medical attention following the injury.[2] Nasal septal abscesses are a rare complication of nasal septal hematomas that occur following nasal trauma. Nasal septal abscesses generally are larger and more painful than uncomplicated nasal septal hematomas. The overlying nasal mucosa is inflamed and occasionally has an inflammatory exudate.[2] Local extension of the infection, if left untreated, into the cavernous sinus with subsequent intracranial infection is the most important potential

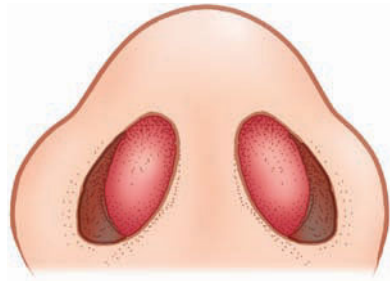


FIGURE 171-1. Bilateral nasal septal hematomas creating a partial obstruction.

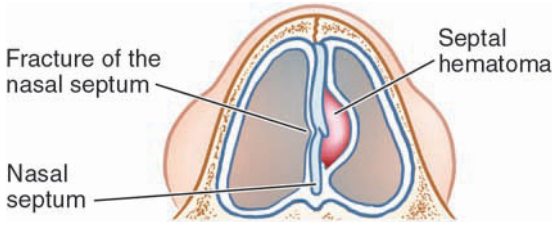


FIGURE 171-2. A small left-sided nasal septal hematoma.

complication.[5,8] The most common complication of a nasal septal abscess is cartilage necrosis that results in nasal structural collapse and a saddle nose deformity (**Figure 171-3**).

ANATOMY AND PATHOPHYSIOLOGY

The nose is both a sensory organ and a respiratory organ. It performs an important function for the entire body by providing both physical and immunologic protection from the environment.[9] The nose aids in the formation of basic speech sounds.[9] The supporting structure of the nose consists of bone, cartilage, and connective tissue. The nose, on frontal view, is in the shape of a pyramid of which approximately the upper two-fifths comprise the bony vault and the lower three-fifths comprise the cartilaginous vault. The upper narrow end joins the forehead at the glabella and is referred to as the root of the nose. The two nares are separated from each other by a skin-cartilage septum known as the columella.[9,10] The cartilaginous framework of the nose provides both its structure and function. **The septal cartilage is avascular and receives its blood supply from the adherent mucoperichondrium.**

The skin covering the external nose is thin and contains an areolar type of subcutaneous tissue. The skin is loosely attached over the upper half. The skin over the lower half of the nose is intimately bound to the lower lateral cartilage and may sometimes be thick, fatty, and contain sebaceous glands.[9,10]

The precise mechanism for a nasal septal hematoma formation following nasal trauma is not known. Nasal septal hematomas are thought to occur when a mechanical force to the nasal cartilage results in rupture or leakage from the perichondrial blood vessels of the nasal septum. In instances where the nasal cartilage is fractured, blood may dissect through the fracture line and form bilateral septal hematomas. Most nasal septal hematomas are secondary to a fracture or surgery. Thus, they almost always distend the mucoperichondrium on both sides of the nose. Accumulation of the extravasated blood strips the perichondrium from the cartilage, forming a closed space in which the blood accumulates (**Figure 171-2**). **The nasal septal hematoma, when not recognized initially and evacuated promptly, can expand and mechanically obstruct the blood vessels that supply the nasal cartilage. Pressure-induced avascular necrosis of the nasal septal cartilage can develop rapidly because there is no alternative blood supply to the cartilage.**[1–3,7] The accumulated blood and necrotic tissue can form a nidus for infection from bacteria that colonize the nasal mucosa.[1–3,7]

Cartilage necrosis subsequently leads to the saddle nose deformity. The term "saddle nose deformity" is a nonspecific description of a nose with a depression over its dorsal surface[9] (**Figure 171-3**). The saddle nose deformity is a result of the nasal septal cartilage becoming ischemic from loss of its blood supply, subsequent nasal septal cartilage resorption and collapse, and the lack of support for the nasal bridge. The deformity is the ultimate result of a nasal septal hematoma or abscess not being evacuated. Necrosis with subsequent fibrosis may develop causing a permanent thickening or absorption of the nasal septum with partial obstruction of the nasal airway.[7–9]

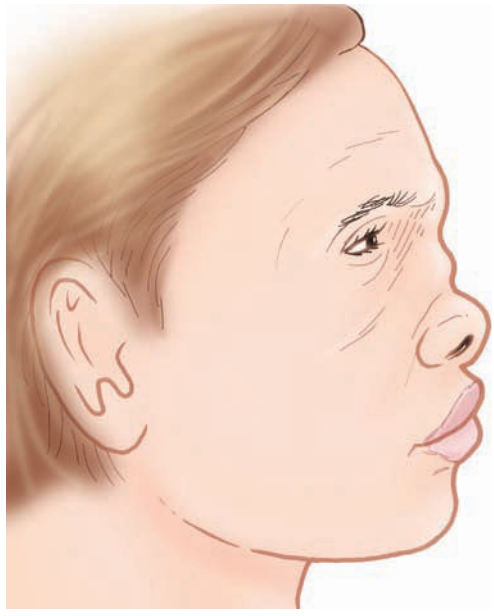


FIGURE 171-3. The saddle nose deformity.

The sphenopalatine branches of the internal maxillary artery and the ethmoidal arteries from the ophthalmic artery supply the internal nose. The veins terminate in the anterior facial and ophthalmic veins.[10] Venous drainage is clinically important in understanding the complications of a septal abscess. Branches of the trigeminal nerve provide sensory innervation to the nose.[9,10]

INDICATIONS

Any significant nasal septal hematoma requires evacuation. A nasal septal hematoma may progress to form an abscess with associated complications of avascular necrosis of the nasal septum, meningitis, or cavernous sinus thrombosis in as little as 3 to 4 days.[7,8] It is not urgent to evacuate a simple nasal septal hematoma in the Emergency Department as complications occur over a period of days. It is essential, however, to identify a nasal septal hematoma so that a treatment plan is initiated and to rule out a septal abscess that does require immediate evacuation.[5]

CONTRAINDICATIONS

There are no absolute contraindications to the evacuation of a nasal septal hematoma. Address any life-threatening or serious injuries or conditions prior to drainage of the nasal septal hematoma. This procedure requires a cooperative patient to prevent secondary iatrogenic injury. Any patient that is uncooperative, unable to follow instructions, very young, or that has an altered mental status may require evacuation under procedural sedation or general anesthesia.

EQUIPMENT

- Headlight
- Nasal speculum
- Nasal vasoconstrictor (e.g., 2% ephedrine. 0.25% oxymetazoline or phenylephrine)
- Nasal anesthetic (e.g., 4% cocaine, 2% pontocaine, and 4% lidocaine)

- Nasal atomizer device, optional
- Alcohol swabs
- Povidone iodine or chlorhexidine solution
- Cotton-tipped applicators
- 1 mL and 10 mL syringes
- 25 or 27 gauge needle, 1½ inches long
- Local anesthetic solution containing epinephrine, lidocaine, or bupivacaine
- #15 surgical blade on a handle
- Frazier suction catheter
- Suction source and tubing
- Nasal speculum
- Bayonet forceps
- Nasal tampon or sponge
- Iodoform gauze

PATIENT PREPARATION

Explain the risks, benefits, complications, and aftercare of the procedure to the patient and/or their representative. Obtain a signed consent for the procedure. Aseptic technique should be followed and maintained throughout the procedure. The procedure is considered clean, but not sterile, as the nasal mucosa can never be sterilized. It is crucial, however, that the instruments are sterile.

Administer anesthesia for the evacuation of a nasal septal hematoma by one of two routes: topical application with supplemental infiltration or a regional block. Some authors recommend using both techniques. However, most nasal septal hematomas can be adequately evacuated with topical anesthesia supplemented by local infiltration.[7] Dampen the swabs of four cotton-tipped applicators with either a solution of 2% pontocaine with ephedrine or cocaine. Insert a nasal speculum to expose one nostril. Gently insert the applicator beneath the roof of the nose so that it reaches the branches of the anterior ethmoidal nerve. Pause until some vasoconstriction and anesthesia takes place, if it meets resistance on insertion, and advance the applicator further (**Figure 171-4**). Pass an applicator into the nasal fossa and move it from the floor of the nasal vestibule, across the midportion of the inferior turbinate, and reaching the posterior aspect of the middle turbinate in the region of the sphenopalatine foramen.[11] Infiltrate a maximum of 0.5 mL of local anesthetic solution containing epinephrine, if additional anesthesia is desired, through the mucoperichondrium and circumferentially around the hematoma.

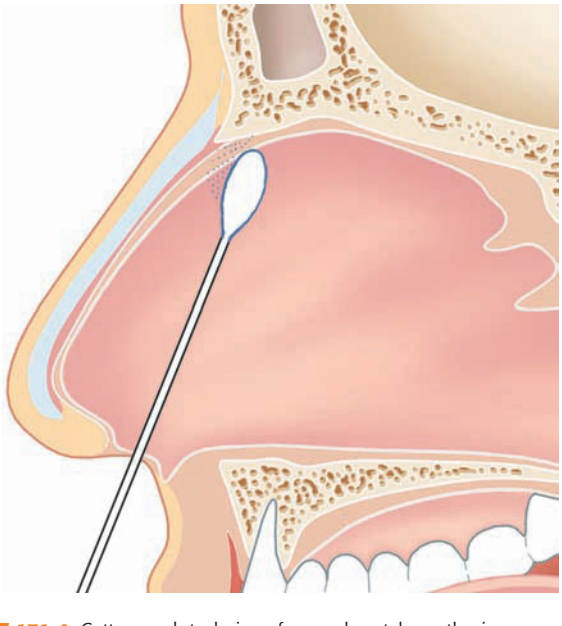


FIGURE 171-4. Cotton swab technique for nasal septal anesthesia.

An atomizer or nasal spray bottle can provide an alternative and commonly used method for nasal septal anesthesia. While an actual atomizer is not often available in the Emergency Department, its use is less painful to the patient than the application of cotton-tipped applicators into the nasal cavity. Alternatives to an atomizer are devices to attach to a syringe to atomize the contents or using a commercially available nasal spray container after emptying its contents. Mix equal amounts of 2% pontocaine or 4% lidocaine with ephedrine and place this in the atomizer or nasal spray bottle. Insert the nasal speculum to gain access to the entire nasal cavity. Open the nasal speculum vertically to expose as much of the nasal septum as possible. Insert the atomizer or nasal spray bottle into the nostril. Instill two puffs of solution into the nostril. Allow 5 to 10 minutes for the anesthetic to take effect. Infiltrate a maximum of 0.5 mL of local anesthetic solution containing epinephrine, if additional anesthesia is desired, through the mucoperichondrium and circumferentially around the hematoma.

Confirm the presence of a septal hematoma. Compress the area with a cotton-tipped applicator. The bulge from the hematoma is compressible with the applicator. It should not shrink with the application of a topical vasoconstrictor.[2,6]

TECHNIQUES

ASPIRATION

Some authors feel that simple aspiration with an 18 gauge needle may be adequate for a small, early hematoma. Most patients require a more extensive evacuation as clotted blood cannot be removed with aspiration. Since blood clots form within minutes and remain in clotted form for days, needle aspiration is generally not effective. Simple aspiration may, however, be used to diagnosis a septal hematoma.[6–8] Insert the nasal speculum. Open the nasal speculum vertically so that the nasal septum is maximally visible. Instruct an assistant to hold the nasal speculum in position and open, allowing the Emergency Physician to have both hands free to perform the procedure. Insert an 18 gauge needle, attached to a 10 mL syringe, into the nasal septal hematoma. Aspirate the contents of the hematoma. No additional procedure is necessary if the hematoma can be completely evacuated by aspiration. Simple clinical assessment of the septum is the guide to determine if the hematoma has been evacuated. Apply a nasal pack as described below.

INCISION AND DRAINAGE

The incision and drainage technique is the primary procedure to drain a nasal septal hematoma. Cleanse the skin surrounding the nares of any dirt and debris. Apply an alcohol swab, povidone iodine, or chlorhexidine to the area and allow it to dry. Insert the nasal speculum. Open the nasal speculum vertically so that the nasal septum is maximally visible. Instruct an assistant to hold the nasal speculum in position and open, allowing the Emergency Physician to have both hands free to perform the procedure. Make a 1.0 to 2.0 cm long vertical incision, with a #15 scalpel blade, in the septal mucoperichondrium overlying the hematoma (**Figure 171-5**). **Be cautious to not cut into the cartilaginous septum.** The length of the incision depends upon the size of the nasal septal hematoma. Some authors prefer to use an L-shaped incision in the mucoperichondrium.[12–16]

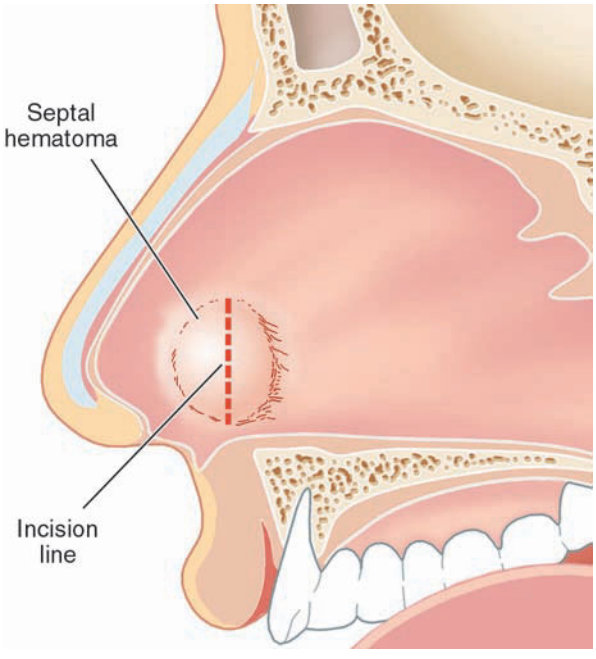


FIGURE 171-5. Nasal septal hematoma with markings for a vertical incision through the mucoperichondrium.

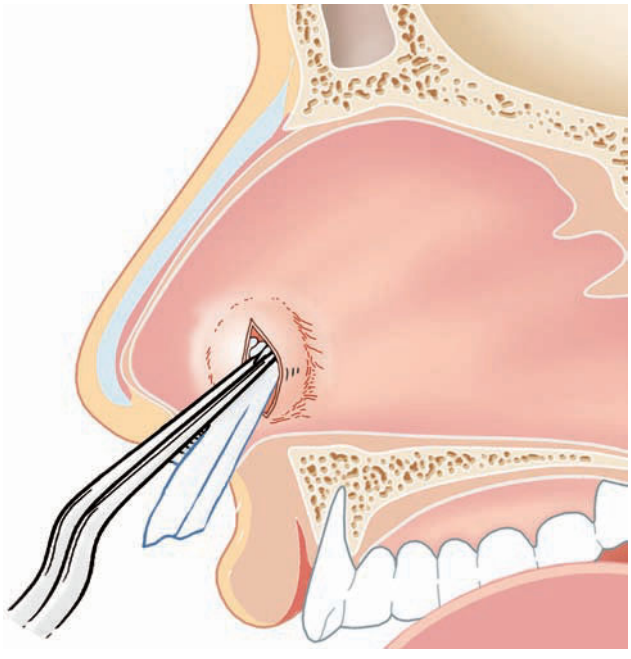


FIGURE 171-6. Iodoform gauze is placed between the separated mucoperichondrium and the cartilaginous septum.

These authors feel that this incision allows the mucoperichondrium to reposition flat against the cartilaginous septum. The choice of incision type is left to the preference of the Emergency Physician.

Use the Frazier suction catheter to gently evacuate any clot or necrotic debris from the hematoma cavity. Clots are difficult to evacuate by suction and may require mechanical removal. Always send a sample of the fluid or hematoma to the laboratory for Gram's stain, anaerobic cultures, and aerobic cultures.[2,7,8] Apply topical antibiotic ointment over the incision, a wick, and nasal packing as described below.

A bilateral septal hematoma can, almost always, be evacuated from one side. Apply gentle pressure to the contralateral hematoma to express it out the incision. Make a second vertical incision contralaterally, either anterior or posterior to the first incision to prevent septal perforation, if complete evacuation is not achieved unilaterally.

WICK INSERTION

Insert a wick of 1/8 inch iodoform gauze through the incision (**Figure 171-6**). Allow 1 inch of the wick to extend into the nasal cavity for easy removal. **Be careful to ensure that the wick is flat between the mucoperichondrium and the cartilaginous septum. Do not pack the cavity with the wick.** Some authors recommend inserting a Penrose drain, or a piece of one, instead of the iodoform gauze.[6] This has not been found to be beneficial when compared to iodoform gauze.[6] The Penrose drain can be a substitute if iodoform gauze is not available or the patient is allergic to iodine.

NASAL PACKING

Apply bilateral nasal packs following the successful drainage of a septal hematoma. Packing inhibits the reaccumulation of the hematoma, or serous fluid, thereby preventing the severe complications associated with a septal hematoma. The use of commercially available nasal packing devices, such as nasal tampons or sponges, provides adequate protection against reaccumulation. Patients report such devices to be significantly more comfortable than traditional gauze packing. This, coupled with the ease of insertion when compared to gauze packing, has made such devices very popular.

Place the patient's head in the sniffing position. Coat a nasal tampon with a water-soluble antibiotic ointment. Insert the nasal speculum to obtain adequate visualization of the nasal septum. Grasp the nasal tampon with a bayonet forceps. Introduce the forceps with the nasal tampon in a horizontal position through the speculum. **Be careful to not tear the incision in the mucoperichondrium open or to dislodge the wick.** Place the nasal tampon on the floor of the nasal cavity and against the nasal septum.[8] Withdraw the bayonet forceps and the nasal speculum. Repeat the nasal packing procedure on the contralateral side. Both nasal cavities must be packed to maintain the septum in the midline, prevent bowing of the septum into the contralateral nasal cavity, and the reaccumulation of the hematoma. Refer to Chapter 172 regarding the complete details of nasal packing.

PEDIATRIC CONSIDERATIONS

Nasal septal hematomas can occur at any age. The diagnosis and treatment are the same for adult and pediatric patients. Generally, however, any treatment for children would be done under procedural sedation in the Emergency Department or general anesthesia in the operating room.

AFTERCARE

Proper follow-up is vital to prevent any infectious process or cosmetic deformity. All patients must be reevaluated within 24 hours and again in 48 hours for removal of the nasal packs. Prescribe acetaminophen and narcotic analgesics for pain control. Prescribe broad-spectrum antibiotics, specifically those with staphylococcal coverage, as prophylaxis against infection and the development of a septal abscess.[6] Instruct the patient to avoid nonsteroidal anti-inflammatory drugs as they increase the risk of bleeding. Provide all patients with proper discharge instructions. They should

return to the Emergency Department immediately if they experience increased pain, bleeding, or a fever. Refer all patients to an Otolaryngologist within 24 hours.

COMPLICATIONS

The most common acute complication of a nasal septal hematoma is an abscess or cosmetic deformity. Complications are primarily related to incomplete evacuation or reaccumulation of the hematoma. This may be avoided by adequate removal of the hematoma with suction, placement of an iodoform gauze wick, and bilateral nasal packing. An abscess may result in ascending infections including meningitis and cavernous sinus thrombosis. *Staphylococcus aureus* is the primary pathogen isolated from the majority of reported cases, regardless of patient age. Prescribe appropriate prophylactic antibiotics.[2,5,6] Many patients cannot tolerate complete hematoma evacuation under local anesthesia. When complete evacuation is not performed, consult an Otolaryngologist and schedule the patient for evacuation under anesthesia within 24 hours. Early and/or appropriate treatment may not prevent complications if the nasal septal cartilage is already ischemic at the time of the procedure.

Other complications of nasal septal hematoma drainage are rare and include nasal bleeding, inadequate evacuation, and septal perforation. Nasal bleeding can usually be controlled with the prescribed packing. Incomplete removal of the hematoma is not a serious problem if identified. A nasal septal hematoma may reoccur if the incision is made on opposite sides of the septum. Limit the incision to one side if possible. The second incision, if required, on the contralateral side must not oppose the first incision.

SUMMARY

A nasal septal hematoma is a rare but potentially serious complication of nasal trauma. Proper management consists primarily of early recognition, prompt evacuation, wick insertion, and bilateral nasal cavity packing. Administration of antimicrobial therapy is necessary to prevent or treat a secondary nasal abscess. Follow-up with an Otolaryngologist is required within 24 hours of the procedure to evaluate for the reaccumulation of the hematoma and/or an abscess. These patients require continual follow-up until the nasal septum is healed.

172 Epistaxis Management

Stephen M. Kelanic, David D. Caldarelli, and Eric F. Reichman

INTRODUCTION

Epistaxis is an extremely common condition in the United States with an incidence estimated at 10 per 10,000 people per year.[1] It is a common reason for patient visits to the Emergency Department. There is an early peak in those less than 10 years of age.[2] The frequency of epistaxis decreases in the teens and begins to progressively increase after 20 years of age, with the highest frequency in the elderly.[2] Epistaxis usually is the result of well-localized intranasal trauma. However, it may be the initial sign of a more serious underlying systemic illness. Epistaxis is often self-limited and can be managed conservatively. Epistaxis can also manifest itself as a profuse spontaneous hemorrhage that is extremely difficult to control and result in aspiration, hypotension, cardiovascular collapse, syncope, and airway compromise.

The proper management of epistaxis and the prevention of adverse consequences depend on a timely and thorough evaluation of the patient as well as the appropriate intervention. The Emergency Physician must be familiar with a variety of techniques to control intranasal hemorrhage.

ANATOMY AND PATHOPHYSIOLOGY

An understanding of the vascular anatomy of the nasal cavity is essential to efficient and immediate control of nasal bleeding. The blood supply to the sinonasal cavity arises from both the internal and external carotid artery system (**Figure 172-1**). The sphenopalatine artery arises as one of the terminal branches of the internal maxillary artery, a branch of the external carotid system, and is the primary blood supply to the sinonasal cavities. The anterior and posterior ethmoid arteries, terminal branches of the internal carotid system, supply blood to the superior straits of the nose. The superior labial branch of the facial artery supplies the anterior nasal cavity and anastomoses with branches from the anterior ethmoid artery and the sphenopalatine artery in an area of the anterior nasal septum known as Kiesselbach's plexus or Little's area (**Figure 172-2**). **It has been estimated that 90% of all nasal bleeding occurs in the area of Kiesselbach's plexus.**[3] This is particularly true for children and young adults. Older adults tend to bleed from the posterior nasal cavity, from branches of the sphenopalatine and posterior ethmoidal arteries. This has been attributed to arteriosclerosis.[3]

Epistaxis may result from numerous local and/or systemic factors that damage the delicate mucosal lining of the nasal cavity and expose the underlying vasculature. The most common cause of epistaxis is accidental or self-inflicted trauma, often from digital manipulation of the nasal mucosa (i.e., nose picking). This eventually heals and crusts over but is subject to repeated irritation and bleeding when the patient sneezes or blows their nose. The anterior source of this bleeding makes it very easy to treat. High-velocity trauma to the region of the midface and skull base may be manifest as a severe, life-threatening hemorrhage that may be extremely difficult to control.

Local inflammatory reactions due to acute upper respiratory infections, allergic rhinitis, and chronic sinusitis may cause epistaxis.[4] The mucosa becomes inflamed, hypervascular, and is easily disrupted with forceful nose blowing. The presence of an intranasal foreign body may inflame the nasal mucosa, with consequent granulation tissue and bleeding. This should be expected if the bleeding is unilateral and associated with nasal obstruction and foul rhinorrhea.

Epistaxis may be attributed to a nasal septal deformity.[5] The deflected nasal septum creates turbulent airflow that desiccates the mucosa and leads to crusting and bleeding. Epistaxis attributed to nasal septal deviation presents just posterior to the deflection and may be difficult to control. Nasal septal perforations bleed frequently and easily from mucosal irritation and granulation tissue.

Postoperative bleeding as the result of sinonasal surgery—such as septoplasty, rhinoplasty, turbinectomy, and endoscopic sinus surgery—may also be encountered. Blood-tinged nasal secretions are to be expected for the first 2 weeks after surgery. Severe epistaxis may occur during the first postoperative week, with an estimated incidence ranging from 0.9% to 8.9%.[6] The bleeding is usually posterior, brisk, and may be difficult to control. Consult the Otolaryngologist who performed the procedure in all cases of postoperative bleeding.

Nasal bleeding may be the first sign of a sinonasal neoplasm. The bleeding is usually intermittent and often accompanied by nasal obstruction and pain. Severe bleeding is unusual except in

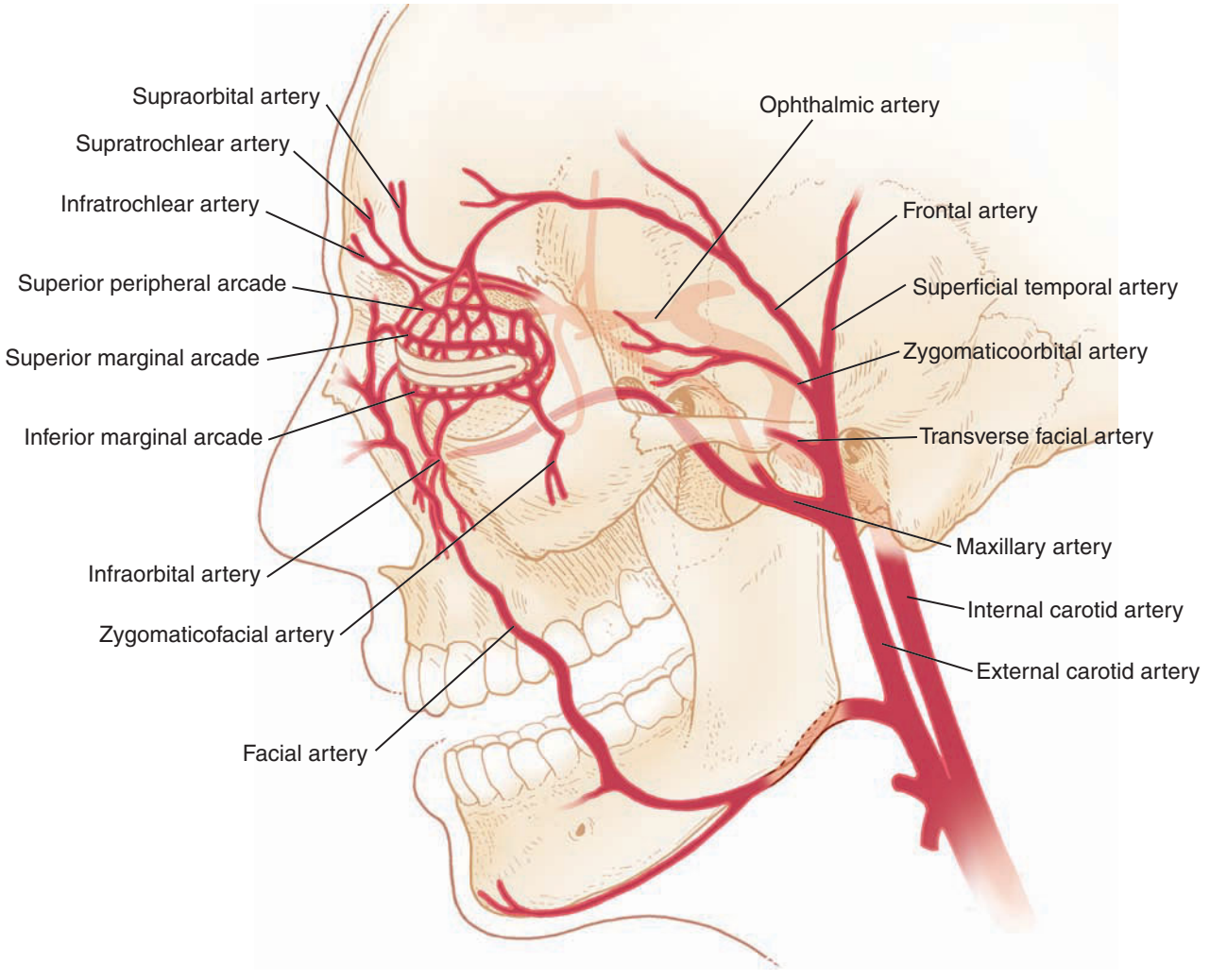


FIGURE 172-1. The blood supply of the nasal cavity arises from the internal and external carotid artery systems.

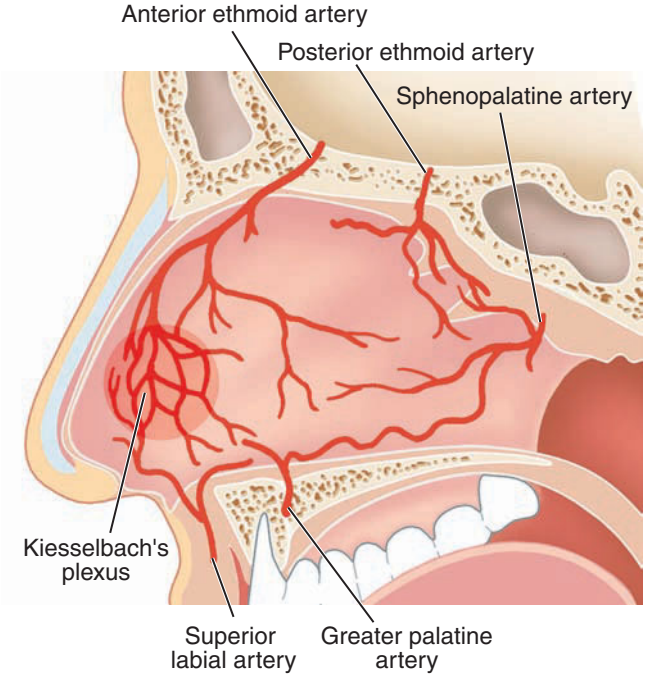


FIGURE 172-2. Arterial supply to the nasal septum and Kiesselbach's plexus.

the case of juvenile nasal angiofibromas, which should be suspected in adolescent males.

Patients without identifiable local causes for epistaxis most likely suffer from an underlying systemic process. Consider the possibility of a defect in the coagulation cascade. Hypertension is often cited as a significant factor for epistaxis. Studies have been unable to demonstrate a significant difference in the prevalence of epistaxis in patients with hypertension versus patients without hypertension.[7,8] Nonsteroidal anti-inflammatory drugs and aspirin containing products have been associated with epistaxis.[9,10] Osler-Weber-Rendu disease is an autosomal dominant inherited condition in which the blood vessel walls lack contractile elements. Consequently, prolonged heavy bleeding occurs from relatively minor insults, as the vessels are unable to contract and allow clotting to take place. The patient's coagulation profile is normal and the diagnosis is made by the family history. Other systemic etiologies include alcoholism, blood dyscrasias, liver disease, malnutrition, and pregnancy.

INDICATIONS

A patient with epistaxis must be evaluated expediently. All patients with epistaxis require a thorough examination and control of the bleeding. Epistaxis that has resolved still requires management to prevent rebleeding.

CONTRAINDICATIONS

There are no contraindications to the management of epistaxis. **Manage any unstable vital signs, unstable airway, life- or limb-threatening injuries, or any complications related to blood loss (e.g., hypotension, chest pain, syncope, etc.) before managing the epistaxis.** In the interim, apply a nose clip or a nasal sponge/tampon to control the bleeding. A thorough examination and more definitive means of control can be performed after the patient has been stabilized.

EQUIPMENT

- Nose clip
- Headlight or overhead light source
- Yankauer suction catheter
- Frazier suction catheters, #5 and #7
- Nasal speculum, short and medium lengths
- Bayonet forceps
- Kidney basin
- Weeder metal tongue blade or wooden tongue depressors
- Gown, gloves, face mask with an eye shield or goggles
- Cotton balls
- Topical anesthetics and vasoconstrictors (**Table 172-1**)
- Silver nitrate applicator sticks
- Petrolatum (e.g., Vaseline) impregnated gauze ribbon, 0.5 inches wide
- Synthetic nasal sponges/tampons, various lengths
- Nasal balloons (anterior, posterior, anterior and posterior)
- 14 French Foley catheter with a 30 mL balloon
- Umbilical clamp
- Gelfoam
- 4 × 4 gauze squares
- Surgicel
- ENTaxis nasal packing
- 3 inch long dental rolls or tonsil packs, or 3 × 36 inch Vaseline gauze
- Umbilical tape or 0 silk suture
- Red rubber catheters
- Lubricant

TABLE 172-1 Anesthetics and Vasoconstrictors of the Nasal Mucosa

Anesthetics
4% cocaine
4% lidocaine
2% pontocaine
Topical anesthetic spray (e.g., Cetacaine)
Vasoconstrictors
4% cocaine
3% ephedrine
1:1000 epinephrine
0.5% oxymetazoline
0.5% to 1.0% phenylephrine
0.05% to 0.10% xylometazoline
Anesthetic and vasoconstrictor combinations
4% cocaine
0.25 mL of 1:1000 epinephrine and 20 mL lidocaine mixture
4% lidocaine and 0.05% oxymetazoline, 50:50 mixture
4% lidocaine and 0.5% to 1.0% phenylephrine, 50:50 mixture

The list of equipment required to manage a patient with epistaxis is quite long. Most Emergency Departments keep all the required equipment, except medication, in a rolling cart or tackle box. This system allows for more efficient stocking and restocking. It is also more efficient to have all the required equipment readily available in one convenient and portable location. Single patient use and disposable nosebleed trays are commercially available (e.g., Centurion ENT/Nosebleed Tray, Tri-State Hospital Supply Corp., Howell, MI). They contain all the required instruments but lack the medications and other supplies.

PATIENT PREPARATION

Explain the procedure, its risks, and its benefits to the patient and/or their representative. Obtain a signed informed consent for the procedure. Ensure that the patient has a thorough understanding of the postprocedural care instructions and follow-up requirements.

Position the patient sitting in an upright multipositional procedure chair. Alternatively, place the patient sitting upright on a gurney with the back elevated. Prepare the wall suction unit to make sure that it is working. Apply suction tubing and a suction catheter to the suction source.

The importance of good lighting cannot be overemphasized. Apply a headlamp if one is available. An alternative is an overhead adjustable light source. Position the light so that it is aimed in the patient's mouth. The overhead light often hits the examiner in the head, casts shadows, and is too bright for the patient's eyes. It is also difficult to position properly as both of the examiner's hands must be used for the procedure.

Instruct the patient to blow their nose firmly, one nostril at a time, in order to evacuate the nasal cavities before the examination. This allows the anterior nasal septum, Kiesselbach's plexus, the nasal vestibule, the inferior turbinate, and the floor of the nasal cavity to be examined. Inspect the posterior oropharynx for active bleeding using the Weeder tongue blade or a wooden tongue blade. Insert a short nasal speculum to evaluate each side of the anterior nasal cavity. Open the speculum vertically. Suction out any blood and blood clots with the Frazier suction catheter. Consider a posterior site of bleeding if the source is difficult to localize. A patient will occasionally present with bilateral epistaxis. It is sometimes difficult to determine from which side the bleeding is originating. Ask the patient which side started bleeding first. This is usually the side where the bleeding point can be found.

Vasoconstrict and anesthetize the nasal mucosa (**Table 172-1**). Decongest the nasal mucosa with an aerosolized agent. Instruct the patient to sniff in deeply after the spray is applied. Allow 3 to 5 minutes to pass for the vasoconstriction to occur. Apply a topical anesthetic spray to the nasal passageway. Spraying achieves excellent vasoconstriction and anesthesia as the agents diffuse through the entire nasal cavity and pharynx. It is possible to anesthetize and vasoconstrict the nasal mucosa in one step by using cocaine or a combination of an anesthetic and vasoconstrictor agent (**Table 172-1**). Alternatively, place cocaine-soaked pledgets into the nasal cavity. Direct the pledgets along the floor of the nose, against the nasal septum, and toward the superior straits of the nose. Monitor the patient's vital signs when vasoconstrictors are applied.

There are numerous techniques to manage epistaxis. These include the use of absorbable packs, electrocautery, Foley catheters, gauze rolls, intranasal balloon catheters, petrolatum impregnated ribbon gauze, nasal tampons or sponges, and silver nitrate. The technique and material of choice depend upon the location of the bleeding (anterior vs. posterior) and Emergency Physician preference. Different techniques and equipment are required to control anterior versus posterior bleeding.

RADIOLOGIC STUDIES

Imaging is not routinely indicated for the initial evaluation and management of epistaxis in the majority of cases. Damrose and Maddalozzo reviewed CT scans of pediatric patients who were referred for evaluation of epistaxis.[11] While 79% of the studies demonstrated some abnormality, none of the patients were found to have a neoplasm. They concluded that routine imaging of the sinuses is not recommended. CT imaging of the paranasal sinuses and facial bones should be considered when there is a history of facial trauma or when there is a high index of suspicion for a neoplasm.

ANTERIOR EPISTAXIS MANAGEMENT TECHNIQUES

Anterior nasal packing is required when local measures fail to control epistaxis. This may be due in part to anterior or structural problems in which the bleeding source cannot be identified. It may also be due to heavy or profuse bleeding. **The premise behind placing nasal packing is that it provides mechanical pressure and tamponades the bleeding site.**[12] Note that this is an uncomfortable procedure; therefore, the previously described steps for applying topical anesthesia should be undertaken.

ABSORBABLE PACKING

Diffuse bleeding is frequently encountered in patients with coagulopathies and blood dyscrasias. The trauma of inserting the nasal packing (e.g., a tampon or petrolatum gauze) can lead to more serious bleeding. A piece of Gelfoam sponge or oxidized cellulose (e.g., Surgicel) is often effective. These substances, coated with an antibiotic ointment (e.g., Bacitracin), provide adequate pressure and hemostasis without extreme trauma to the nasal mucosa. This packing does not need to be removed and will slowly dissolve with the use of a topical saline spray, which may be started within 24 hours of the packing being placed.

The two most commonly used absorbable dressings are Gelfoam and Surgicel. Gelfoam is an absorbable gelatin sponge that is readily available and inexpensive. It forms a scaffold for the formation of a blood clot. Surgicel is composed of oxidized and regenerated cellulose. It promotes coagulation better than Gelfoam. Unfortunately, Surgicel results in delayed healing and its use should be reserved for persistent bleeding or when Gelfoam is not available.

Absorbable packs may be used for primary and secondary hemostasis. Apply a piece of Gelfoam or Surgicel directly over the site of discrete bleeding or diffuse oozing. The material may be used for secondary hemostasis and be placed over an area that has clotted and stopped bleeding. This can serve as a "Band-Aid" to help prevent the clot from dislodging prematurely and the bleeding to restart. It can be placed over areas that have been chemically or electrically cauterized. An absorbable pack can be placed prior to packing the nasal cavity with a sponge/tampon or gauze. The absorbable pack will prevent the clot from becoming dislodged when the sponge/tampon or gauze is removed.

Insert the nasal speculum and identify the scabbed or bleeding site. Apply a piece of Gelfoam or Surgicel over the site. Allow a clot to form onto the absorbable packing. The nasal cavity may then be packed with a sponge/tampon, petrolatum gauze, or a balloon catheter if the Emergency Physician chooses.

Two additional absorbable dressings are topical thrombin and collagen. They are expensive, not usually available in the Emergency Department, and should be limited to circumstances where other hemostasis methods have failed. Topical thrombin is made from bovine thrombin. Place a piece of Gelfoam saturated with thrombin over the bleeding site. Thrombin converts fibrinogen to fibrin, bypassing the coagulation cascade, to form a clot. Collagen is available in multiple forms from a variety of sources. It promotes platelet aggregation and forms a scaffold for the formation of a clot. Cover the bleeding site with collagen followed by a piece of Gelfoam.

CHEMICAL CAUTERIZATION

The location of the bleeding is usually within the anterior nasal cavity, specifically on the anterior nasal septum. Sometimes no active bleeding is found at the time of the evaluation. Suctioning of the nasal cavity will remove clots and may allow the site to bleed and be visualized. A scabbed excoriation or an exposed blood vessel may be found along the nasal septum. Chemically cauterize these areas using silver nitrate applicators.

Insert the nasal speculum and identify the scabbed site or the exposed vessel. Apply the silver nitrate under direct vision by rubbing the applicator on the area immediately surrounding the scab or blood vessel. Apply the silver nitrate for 3 to 10 seconds. **Do not apply the applicator in any one spot for more than 10 seconds. This may cause mucosal necrosis and damage to the underlying cartilaginous septum. Do not apply the silver nitrate too excessively or in the same spot on both sides of the septum, as this may result in a septal perforation.** Apply a topical antibiotic ointment to the area. Consider placing a piece of Gelfoam or Surgicel over the site to help stabilize the clot.

A relatively dry field is required to use the silver nitrate applicator. Moderate-to-severe bleeding results in the silver nitrate coagulating the blood. It will not contact the mucosal tissue and bleeding will continue. Attempt to simultaneously suction the blood while using the silver nitrate applicator. Unfortunately, the suction often pulls off the coagulum and the bleeding continues. A final technique is to apply the silver nitrate centripetally around the bleeding site. This will cauterize the feeder vessels and may stop the bleeding. **Do not cauterize an area over 0.75 cm in diameter, as this can result in damage to the underlying cartilaginous septum.** Pack the nasal cavity with a sponge/tampon, petrolatum gauze, or a balloon catheter if these techniques fail.

ELECTRICAL CAUTERIZATION

Electrocautery can effectively control bleeding if the site is identified. **This technique is reserved for the experienced Otolaryngologist.** It can cause significant damage to the mucosa and cartilage in inexperienced hands. The technique of electrocautery is not discussed for these reasons.

RIBBON GAUZE PACKING

The traditional technique of anterior nasal packing consists of using 0.5 inch wide petrolatum impregnated gauze ribbon (**Figure 172-3**). This technique is extremely effective but not often used as it is cumbersome, time-consuming, and simpler methods exist (e.g., silver nitrate cautery, sponges/tampons, and balloon catheters).

Insert the nasal speculum. Grasp one end of the petrolatum gauze with a bayonet forceps. Insert the petrolatum gauze into the nasal cavity and along the nasal floor (**Figure 172-3A**). Tightly pack the nasal cavity in a layered fashion from bottom to top, extending as far back as possible toward the choanal arch (**Figure 172-3B**). **Be careful to avoid injuring the mucosa overlying the septum and the turbinates.** Cut the petrolatum gauze so that it protrudes approximately 2 cm from the nostril. Tape this loose end to the patient's cheek so that it does not accidentally pull the packing out. The

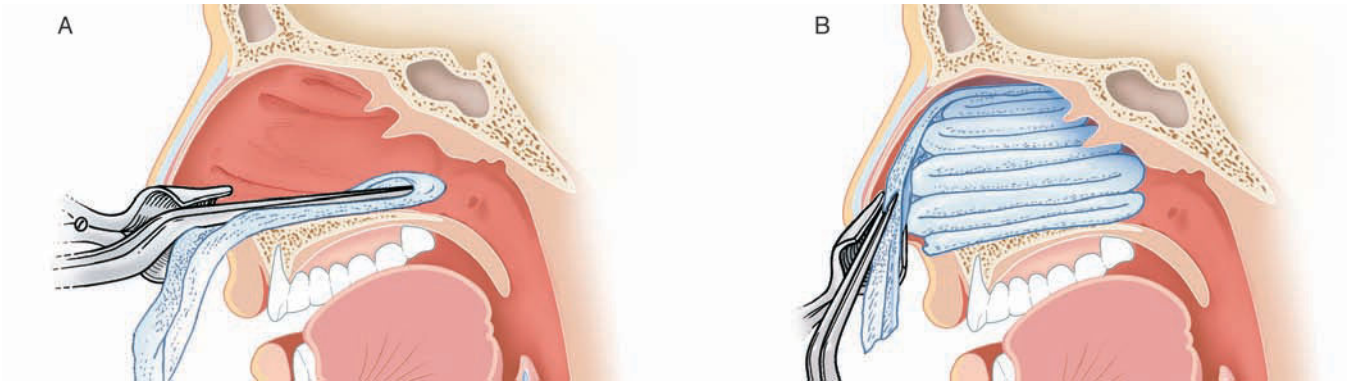


FIGURE 172-3. Anterior nasal packing using petrolatum (e.g., Vaseline) impregnated gauze ribbon. **A.** Insert a nasal speculum and begin packing inferiorly to superiorly. **B.** The gauze-packed anterior nasal cavity.

packing is later removed by gently pulling on this free end of gauze ribbon protruding from the nostril.

The pressure of one-sided anterior nasal packing can bow the septum contralaterally, allowing the packing to "loosen" and the bleeding to restart. Consider packing the contralateral anterior nasal cavity to maintain the septum in the midline and exert pressure on the bleeding site.

EXPANDABLE NASAL SPONGES/TAMPONS

One of the easiest, quickest, and most effective techniques to control anterior epistaxis is to insert an expandable sponge or tampon (e.g., Merocel packing). These packs are particularly useful when the bleeding is diffuse, a specific site cannot be clearly identified, or the bleeding is heavy. The packs come in various sizes (4.5, 6, 8, and 10 cm), shapes, and styles (**Figure 172-4**). Initially quite rigid, they soften and expand with the absorption of saline or surrounding blood. A 4.5 or 6 cm sponge is generally adequate for anterior epistaxis.

Prepare the sponge/tampon. Cut the string from the sponge/tampon as it is not necessary to remove the packing. The sponge/tampon is barely visible when properly inserted. The string hanging from the nostril is irritating to the patient and not cosmetically appealing. Lightly coat two-thirds of the sponge/tampon with a non-water-soluble lubricant (e.g., Vaseline) or antibiotic ointment (e.g., Neosporin). This will prevent premature expansion of the tampon from a water-soluble lubricant or antibiotic ointment, nasal secretions, or blood.

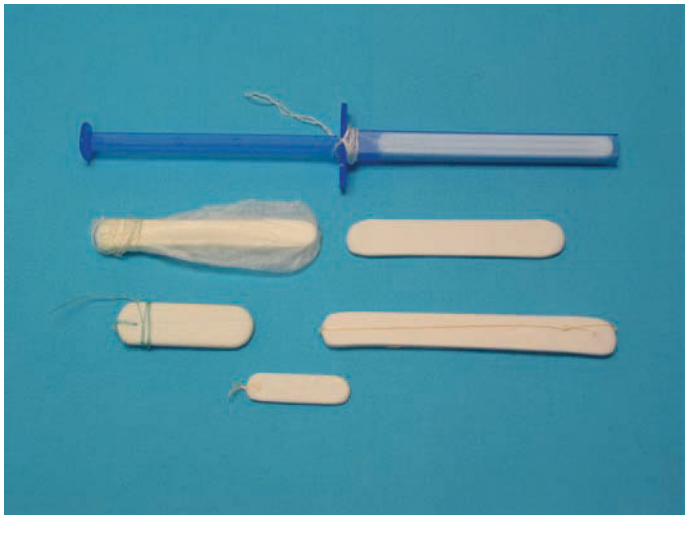


FIGURE 172-4. Various sizes, shapes, and styles of nasal sponges/tampons.

Insert and open the nasal speculum within the affected nasal cavity. Grasp the unlubricated end of the sponge/tampon with a bayonet forceps or the dominant thumb and index finger. Insert and advance the sponge/tampon just lateral to the nasal septum, in a vertical position, with the length of the pack directed along the floor of the nose (**Figure 172-5A**). Advance the sponge/tampon until it is completely within the nasal cavity. The sponge/tampon will expand from the blood and secretions within the nasal cavity (**Figure 172-5B**). Slowly drip 1 to 3 mL of tap water or saline onto the unlubricated tip of the sponge/tampon to help it expand more rapidly.

Inspect the oropharynx for bleeding. Persistent bleeding may be due to the septum bowing contralaterally. Pack the contralateral anterior nasal cavity with a sponge/tampon of equal length and size. Observe the patient for oozing or bleeding anteriorly or posteriorly. Continued bleeding requires removal of the sponge/tampon from the bleeding nasal cavity and insertion of a larger one, two small ones, or Vaseline gauze packing.

Keep several helpful hints in mind when using the nasal sponges/tampons. Trim large sponges/tampons to 5 to 6 cm in length. The extra length is not required for anterior epistaxis, is uncomfortable for the patient, and is more difficult to remove. The Rhino Rocket is a sponge/tampon within a plastic syringe-like device. Remove the sponge/tampon from the syringe-like device before inserting it. The device can generate significant force and result in mucosal tears, septal injuries, and turbinate injuries. Insert and advance the sponge/tampon rapidly to prevent premature expansion. There is no advantage to using a non-water-soluble antibiotic ointment versus a lubricant. The antibiotic ointment is more expensive and its antibacterial activity lasts only 2 to 4 hours. Insert two sponges/tampons side by side if the patient has a large nasal cavity.

Removal of the sponge/tampon is simple and quick. Apply 1 to 2 mL of tap water, saline, or a vasoconstrictor in a dropwise fashion to the tip of the sponge/tampon in the nostril. This will thoroughly hydrate the packing and ensure that it can be withdrawn atraumatically. Allow 5 to 10 minutes to ensure that the packing is completely hydrated. Grasp the end of the sponge/tampon with a hemostat. Place a kidney basin under the patient's nose. Pull quickly and parallel to the floor of the nasal cavity to remove the packing. Epistaxis after removal is often due to dislodgement of the clot. Use an absorbable pack or silver nitrate to stop the bleeding.

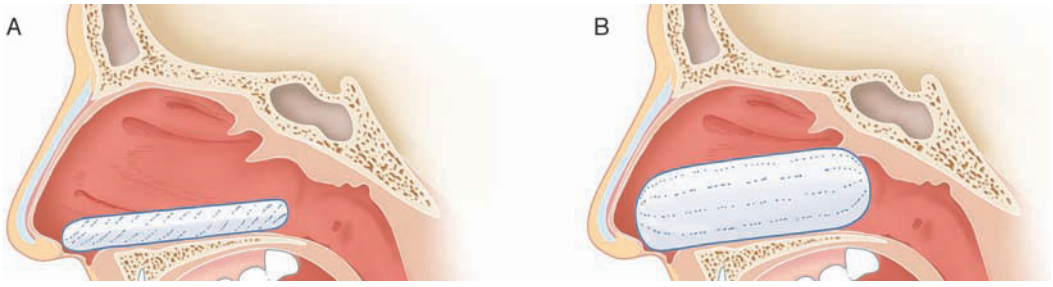


FIGURE 172-5. The expandable nasal sponge/tampon. **A.** Insertion along the floor of the nasal cavity. **B.** The expanded state.

Look at the sponge/tampon to identify the blood spot and the location of the bleeding.

INFLATABLE NASAL BALLOON CATHETERS

The development of plastic inflatable balloon catheters has simplified the management of epistaxis. The nasal balloons are easy to use and quick to place. They are available in a variety of sizes and shapes (**Figure 172-6**). They are available with anterior balloons, posterior balloons, or dual balloons. The anterior balloon fills the nasal cavity and acts as an anterior pack. The posterior balloon occludes the nasopharynx and acts as a posterior pack. The inflatable balloons are more expensive than other methods used to manage epistaxis. The increased cost is offset by decreased Emergency Physician contact time as compared with that required for petrolatum (e.g., Vaseline) gauze packing. The balloons have a maximal inflatable volume that is manufacturer-specific, noted on the packaging, and noted on the balloon's inflation hub.

Prepare the equipment. Select an anterior balloon catheter. A dual-balloon catheter may be used if an anterior balloon catheter is not available. Inflate the balloon with air to just below its maximum capacity. Observe and palpate the balloon for leaks. It may also be inflated in a cup of water to look for leaks. Completely deflate the balloon. Apply a lubricant over the catheter and balloon.

Insert the nasal speculum. **Insert the catheter with the distal bevel toward the nasal septum.** This prevents the distal end of the catheter from getting caught on the turbinates, damaging the mucosa overlying the turbinates, and causing a second source of epistaxis. Advance the catheter along the floor of the nasal cavity until just the inflation hub is protruding from the nostril (**Figure 172-7**). Inflate the balloon with air and 10 mL less than the maximum volume of the balloon (**Figure 172-7**). **Do not use saline or water to inflate the balloon.** Rupture of the balloon can result in aspiration if it is filled with liquid. **Do not inflate the balloon with more than the manufacturer's recommended volume.** If the patient complains of pain, the balloon may have been inflated larger than the nasal cavity. Slowly deflate the balloon in 2 mL increments until the pain subsides.

Observe the patient for continued bleeding. Increase the volume of the balloon to the maximum volume if the patient does not complain of pain. The balloon may cause a bowing of the septum to the contralateral side. If the bleeding continues, pack the contralateral anterior nasal cavity to keep the septum in the midline. Observe the patient for further bleeding from the nostril or into the nasopharynx. Continued bleeding suggests that the source is high in the nasal cavity or posterior. **The inflatable balloons do not always fill the upper portion of the nasal cavity.** Deflate the balloon, pack the high anterior nasal cavity with petrolatum gauze, and reinflate the balloon. Observe the patient for continued bleeding that would require a posterior pack, as described in the following sections.

RAPID RHINO

The Rapid Rhino Nasal Pac (Applied Therapeutics Inc., Tampa, FL) is a form of balloon catheter. The balloon is covered with a



FIGURE 172-6. Examples of some inflatable nasal balloon catheters.

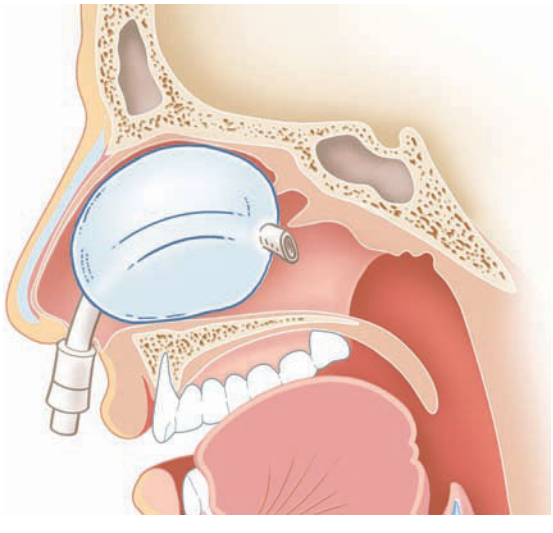


FIGURE 172-7. Inflation of an anterior balloon catheter to control anterior epistaxis.

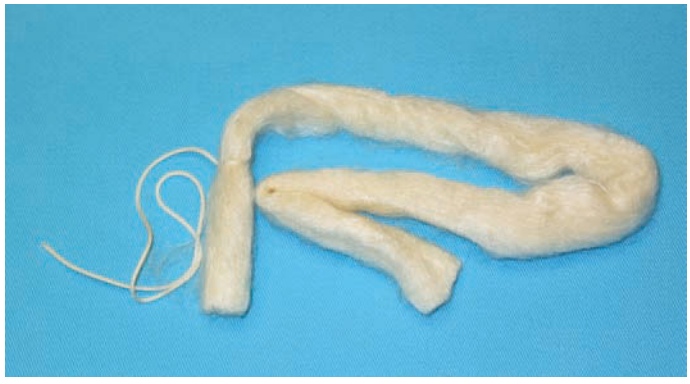


FIGURE 172-8. The ENTaxis nasal packing (Boston Medical Products, Westborough, MA).

hydrocolloid fabric that is self-lubricating, easy to insert, and promotes platelet aggregation. It is available in different lengths to accommodate children, anterior epistaxis, and posterior epistaxis. It is also available in a variety of sizes in both a unilateral balloon design and a bilateral balloon design with a single inflation port. The bilateral model allows for bilateral nasal packing with a single inflation port, maintaining equal pressure on both sides of the nasal septum. Dip the fabric covered balloon in sterile water for approximately 30 seconds to prelubricate it before insertion. Insert the balloon and inflate it as described previously. The advantage to this product is the ease of insertion, minimal bleeding upon removal, and patient comfort.[13]

ENTaxis NASAL PACKING

A relatively new anterior nasal packing is the ENTaxis (**Figure 172-8**). It is a natural polymer derived from seaweed and contains calcium alginate.[14] The packing provides hemostasis, has healing properties, and is atraumatically inserted and removed. Hydration with normal saline activates the calcium alginate and makes it pliable. The packing expands 300% and conforms to the anterior nasal cavity. It activates platelet aggregation to provide hemostasis, keeps the nasal mucosa moist, and gels into a smooth surface that allows easy removal.

Prepare the packing. The ENTaxis is packaged in a plastic tray with a tear-off paper lid. Peel the lid completely off the tray. Fill the tray with normal saline to saturate the packing. Remove the hydrated packing from the tray. Squeeze out the excess saline from the packing.

Insert a nasal speculum. Grasp the packing on the end opposite the string with a bayonet forceps. Insert the packing along the floor of the nasal cavity. Continue to insert the packing in an accordion-like fashion until the entire packing is within the nasal cavity. The packing will expand and gel to fill the nasal cavity. Secure the string to the patient's cheek or nose with a piece of tape.

Removal of the packing is simple and quick. The packing remains hydrated and in a gelled state while within the nasal cavity. Place a kidney basin under the patient's nose. Untape the string from the patient's face. Grasp the packing with a bayonet forceps. Gently withdraw the packing from the nasal cavity.

THROMBIN-JMI

THROMBIN-JMI Epistaxis Kit (Pfizer Pharmaceuticals, New York, NY) is a topical bovine thrombin approved for the management of epistaxis. It works on sites of minor bleeding and oozing. The thrombin causes fibrinogen in the blood to clot without the requirement of platelet activation. The kit contains one vial of thrombin, one vial of diluent, a needle and syringe, and a nasal delivery device.

Open the outer packaging to reveal a sterile inner tray with the kit components. Use the syringe with the needle to draw up the saline diluent. Inject the saline diluent into the THROMBIN-JMI vial. Gently swirl the vial to mix the components and reconstitute the thrombin powder. When completely dissolved, draw the thrombin solution into the syringe. Remove the needle from the syringe and attach the nasal delivery device. Insert the nasal delivery device into the nares. Depress the plunger to spray the thrombin solution onto the nasal mucosa. Remove the device. Allow the solution to form a clot. Apply additional thrombin solution if the bleeding continues. Consider applying a piece of Gelfoam to the newly formed clot to support it.

FLOSEAL

The Floseal Hemostatic Matrix (Baxter Healthcare Corporation, Hayward, CA) is composed of human-derived thrombin and bovine-derived gelatin. It stops bleeding fast and in up to 97% of cases.[15] The thrombin–gelatin matrix begins to break down in 3 to 5 days and is gone by 7 days. Floseal does not require platelet activation, allowing it to function in patients taking aspirin and other antiplatelet medications.

Floseal is provided in components that must be mixed. The process is more complicated than other thrombin products and can take several minutes. The kit contains all of the required components and supplies. Use the 5 mL syringe and attached needle to draw up the calcium chloride solution. Inject the calcium chloride solution into the lyophilized thrombin vial. Gently swirl the vial to mix the components and reconstitute the thrombin. Draw up the thrombin solution into the syringe. Gently transfer it into the bowl in the kit. Use the empty 5 mL syringe with a female Luer lock to aspirate the thrombin solution from the bowl into the syringe. Connect this syringe to the syringe containing the gelatin matrix granules. Push the plunger to fully transfer the thrombin solution into the gelatin containing syringe. This is considered "one pass." Transfer the gelatin–thrombin solution back and forth between the syringes for at least 20 passes. Disconnect the syringes. Attach one of the two applicator tips to the syringe containing the gelatin–thrombin solution.

Apply a small mound of the Floseal to the bleeding source. The Floseal must remain at the site for 2 minutes. Place a sterile saline-moistened gauze sponge over the Floseal mound to ensure it maintains a seal against the bleeding site. After 2 minutes, remove the gauze and inspect the site. If the gauze adheres to the clot or the Floseal, moisten it with sterile normal saline. If bleeding persists, insert the applicator tip through the Floseal mound and deliver fresh Floseal to the bleeding site. Remove any excess Floseal by gentle irrigation after the bleeding is controlled. Consider applying a piece of Gelfoam to the newly formed clot to support it.

WOUNDSEAL

WoundSeal for Nosebleeds (Biolife LLC, Sarasota, FL) was previously marketed as NoseBleed QR. It is an over-the-counter product that comes in a variety of applications to control bleeding. It is marketed to control epistaxis and external wounds of all types. It consists of a powder containing a hydrophilic polymer and potassium ferrate. When the powder comes in contact with blood, the polymer absorbs liquid and concentrates the red blood cells and plasma proteins under the powder to form a clot. The potassium ferrate releases iron to bind the blood proteins into a clot.

The WoundSeal powder is simple to apply. Open the blister pack. Roll the tip of the applicator stick in the powder to completely coat

it. Roll the powder coated applicator onto the nasal mucosa. Remove the applicator stick from the nasal cavity. Pinch the nostrils closed for 30 seconds. Reassess the nasal cavity for continued bleeding and the need for additional applications of the powder. Consider applying a piece of Gelfoam to the newly formed clot to support it.

ANKAFERD BLOOD STOPPER

Ankaferd Blood Stopper (ABS, Ankaferd Health Products LTD, Istanbul, Turkey) is a medicinal plant extract. It is approved in Turkey for the management of postsurgical dental bleeding and external hemorrhage.[16] ABS is not currently available in the United States and most other countries. It induces the rapid formation of a hemostatic protein network to control hemorrhage that is not dependent upon coagulation factors and platelets.[16] It has been successfully used to control epistaxis.[17] ABS may provide a new method to control epistaxis in the future.

POSTERIOR EPISTAXIS MANAGEMENT TECHNIQUES

A posterior source of the bleeding must be sought when epistaxis is bilateral, brisk, and not controlled with anterior nasal packing. It is estimated that 5% of all cases of epistaxis originate from a posterior source.[18] **The placement of a posterior nasal pack is extremely uncomfortable.** The patient may require, on some occasions, intravenous sedation and analgesia in addition to the topical anesthesia previously described. Consider spraying the patient's soft palate, uvula, and oropharynx with a topical anesthetic spray (e.g., Cetacaine). This will minimize their gag reflex during the placement of the posterior pack.

The rationale behind placing a posterior pack is that the occlusion of the choanal arch provides a semirigid buttress against which anterior nasal packing may be placed, allowing adequate hemostasis to be achieved. This buttress may be formed from either a gauze pack, a 30 mL Foley catheter, an expandable nasal sponge/tampon, or an inflatable nasal balloon catheter. From a practical standpoint, the Foley catheter and inflatable nasal balloon catheter are most easily tolerated by the patient. The inflatable nasal balloon catheter is definitely the easiest to place, as it has two balloons that serve as both anterior and posterior packs. **An anterior nasal pack is always required on the side of a posterior pack.** Strongly consider inserting a contralateral anterior nasal pack to maintain the septum in the midline.

TRADITIONAL (GAUZE ROLL) PACKING

The traditional technique of posterior nasal packing involves using rolled gauze, dental rolls, or tonsil packs placed through the oropharynx (**Figure 172-9**). This technique is difficult, time-consuming,

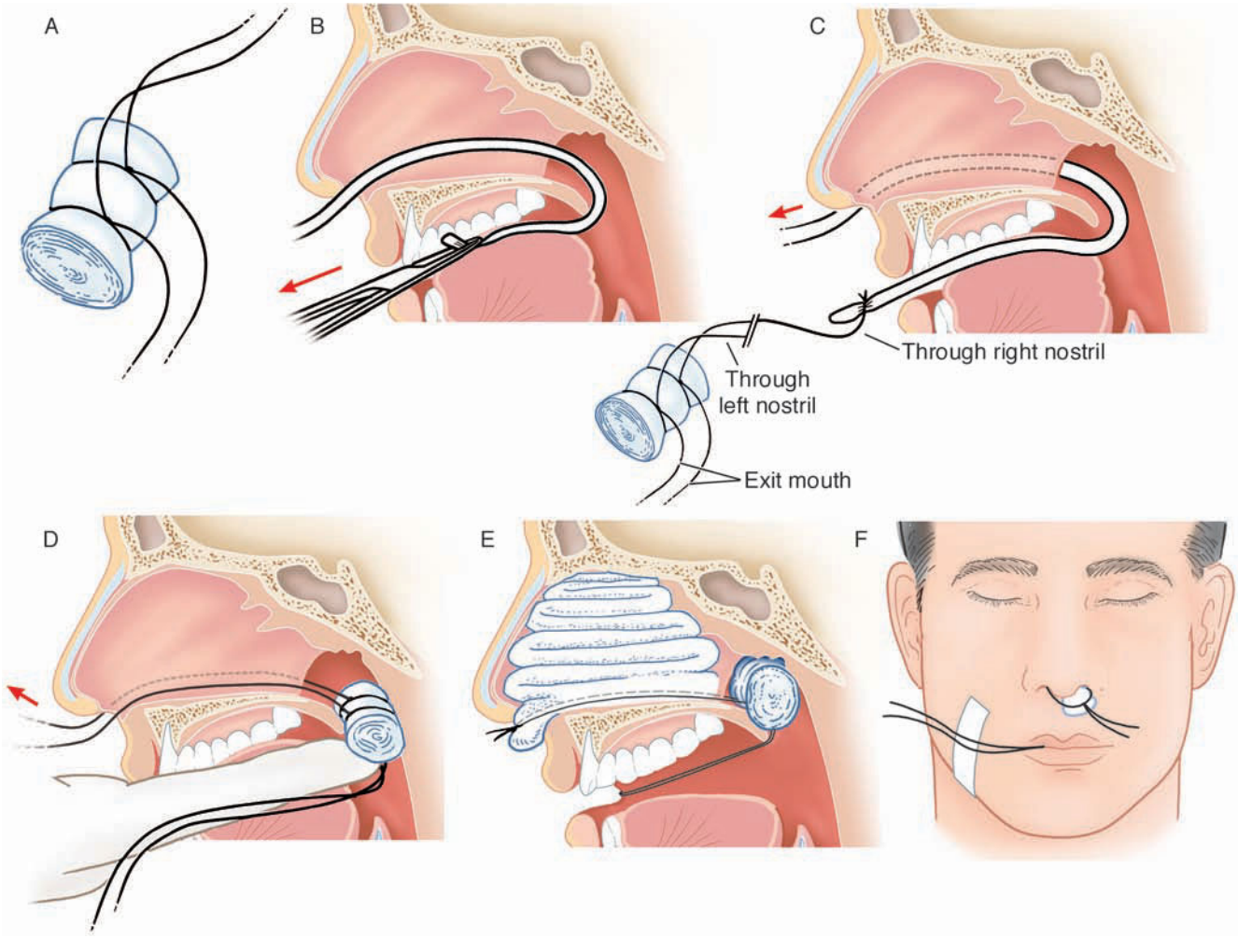


FIGURE 172-9. The traditional technique of placing a posterior nasal pack. **A.** Preparation of the pack. **B.** A red rubber catheter inserted through the nostril and pulled out the mouth. **C.** The pack is attached to the two red rubber catheters. **D.** The pack is pulled into place. Use a finger to pass the pack around the soft palate and uvula. **E.** An anterior nasal pack has been placed. **F.** The ties of the posterior pack are secured.

messy, requires many supplies, and is not well tolerated by the patient. Easier and quicker techniques exist. For these reasons, this technique is not often performed.

Prepare the equipment. Gather the required equipment on a bedside procedure table. Use 3 inch long dental rolls or tonsil packs. An alternative is to use 3 inch wide and 36 inch long petrolatum gauze. Form a tight cylindrical roll with the gauze (**Figure 172-9A**). Tie two pieces of umbilical tape or 0 silk suture around the pack to divide it into thirds (**Figure 172-9A**).

Anesthetize and vasoconstrict both nasal cavities. Apply a topical anesthetic spray to the soft palate, uvula, and oropharynx. Lubricate a red rubber catheter. Pass the red rubber catheter through one nostril and along the floor of the nasal cavity. Advance the catheter so that the tip is visible in the patient's oropharynx. Grasp the tip of the catheter with a hemostat or forceps and pull it out the patient's mouth (**Figure 172-9B**). Clamp the free ends of the catheter together. Pass a second red rubber catheter through the other nostril and out the patient's mouth.

Insert the posterior pack. Tie the free end of one piece of the umbilical tape or silk surrounding the packing to the distal end of one red rubber catheter exiting the patient's mouth (**Figure 172-9C**). **Tie the knots tightly.** Tie the second piece of umbilical tape or silk to the second red rubber catheter. Pull the proximal ends (i.e., the portion exiting the nostrils) of both red rubber catheters until the packing is against the choanae (**Figure 172-9D**). It may be necessary to place a finger into the patient's mouth and push the pack behind the soft palate and uvula if it gets caught (**Figure 172-9D**). Place a hemostat on both pieces of umbilical tape exiting the nostrils. Apply slight traction with the hemostat to maintain the posterior pack against the choanae. Instruct an assistant or the patient to hold the hemostat. Untie or cut the red rubber catheters from the umbilical tape or silk sutures.

Place an anterior pack and secure the posterior pack. **An anterior nasal pack is always required when placing a posterior nasal pack.** The anterior pack may be an expandable sponge/tampon, petrolatum gauze, or a balloon catheter (**Figure 172-9E**). Tie the umbilical tape or silk exiting each nostril together (**Figure 172-9F**). **Always place a piece of cotton or gauze between the knot and the columella to prevent pressure necrosis (Figure 172-9F). Tie the umbilical tape or silk snugly but not too tight to hold the posterior pack in place and not apply pressure to the choanae or the columella.** Tape the umbilical tape or silk exiting the patient's nostril and mouth to their face (**Figure 172-9F**).

Removal of this packing is simple and requires several stages. Remove the anterior packing. Thoroughly examine the mucosa to make sure that the epistaxis has not restarted. Suction any clots and blood from the nasal cavity. Rebleeding requires the placement of a new anterior pack if it cannot be controlled with an absorbable dressing or silver nitrate. Cut the knot, securing the umbilical tape or silk around the columella. Pull the pieces of umbilical tape or silk exiting the patient's mouth to remove the posterior pack completely.

FOLEY CATHETER TECHNIQUE

A Foley catheter may be used to provide a posterior buttress. Using a Foley catheter is easy, quick, and simple. Select a 14 French Foley catheter with a 30 mL balloon. Inflate the balloon with air. Ensure the integrity of the balloon. Some Emergency Physicians cut off the portion of the Foley catheter distal to the balloon. They believe that the distal tip is irritating to the patient and may stimulate their gag reflex. The practice of cutting off the distal tip is based purely on Emergency Physician preference. Be careful to not cut the balloon or its attachment to the catheter.

Lubricate the distal third of the Foley catheter. Insert the Foley catheter into the nostril and along the floor of the nasal cavity. Advance the catheter until the tip is visible in the patient's oropharynx. Inflate the balloon with 7 to 10 mL of air. **Do not use saline, as the fluid can result in aspiration if the balloon ruptures.** Withdraw the catheter to lodge the balloon against the choanal arch (**Figure 172-10A**). If the balloon withdraws into the nasal cavity, advance it back into the nasopharynx. Add an additional 3 to 5 mL of air and withdraw the catheter. Continue the process by adding 3 to 5 mL aliquots of air until the balloon lodges against the choanal arch. Inflate the balloon with an additional 3 to 5 mL of air and the soft palate just begins to bulge. The balloon is overinflated if the soft palate bulges or the patient experiences pain.

Place an anterior pack and secure the Foley catheter. Apply slight traction to maintain the balloon against the choanal arch. Instruct an assistant or the patient to hold the Foley catheter. Place the anterior pack using an expandable sponge/tampon, petrolatum gauze, or a balloon catheter. **Place a piece of cotton or gauze against the columella and nasal ala to prevent pressure necrosis.**[19] Place an umbilical clamp on the Foley catheter and over the protective padding (**Figure 172-10B**). **The clamp must hold the**

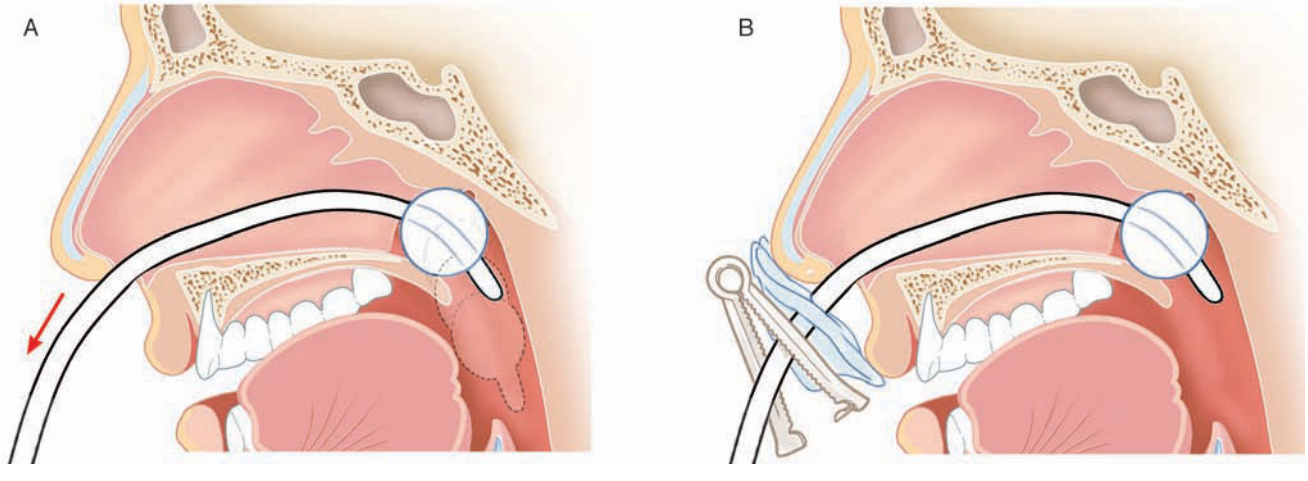


FIGURE 172-10. The Foley catheter technique. Insert a Foley catheter along the floor of the nasal cavity until the tip is visible in the patient's oropharynx. **A.** Inflate the balloon and withdraw the catheter to lodge the balloon against the choanal arch. **B.** Secure the Foley catheter.

balloon against the choanal arch without applying pressure to the choana or columella.

Removal of this packing is simple and requires several stages. Cut the open loop of the umbilical clamp with a scissors. Open the jaws of the clamp and remove them from the Foley catheter. Always maintain a grasp of the catheter and apply slight traction to keep the balloon in place. Remove the anterior packing. Thoroughly examine the mucosa to make sure that the epistaxis has not restarted. Suction any clots and blood from the nasal cavity. Rebleeding requires the placement of a new anterior pack if it cannot be controlled with an absorbable dressing or silver nitrate. Deflate the balloon and pull the catheter out the patient's nostril.

EXPANDABLE NASAL SPONGES/TAMPONS

Many Emergency Physicians prefer to use an 8 or 10 cm sponge/tampon rather than the other techniques of posterior packing. This technique is easy, quick, simple, and inexpensive. The technique for insertion and removal is exactly the same as for the anterior packing technique described previously. The Epistat II (Medtronic Xomed Inc., Jacksonville, FL) is a combination device with an anterior nasal sponge/tampon and a posterior balloon. It provides better posterior hemostasis than a sponge/tampon alone.

INFLATABLE NASAL BALLOON CATHETERS

A dual-balloon catheter can be used when a posterior pack is required. These catheters come in many types and styles (**Figure 172-6**). They are expensive but easy to use and quickly placed. The smaller distal balloon obstructs the choanal arch and acts as a posterior pack (**Figure 172-11**). The larger proximal balloon fills the nasal cavity and acts as an anterior pack (**Figure 172-11**). The distal balloon holds 10 mL and the anterior balloon holds 30 mL in most dual-balloon systems. Note the manufacturer's maximum volume recommendations on the package and on the inflation ports of the balloons.

Prepare the equipment. Fully inflate both balloons with air. Observe and palpate the balloons for leaks. They may also be inflated in a cup of water to look for leaks. Completely deflate both balloons. Apply a lubricant over the catheter and balloons.

Insert the catheter with the distal bevel toward the nasal septum. This prevents the distal end of the catheter from getting caught on the turbinates, damaging the mucosa overlying the turbinates, and causing a second source of epistaxis. Advance the catheter along the floor of the nasal cavity until the distal tip is visible in the patient's oropharynx.

Inflate the distal balloon with 4 to 5 mL of air. **Do not use saline or water to inflate the balloon.** Rupture of the balloon can result in aspiration if it is filled with liquid. Withdraw the catheter to lodge the balloon against the choanal arch (**Figure 172-11**). If the balloon withdraws into the nasal cavity, advance it back into the nasopharynx. Add an additional 2 to 3 mL of air and withdraw the catheter. Continue this process until the balloon lodges or the maximum balloon volume is reached. Inflate the anterior balloon with 20 to 25 mL of air.

Observe the patient for bleeding. Inflate both balloons with additional aliquots of air until the bleeding stops or the maximum balloon volume is reached. The balloon does not always fill the high anterior nasal cavity. Deflate the anterior balloon, pack the high anterior nasal cavity with Vaseline gauze, and reinflate the anterior balloon. Place an anterior pack contralaterally if the bleeding continues to maintain the septum in the midline and apply pressure to the ipsilateral nasal cavity.

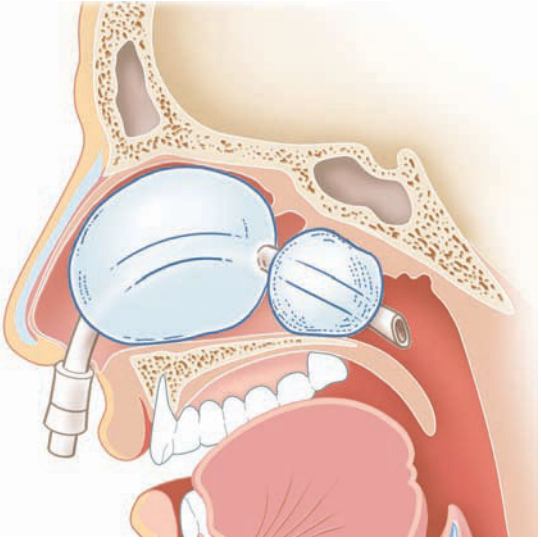


FIGURE 172-11. Placement of a dual-balloon catheter.

SPHENOPALATINE ARTERY BLOCK

This technique is a last resort when an Otolaryngologist is not available, the hemorrhage is unremitting, and other methods to control the hemorrhage have failed. Local anesthetic solution is injected into the pterygopalatine canal to occlude the sphenopalatine artery. The local anesthetic solution can cause pressure necrosis of the adjacent nerves within the bony canal.

Place the patient supine with their mouth open. Apply a topical anesthetic spray to the hard palate. Identify the greater palatine foramen. Insert a 27 gauge needle into the mucosa of the hard palate, 1 cm medial to the gum line between the junction of the second and third maxillary molars. Probe this area with the needle until it falls into the greater palatine foramen. Inject 0.25 mL of local anesthetic solution containing epinephrine into the mucosa overlying the greater palatine foramen. Arm a 3 or 5 mL syringe containing local anesthetic solution with epinephrine with a 22 or 25 gauge needle. Insert the needle approximately 25 to 28 mm into the greater palatine foramen. Inject 3 mL of the local anesthetic solution.

SURGICAL INTERVENTION

Consult an Otolaryngologist when the epistaxis is difficult to control by the described methods, as surgical intervention is then indicated. Surgical therapy may include septoplasty, endoscopic cauterization, arterial ligation (internal maxillary artery, sphenopalatine artery, anterior and posterior ethmoid arteries, external carotid artery), or embolization.[20]

PEDIATRIC CONSIDERATIONS

Epistaxis is a common childhood symptom that may prompt an evaluation in the Emergency Department. Generally, the management of a child with acute epistaxis is straightforward. The source of bleeding is from the anterior one-third of the nasal septum, just posterior to the squamous-mucosal junction in the majority of children. The etiology is often due to digital manipulation, infection, allergic rhinitis, a coagulopathy, a foreign body, trauma, medications, a neoplasm, and surgery.

The principles of management in the pediatric population are similar to those of adult patients. Active bleeding requires immediate attention. The child needs to be assessed for any hemodynamic instability or airway compromise. A brief history should be

obtained during the initial stages of treatment. The minimal equipment required for initial evaluation includes a headlight, Yankauer suction, Frazier tip suction, a small nasal speculum, and a tongue depressor. Additional supplies may be required, as well. A more comprehensive list of equipment and medications has been outlined earlier in this chapter.

After managing any life-threatening injuries and ensuring hemodynamic stability, the goal is to identify the bleeding source. Apply an anesthetic and vasoconstrictor. Evacuate any remaining clot from the nasal airway and inspect the mucosa. If the bleeding source is identified, the vessel should be cauterized with silver nitrate. Once the mucosa has been cauterized, apply a thin piece of oxidized cellulose (i.e., Surgicel) or Gelfoam that has been impregnated with an antibiotic ointment over the site to help stabilize the clot. Place an anterior nasal pack if chemical cauterization fails to control the bleeding. Expandable nasal sponges/tampons are readily available and are relatively easy to place. Trim the sponge/tampon to an appropriate length prior to insertion. Consult an Otolaryngologist if the bleeding cannot be controlled, if there are concerns that the bleeding source is from a posterior location, and for any postsurgical patient.

Once the presenting symptoms have been addressed, the underlying cause should be identified and treated. For patients with epistaxis secondary to digital manipulation, antibiotics ointment and nasal saline should be used to minimize crusting and to hydrate the mucosa. Antibiotic therapy is indicated in cases of acute sinusitis and adenoiditis. Coagulopathy must be considered when a patient presents with recurrent epistaxis. Sandoval et al found that 30% of children who presented with recurrent epistaxis had a diagnosable coagulopathy.[21] Von Willebrand's disease was noted to be the most common disorder identified. Serology should include a CBC, PT, PTT, and INR in patients whose history suggests heavy bleeding, recurrent bleeding, or a personal or family history of bleeding abnormalities.

AFTERCARE

The postprocedural care of patients with anterior epistaxis is just as important as the initial control of bleeding. All patients with nasal packing require prophylactic oral antibiotic therapy with adequate coverage for *Staphylococcus aureus, Streptococcus pneumoniae, Haemophilus influenzae*, and *Moraxella catarrhalis*. This is due to the significant risk of developing sinusitis and toxic shock syndrome. Arrange follow-up with an Otolaryngologist within 24 to 48 hours. Remove the packing in 48 to 72 hours if the patient experienced only minimal blood loss and was hemodynamically stable.

Inform the patient that the anterior pack is "uncomfortable." Acetaminophen will provide any required analgesia. Avoid aspirin containing compounds and nonsteroidal anti-inflammatory drugs, as they can contribute to further bleeding. Instruct the patient to apply saline nasal spray to the packing or each nostril three or four times per hour while awake. The use of a humidifier at home will aid in preventing drying of the packing or the nasal mucosa. The patient must avoid nose picking and nose blowing. Instruct the patient on the proper technique to apply pressure on the nose if bleeding restarts. Such pressure should be maintained for 20 minutes. Continued bleeding calls for a return to the Emergency Department. The patient should also return for increased nasal pain, fever, or any symptoms related to blood loss (e.g., chest pain, dyspnea on exertion, dizziness, light-headedness, presyncope, shortness of breath, and syncope).

Patients with unstable vital signs, uncontrollable bleeding, posterior packing, or serious concomitant medical problems will require hospitalization. Patients with posterior nasal packs require consultation with an Otolaryngologist and admission to a telemetry or intensive care unit. They must be monitored for respiratory distress, hypoxia, hypotension, anemia, and cardiac sequelae. It has been estimated that 40% of patients with posterior nasal packing eventually require intubation.[18] The nasal ala and columella must be evaluated continually in order to prevent pressure necrosis.

Patients with a posterior nasal pack may experience hypoxemia and hypercarbia. The etiology of these phenomena, called the nasopulmonary reflex, is unknown. The PaO_2 may decrease 7.5 to 15 mmHg. The $PaCO_2$ may increase 7 to 15 mmHg. The nasopulmonary reflex is more worrisome in patients with underlying lung disease or comorbid conditions.

COMPLICATIONS

The complications associated with epistaxis are variable, wide-ranging, and estimated to be from 2% to 69%.[22] Epistaxis may be complicated by hemorrhage, hypoxemia, hypovolemia, circulatory collapse, and airway compromise. Complications resulting from the treatment of epistaxis include nasal septal perforation, sinusitis, otitis media, toxic shock syndrome, aspiration, alar necrosis, and hypoxia from intrapulmonary shunting due to the stimulation of the nasopulmonary reflex.[23]

The majority of complications can be prevented by using proper technique, providing supplemental oxygen when not contraindicated, ordering appropriate prophylactic antibiotics, arranging appropriate hospitalization if indicated, obtaining an Otolaryngology consultation, and arranging for adequate follow-up.

SUMMARY

Epistaxis is a common condition that affects 10% to 13% of the general population. The key to successful management includes a prompt and thorough evaluation of the patient, an accurate diagnosis of the problem, and rapid control of the bleeding. Ninety percent of cases of epistaxis stem from an anterior source and can be controlled with either chemical cautery or nasal packing. Posterior bleeding requires the use of both a posterior pack and anterior packing. All patients with nasal packing require prophylactic antibiotics to prevent sinusitis and toxic shock syndrome. Follow-up is required in 24 to 72 hours with an Otolaryngologist or the Emergency Department to remove the nasal packing.

173 Laryngoscopy

Steven Charous

INTRODUCTION

Evaluation of the larynx can be crucial in the diagnosis and management of common and life-threatening disorders. The approach to the patient with laryngeal dysfunction begins with obtaining a complete history. Symptoms may be related to any of the three primary functions of the larynx. These are protection of the lower airway from aspiration, a conduit of the airway, and phonation. Symptoms may include aspiration, cough, dysphagia, odynophagia, dyspnea, or hoarseness. Otalgia may be a referred symptom from the larynx and transmitted by a branch of the vagus nerve. Information regarding patient age, onset, duration, severity, and progressive nature of the process is necessary. Determine the patient's past medical history including prior intubations, neck trauma, reflux esophagitis, similar previous episodes, and other

TABLE 173-1 Summary of the Advantages and Disadvantages of the Different Techniques used to Perform Indirect Laryngoscopy

	Handheld mirror	Per-oral flexible endoscopy	Per-oral rigid endoscopy	Nasal flexible endoscopy
Gag reflex	Moderate	Moderate	Moderate	Minimal
Visual clarity	Good	Good–distorted	Superior	Good–distorted
Anesthesia required	Occasionally	Yes	Occasionally	Yes
Observe larynx during speech	No	No	No	Yes
Patient cooperation	Necessary	Necessary	Necessary	Not necessary
Approximate equipment cost	Minimal	$4500	$4500	$4500
Photodocumentation possible	No	Yes	Yes	Yes

systemic diseases. The social history, including smoking and alcohol usage, needs to be investigated. Medications, allergies, and over-the-counter drugs should be reviewed.

Perform a physical examination, including a complete head and neck examination, once the history has been obtained.[1] Listen for stridor and watch for accessory muscle breathing. Consciously and critically evaluate the patient's voice to hear breathiness, clarity, and volume. Inspect the ears, nose, oral cavity, oropharynx, and nasopharynx. Careful palpation of the neck is extremely important. Note any lymphadenopathy and neck masses. This must include their size, location, tenderness, and mobility. Palpate the larynx and note any crepitus (the lack of crepitus on lateral movement of the larynx over the vertebral bodies can be indicative of a laryngeal or hypopharyngeal mass), movement with swallowing, and asymmetry. This can help in determining the extent of a disease process.

Visualize the larynx after performing a complete history and physical examination, with the exception of true airway emergencies. This allows the Emergency Physician to examine the larynx in context to the patient's symptoms and other physical findings. It also allows a rapport to develop between the patient and Emergency Physician prior to undergoing a mildly invasive procedure.

There are four methods of performing indirect laryngoscopy: mirror laryngoscopy, nasal flexible fiberoptic laryngoscopy, oral flexible fiberoptic laryngoscopy, and rigid telescopic laryngoscopy. The following is a complete description of the procedure involved in performing each of these techniques. An excellent pictorial source for viewing normal and pathological conditions of the larynx may be found in Bruce Benjamin's *Diagnostic Laryngoscopy: Adults and Children*.[2] **Table 173-1** reviews the advantages and disadvantages of each procedure. Each method allows visualization of the larynx with different degrees of distortion (**Figure 173-1**).

ANATOMY AND PATHOPHYSIOLOGY

The larynx occupies the central neck and is located within the hypopharynx[3,4] (**Figures 173-2 & 173-3**). Lateral to the larynx are the pyriform sinuses, the pharyngeal recesses that are the primary route for food to pass into the esophagus. The basic framework of the larynx consists of the thyroid cartilage, cricoid cartilage, epiglottic cartilage, arytenoid cartilage, and the hyoid bone. The shield-like thyroid cartilage supports the soft tissues of the larynx. It is connected to the hyoid bone via the thyrohyoid membrane and is attached to the cricoid cartilage via the cricothyroid membrane and at the cricothyroid joint. The signet ring-shaped cricoid cartilage is the only complete cartilaginous ring in the larynx. On top of its posterior portion sits the paired arytenoid cartilages. The arytenoid cartilages are somewhat shaped like an inverted "T." Each has a body, a muscular process, and a vocal process. The aryepiglottic folds connect the epiglottis to the top portion of the arytenoid body. The vocal ligament attaches the vocal process to the thyroid cartilage. The cricoarytenoid muscles attach to the

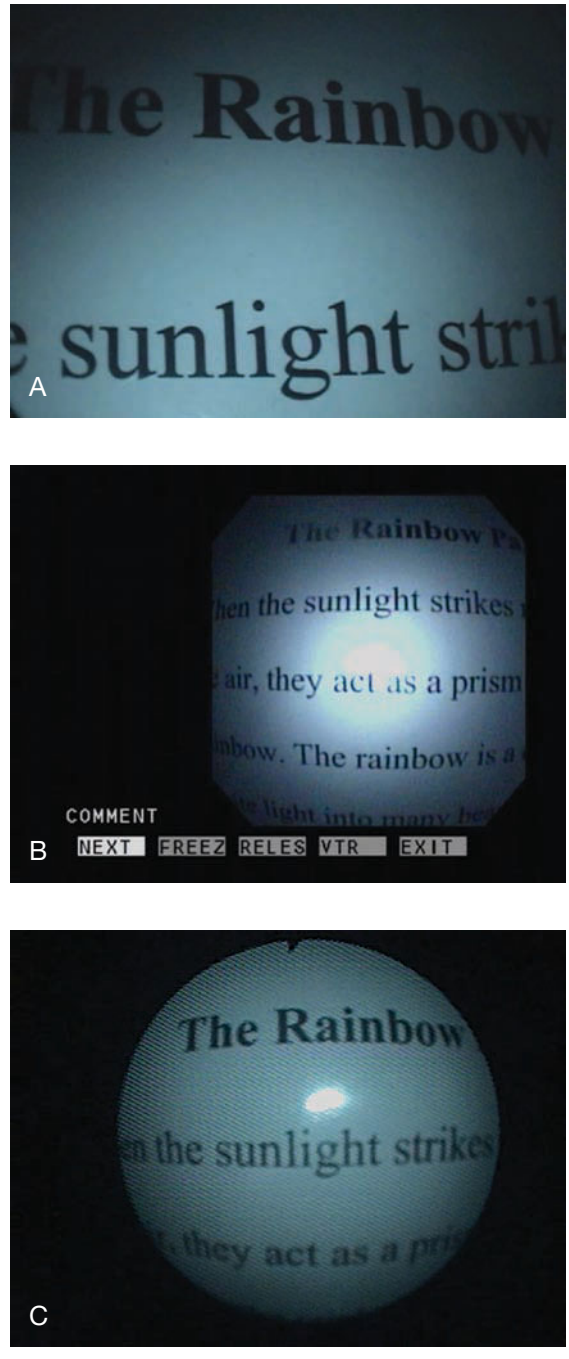


FIGURE 173-1. Visualization through the endoscopes. **A.** Endoscopic view through the 90° rigid telescope. Note the magnification, clarity, and breadth of view. **B.** Endoscopic view through flexible fiberoptic scope. Note the distortion and limited view as compared to the view through the rigid scope. **C.** Endoscopic view through the "chip-in-tip" scope. Note the larger field of vision with minimal distortion.

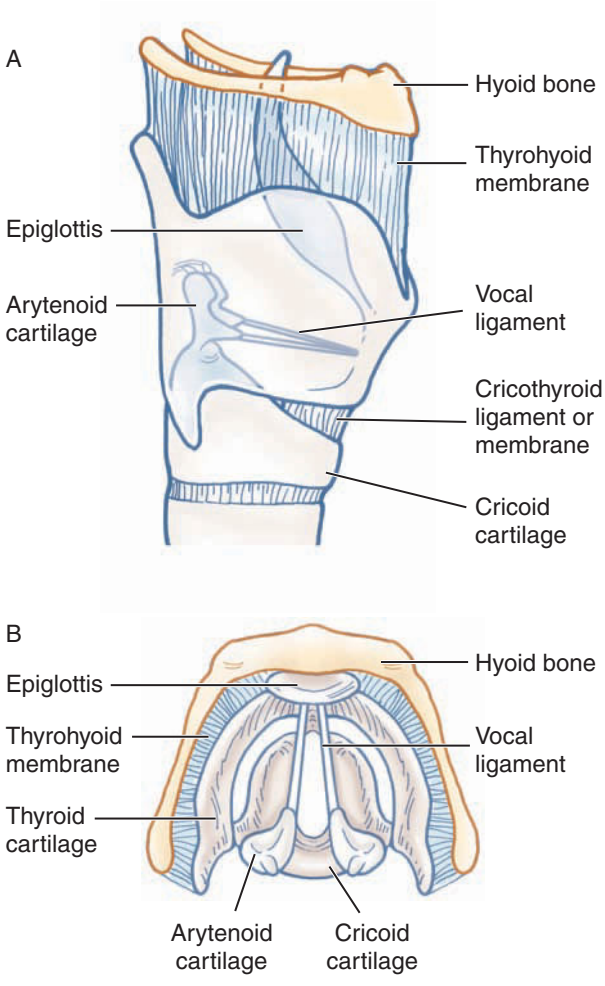


FIGURE 173-2. The laryngeal framework. **A.** Lateral view. **B.** Superior view.

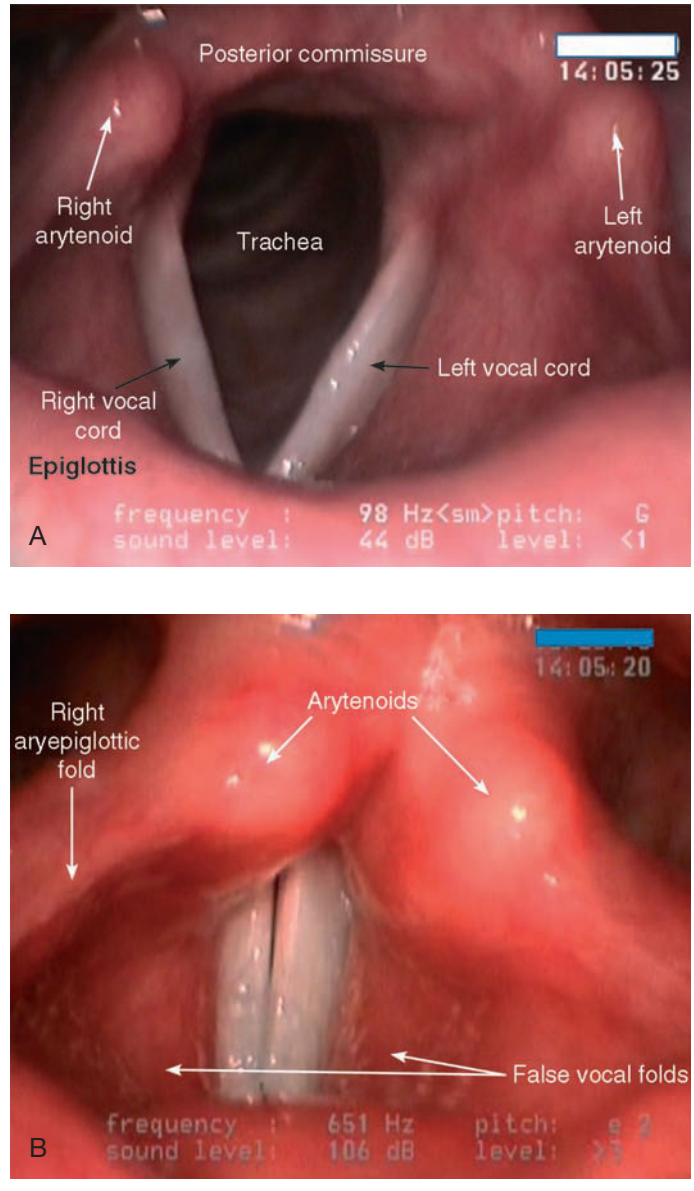


FIGURE 173-3. Endoscopic view of the laryngeal anatomy. **A.** Vocal cords open. **B.** Vocal cords closed.

muscular process. The epiglottic cartilage is leaf-shaped and forms the anterior wall of the laryngeal entranceway. Its main portion projects posterior to the tongue base. It folds downward over the larynx during swallowing to aid in protecting the laryngeal opening from aspiration.

The muscles associated with the larynx may be divided into extrinsic muscles and intrinsic muscles. The extrinsic muscles move the larynx as a unit and can be further subdivided into those muscles that elevate the larynx (stylohyoid, digastric, geniohyoid, and stylopharyngeus) and those that depress the larynx (omohyoid, sternohyoid, and sternothyroid). The intrinsic muscles are involved with vocal cord mobility and all cause adduction with the exception of the cricoarytenoid muscle that causes abduction. Innervation to the intrinsic laryngeal muscles is via the recurrent laryngeal nerve, a branch of the vagus nerve (cranial nerve X). The cricothyroid muscle is the only muscle innervated by the external branch of the superior laryngeal nerve, a branch of the vagus nerve. All of the laryngeal muscles and cartilages are covered with respiratory epithelium.

Just superior to the vocal cords is a recess called the laryngeal ventricle. Just superior to the ventricle are the false vocal folds. These are rounded protrusions rich in mucous secreting glands. The supraglottic larynx is defined as that portion of the larynx extending from the tip of the epiglottis to the laryngeal ventricle. The glottic larynx contains the true vocal cords and extends approximately 5 to 7 mm inferiorly. The subglottis extends from the inferior glottis to the inferior edge of the cricoid cartilage.

The primary function of the larynx is to protect the airway from the aspiration of food particles. A complex reflex arc, with the glossopharyngeal nerve (cranial nerve IX) mediating the sensory arm and the vagus nerve (cranial nerve X) mediating the motor arm, occurs with swallowing. With each swallow the larynx elevates, the aryepiglottic folds squeeze medially, the epiglottis folds posteriorly over the larynx, and the true and false vocal folds close tightly. This allows the food bolus to pass around the larynx, into the pyriform sinuses, and subsequently into the esophagus. Any alteration or disturbance in the reflex arc may predispose a patient to aspiration.

Phonation occurs with adduction of the vocal cords as air passes from the trachea through the vocal cords. The mucosa overlying the muscles of the vocal cords undulates and the two vibrating vocal cords produce sound. Anything that alters the mucosal wave of the vocal cords, impairs adduction, or changes the configuration of vocal cord alignment will result in decreased phonatory performance. Note that mucosal wave abnormalities can only be observed with videostroboscopy of the larynx. Many things can change a person's voice. This includes inflammation, thick mucous, vocal cord

paralysis, and tumors. Be careful and define hoarseness as a change in the patient's vocal quality. What may be normal for one patient may not be for another.

The larynx is crucial in respiratory activity. Inspiration signals the recurrent laryngeal nerve to stimulate vocal cord abduction. Impairment in abduction, unilaterally or bilaterally, can lead to respiratory compromise.

INDICATIONS

Have a very low threshold for examining the larynx. The diagnostic value of laryngoscopy greatly outweighs the minimal discomfort associated with the quick procedure. Any patient presenting with an allergic reaction, angioedema, acute hoarseness or voice changes, symptoms of aspiration, shortness of breath, a foreign body sensation, hemoptysis, stridor, exposure to ingested caustic agents, exposure to hot fumes or gasses, exposure to caustic fumes or gasses, or any other symptom that may be related to the larynx should have laryngoscopy performed as part of a complete physical examination.

CONTRAINDICATIONS

There are no absolute contraindications for laryngoscopy. Patients with severe respiratory compromise, such as a child with suspected epiglottitis, should have laryngoscopy performed in the Operating Room (or in a controlled area) with an Anesthesiologist, intubation equipment, and tracheotomy instrumentation ready for use. Performing laryngoscopy in the respiratory distressed patient can lead to increased distress and ventilatory collapse if laryngospasm ensues. Use caution when performing laryngoscopy in a patient with a high-grade airway obstruction, a supraglottic expanding hematoma, or significant laryngeal trauma. In general, the patient must be able to follow instructions and cooperate with the examination.

EQUIPMENT

Anesthesia and Vasoconstriction

- 10% lidocaine spray
- 20% benzocaine spray
- 2% tetracaine spray
- 4% cocaine
- 3% ephedrine or Neo-Synephrine spray
- Cotton pledgets

Scopes

- #4 or #5 dental mirror, with or without magnification
- 3 to 5 mm diameter flexible fiberoptic laryngoscope; 3 mm is better for children
- 90° rigid laryngoscope

Light Sources

- Headlight for mirror examinations
- 125 to 250 watt halogen or xenon light sources for fiberoptic laryngoscopes

Miscellaneous

- Alcohol lamp, heated beads, or glass of warm water for mirror examination
- 4 × 4 gauze squares
- Water-soluble lubricant
- Antifog solution
- Video camera and equipment for teaching and photodocumentation, optional



FIGURE 173-4. Basic equipment required for examination of the larynx in the ambulatory setting. Included are the rigid 90° telescope, dental mirror, flexible fiberoptic scope, gauze, oral anesthetic, antifog solution, and a light source. Not included is topical spray for nasal decongestion and anesthesia.

Set up all of the required equipment on a bedside procedure table (**Figure 173-4**). Prepare several different endoscopes, if available. If one fails, or is inadequate, another will be immediately available. The availability of multiple endoscopes allows the Emergency Physician to choose the scope and technique of their choice.

The flexible fiberoptic scopes are comprised of fiberoptic strands and lenses along its length. Do not manipulate or bend it into acute angles. Do not place objects onto the scope. Do not use abrasive materials (i.e., gauze, paper towels) to wipe the lens at the end of the fiberoptic cord.

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. **Patient reassurance and relaxation is of the utmost importance in obtaining excellent visualization of the larynx.** This can be achieved by reviewing what can be expected from the patient's perspective, by reassuring them of the minimal discomfort, and by reassuring them of the short duration of the procedure.

Patient positioning is crucial in obtaining laryngeal visualization in any per-oral technique. Place the patient sitting upright in a multipositional procedure chair or on a gurney with their legs together. Instruct the patient to lean slightly forward and to draw their chin forward. This aligns the larynx and the oropharynx in a vertical plane to allow visualization of the anterior portion of the larynx. Raise or lower the multipositional chair, or the gurney, so that the patient's mouth is at the examiner's eye level.

Patient cooperation and positioning is not crucial for flexible fiberoptic examination of the larynx performed through the nose. Place the patient, optimally, sitting upright with their head against a headrest. The headrest will prevent the common occurrence of the patient's head backing away during the examination. The examination with the patient in the supine position is technically more challenging as gravity pushes the tongue posteriorly and the scope falls against the posterior pharyngeal wall; both of which make visualization of the anteriorly placed larynx more difficult. However, in most instances, it can still be performed without significant problems.

The use of good lighting cannot be overemphasized when performing a mirror examination. Apply a headlamp if one is available. An alternative is an overhead adjustable light source. Position the light so that it is aimed in the patient's mouth. The overhead light often hits the examiner in the head, casts shadows, and is too bright for the patient's eyes. It is also difficult to properly position as both of the examiner's hands must be used for the procedure.

TECHNIQUES

THE MIRROR EXAMINATION

Determine whether the patient has a significant gag reflex. If so, apply topical anesthesia. Spray a topical local anesthetic agent (e.g., benzocaine, lidocaine, or tetracaine) onto the patient's palate, tonsillar pillars, posterior pharyngeal wall, and base of the tongue. The application of a topical anesthetic agent is optional if the patient does not have a significant gag reflex. Instruct the patient to keep their eyes open and focus on a distant object to diminish the gag reflex. Practicing the entire procedure once with the patient, without inserting the mirror, is often a more reassuring and efficient manner of performing indirect laryngoscopy.

Instruct the patient to protrude their tongue. Grasp the tongue firmly, between the nondominant thumb and index finger, with a neatly folded gauze square (**Figure 173-5**). **Do not apply excessive traction on the tongue.** This is counterproductive as it elevates the tongue and makes the patient uncomfortable. Place the nondominant middle finger against the upper teeth as a brace. It may also be used to elevate the upper lip if needed. Instruct the patient to breathe through their mouth in a slow "panting-like" manner and to try to relax their tongue. This maneuver diminishes the gag reflex, elevates the palate, and lowers the tongue giving better access and visualization of the oropharynx.

Warm the mirror over an alcohol lamp, in heated beads, or in a cup of warm water to prevent fogging during the examination. Test the mirror back, if any type of heat is used, on the examiner's wrist for excessive heat that can injure the patient. An alternative is to use a mirror that has antifog solution placed on it to prevent fogging during the examination. Grasp the mirror with the dominant hand midway down the shaft like a pen (**Figure 173-5**). Brace the dominant fifth finger against the patient's face.

Introduce the mirror into the oral cavity with the glass surface parallel to the tongue (**Figure 173-5**). Instruct the patient to say a high-pitched "e-e-e" and hold it for 5 seconds just before the mirror touches and elevates the uvula and soft palate. The high-pitched "e-e-e" tilts the epiglottis forward and brings the vocal cords into view and apposition. Inform the patient that the "e-e-e" may sound like "ahhhhhh" while their tongue is held. This is helpful to them as they try to cooperate fully with the instructions. The Emergency Physician should simultaneously demonstrate the high-pitched sound as patients invariably will phonate in too low of a pitch for too short of a time period. Prevent gagging by asking the patient to phonate before the mirror actually touches the soft palate, avoiding touching the base of the tongue, and avoid touching the anterior tonsillar pillars.

Focus the headlight (or overhead light), as the patient phonates, on the mirror. Gently and slightly maneuver the mirror until the larynx is visualized. **Remember the orientation through the mirror. Left and right are the same but anterior and posterior have reversed orientation.**

Perform a quick and systematic evaluation of the larynx and hypopharynx. Assess the airway structures including the base of the tongue, vallecula, epiglottis, aryepiglottic folds, true and false vocal cords, arytenoids, posterior pharyngeal wall, and pyriform sinuses. Visualize adduction and abduction of the vocal cords during phonations and inspirations. Several reinsertions of the mirror are often required to obtain a complete examination.

PER-ORAL FLEXIBLE FIBEROPTIC LARYNGOSCOPY

The examiner will often have a more leisurely view of the larynx with this technique, as compared to the mirror exam. Patients usually gag less and can tolerate this examination for longer periods of time.

Position the patient the same as for the mirror examination. All patients undergoing this procedure, in contrast to the mirror examination, must be topically anesthetized with an aerosolized local anesthetic agent as described above. Connect the light source to the fiberoptic scope and turn it on. Turn off the overhead room lights, if possible, to provide better contrast.

Instruct the patient to protrude their tongue and to grasp it with a gauze square (**Figure 173-6**). Hold the eyepiece of the scope in the dominant hand. Use the dominant thumb to manipulate the



FIGURE 173-5. Proper positioning for an indirect mirror examination of the larynx. Both of the examiner's hands should be braced against the patient for stability once the mirror is positioned in the oropharynx.



FIGURE 173-6. Positioning for an oral flexible fiberoptic examination of the larynx. The patient grasps their tongue with a gauze square. The examiner's left hand is braced against the patient's face.

tip controller. Grasp and hold the middle portion of the fiberoptic scope with the thumb and index finger of the nondominant hand. Brace the remaining fingers of the nondominant hand against the patient's face (**Figure 173-6**). Instruct the patient to breathe slowly through their mouth in a "panting-like" manner.

Advance the scope with both hands until the tip is situated within the middle of the mouth and over the base of the tongue. Use the hand control to direct the tip of the scope downward. Look through the scope and visualize the base of the tongue, the vallecula, and the tip of the epiglottis. Direct the scope posteriorly over the epiglottis. The larynx and hypopharynx will come into view (**Figure 173-3**). Adjust the eyepiece, if necessary, to focus the scope. **Avoid touching the epiglottis as this may induce gagging.** Entry into the laryngeal vestibule will allow a more detailed examination, but may also induce laryngospasm if the vocal cords are touched. Perform a systematic examination of the laryngeal and hypopharyngeal anatomy. Instruct the patient to say "e-e-e" while viewing abduction and adduction of the vocal cords.

PER-ORAL RIGID FIBEROPTIC LARYNGOSCOPY

Position the patient the same as for the mirror examination. All patients undergoing this procedure, in contrast to the mirror examination, must be topically anesthetized with an aerosolized local anesthetic agent as described above. Connect the light source to the fiberoptic scope and turn it on. Turn off the overhead room lights, if possible, or dim them to provide better contrast. Apply antifog solution onto the laryngoscope lens.

Instruct the patient to protrude their tongue. Either the patient or the examiner may grasp the patient's tongue with gauze as it protrudes (**Figure 173-7**). Hold the scope with both hands while stabilizing the nondominant hand against the patient's face if the patient holds their own tongue. Hold the scope with the dominant index finger and thumb if the examiner is grasping the patient's tongue (**Figure 173-7**). Stabilize the scope with the dominant fifth finger against the patient's face. Instruct the patient to breathe slowly through their mouth in a "panting-like" manner.

Insert the laryngoscope into the center of the mouth. Advance it straight backward and over the tongue. Stop advancing the scope when the circumvallate papillae are reached. Instruct the patient to phonate as described above. Advance the scope until the larynx is visualized (**Figures 173-2 & 173-8**). Tilt and gently rotate the scope to visualize the entire larynx and hypopharynx during phonation and quiet breathing.



FIGURE 173-7. Positioning for a rigid telescopic examination of the larynx. Note that the telescope is stabilized on the left thumb and the left fifth finger is braced against the patient's face.

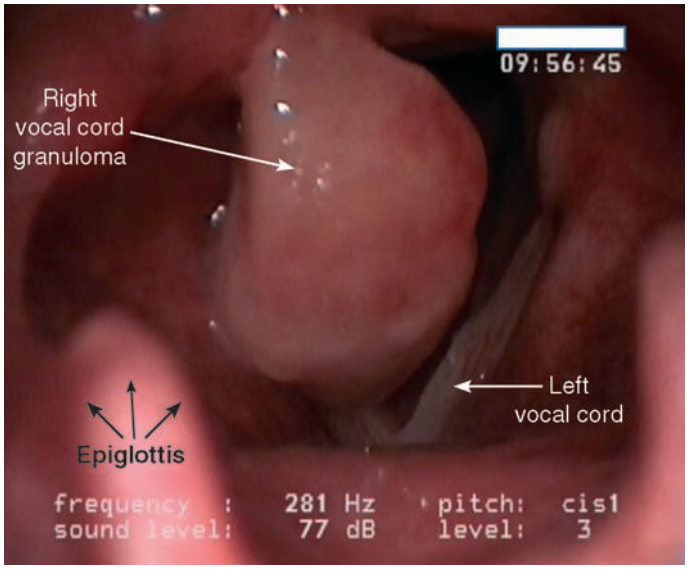


FIGURE 173-8. Endoscopic view of the larynx through a rigid 90° telescope.

FLEXIBLE NASOPHARYNGOSCOPY OR NASOLARYNGOSCOPY

A relatively new technology for laryngeal visualization is the "chip-in-tip" laryngoscopes. Rather than fiberoptic cables, these flexible scopes have the video and lens apparatus at the tip of the scope and transmits the data to a processor. The processor converts the data into video images onto a screen. This scope produces a picture that is significantly brighter and less distorted (**Figure 173-1C**). It is an excellent tool for teaching. However, the cost for a complete digital unit is three to four times the cost of a traditional fiberoptic laryngoscope.

Patient positioning is not crucial with this technique. Anesthetize the nasal passage so that the procedure is best tolerated. Visualize both nasal cavities with a nasal speculum to determine which nasal passageway will be easier to pass the scope through. Decongest the nasal mucosa with aerosolized oxymetazoline, 3% ephedrine, or cocaine. Instruct the patient to sniff in deeply after the spray is applied. Allow 3 to 5 minutes to pass for the vasoconstriction to occur. Apply a topical anesthetic spray to the nasal passageway. Spraying achieves excellent vasoconstriction and anesthesia as the agents diffuse through the entire nasal cavity and pharynx. Alternatively, place cocaine-soaked pledgets into the nasal cavity inferior and superior to the inferior turbinate for 10 minutes to achieve excellent anesthesia and vasoconstriction.

Connect the light source to the fiberoptic scope and turn it on. Turn off the overhead room lights, if possible, to provide better contrast. Apply water-soluble lubricant onto the fiberoptic cord. Do not get the lubricant on the lens or it will blur visualization. Hold the eyepiece of the scope in the dominant hand (**Figure 173-9**). Use the dominant thumb to manipulate the tip controller. Grasp and hold the middle portion of the fiberoptic scope with the thumb and index finger of the nondominant hand. Brace the remaining fingers of the nondominant hand against the patient's cheek (**Figure 173-9**).

Insert the tip of the scope into the nose. Advance the scope with both hands and directed either along the floor of the nose or along the superomedial aspect of the inferior turbinate, depending



FIGURE 173-9. Positioning for a nasal flexible fiberoptic examination of the larynx. Note that the left, nondominant, hand is stabilized against the patient's face.



FIGURE 173-11. Nasopharyngoscopy using an external monitor for visualization of endoscopic images.

upon the nasal anatomy (**Figure 173-10**). Instruct the patient to breathe through their nose as the nasopharynx is encountered. This lowers the soft palate and opens the nasopharynx. Direct the tip of the endoscope downward and advance it past the oropharynx. Slide the tip of the scope behind the epiglottis, along the posterior pharyngeal wall, and into the hypopharynx and larynx. **Avoid touching the epiglottis to prevent gagging and the vocal cords to prevent laryngospasm.** Almost all patients can tolerate this procedure. Gagging is unusual. Apply a topical anesthetic agent to the oral cavity and oropharynx if the patient gags. Perform a leisurely and thorough examination of the airway. This is the only laryngoscopy technique in which normal speech can be observed.

ALTERNATIVE TECHNIQUES

The Emergency Physician must be looking through the rigid or flexible scope during the procedure. This in combination with holding, stabilizing, and advancing the scope makes fiberoptic laryngoscopy awkward if the Emergency Physician does not have much experience with this technique. An alternative, if available, is to connect the scope to a portable monitor (**Figure 173-11**). This makes the procedure less cumbersome and easier to perform. This type of setup is especially helpful in training situations (e.g., medical students, residents, and midlevel providers) as well as educating the patient and their family to the examination findings.

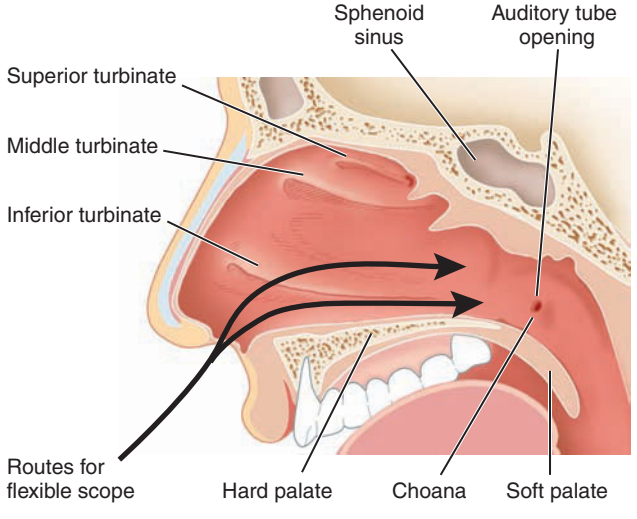


FIGURE 173-10. Anatomy of the lateral nasal wall and the two routes that the flexible scope can follow to gain access to the nasopharynx and subsequently the larynx.

AFTERCARE

Inform the patient that the effects of the topical anesthetic persist an average of 30 to 45 minutes. Alert the patient that they may experience symptoms of aspiration, such as coughing or choking, when swallowing. Liquids are more likely to cause problems than solids. Instruct the patient not to ingest any solid or liquid substances until the topical anesthetic agent wears off. Mild bleeding from the scope abrading the mucosa is usually minimal and self-limited. The patient will need reassurance as rarely is any treatment required.

Scopes require cleaning and disinfection between uses. Gently wipe any blood, lubricant, mucous, and other body fluids off the scope. Disinfect the scope per the manufacturers' recommendations and hospital guidelines.

COMPLICATIONS

Few complications arise from laryngoscopy. Epistaxis is possible with nasal endoscopy. It is uncommon when using vasoconstrictive agents and careful manipulation of the scope. Emesis is rare, even in the patient with an extremely sensitive gag reflex. Laryngospasm can be avoided as long as care is taken to avoid direct contact with the vocal cords. Although rare, the patient can have an adverse reaction to the local anesthetic agent or the decongestant. These should be evaluated and managed similar to any other allergic reaction.

Aspiration during or after the procedure is extremely rare. Aspiration can be minimized by performing laryngoscopy on patients with an empty stomach, although this is often impractical in the Emergency Department.

Other complications are minor and result from mechanical trauma. The tip of the scope can rub against and abrade the mucosa. This can result in mild irritation, rhinorrhea, and hemorrhage. Inappropriate technique or patient movement during the procedure can result in mucosal lacerations.

SUMMARY

Visualization of the larynx is a basic and often crucial component in the physical examination of the patient. A variety of techniques have been described, all of which are adequate in evaluating the larynx and hypopharynx. Risks and complications are rare. Maintain a very low threshold when deciding whether or not to perform laryngoscopy. Patient education and preparation are as, if not more, important than equipment and instrumentation in obtaining a thorough examination.

174 Airway Foreign Body Removal

David L. Walner

INTRODUCTION

The presence of an airway foreign body is a common cause of morbidity and mortality in children, especially those younger than 3 years of age. Over 70% of foreign body aspirations occur in children.[1] The mortality rate following foreign body aspiration is estimated at 1% to 2%. In the year 2000, ingestion or aspiration of a foreign body was the cause of 160 unintentional deaths and more than 17,000 Emergency Department visits in the United States.[2] Other reports have estimated the death toll as high as 2000 per year in the United States.[1] The most likely cause of death is complete airway obstruction, generally at the level of the larynx or trachea. Food objects have been associated with 41% and nonfood substances have been associated with 59% of reported deaths.[2] Globular objects such as hot dogs, candies, chewing gum, nuts, and grapes are the most commonly aspirated food objects.[3] Rubber balloons and toys are the most commonly aspirated nonfood objects.[3]

Parents and caregivers should be educated and aware of the types of food and objects that pose a choking risk for children. They should become familiar with the methods to reduce this risk. All parents and caregivers should learn the techniques to treat a choking child. Basic life support classes are often available free or at a minimal cost at hospitals, churches, and community centers.

The management of airway foreign bodies requires specific expertise and training. Airway foreign bodies must be managed by an Otolaryngologist or other qualified Physician, depending on the institution, with experience in airway endoscopy and the knowledge to deal with the potential complications related to airway obstruction. Cases involving children require specialized expertise in pediatric airway endoscopy. Prior to the twentieth century, aspiration of a foreign body resulted in a 24% mortality rate. The morbidity and mortality associated with airway foreign body retrieval has greatly declined due to the development of safe endoscopic techniques, rod-lens telescopes, and optical forceps.

The burden of proof lies in the Emergency Physician's hands in order to diagnose an airway foreign body. Keep in mind that information gained from the history, physical examination, and radiologic studies may not clearly define the presence of a foreign body.[4] Thirty-three percent of airway foreign body cases are neither observed nor suspected. The physical examination may be normal in up to 39% of patients. Radiographic studies may be normal in up to 20% of the patients. The only definitive test when considering the diagnosis of an airway foreign body is endoscopy to evaluate the entire laryngotracheobronchial tree.

ANATOMY AND PATHOPHYSIOLOGY

The airway is divided into three anatomic regions: the larynx, the trachea, and the bronchi. The laryngeal aditus is formed by the epiglottis anteriorly, the aryepiglottic folds laterally, and posteriorly by the corniculate cartilages and upper border of the arytenoid muscle. The larynx extends from the level of the aditus to the lower border of the cricoid cartilage, where it is continuous with the trachea.[5] The infant larynx is located higher in the neck than the adult larynx. The cricoid cartilage descends in the neck through childhood. Due to the superior position of the infant larynx, the epiglottis is located with the tip often resting on the soft palate.[6] The infant larynx is approximately one-third the size of the adult larynx. Laryngeal foreign bodies are most common in infants due to the small size of the inlet. Refer to Chapter 6 for a more complete discussion regarding the differences between the child and adult larynx.

The trachea begins at the lower border of the cricoid cartilage, extending downward from about the level of the sixth cervical vertebra in adults or the fourth cervical vertebra in infants. The trachea extends inferiorly to the level of the carina. The inferior end of the trachea is located at the level of the fifth thoracic vertebra or the sternal angle. The trachea is 4 cm long in a full-term newborn infant and 11 to 13 cm long in an adult. The diameter of the trachea is 3.6 mm in a newborn and 12 to 23 mm in an adult.[7]

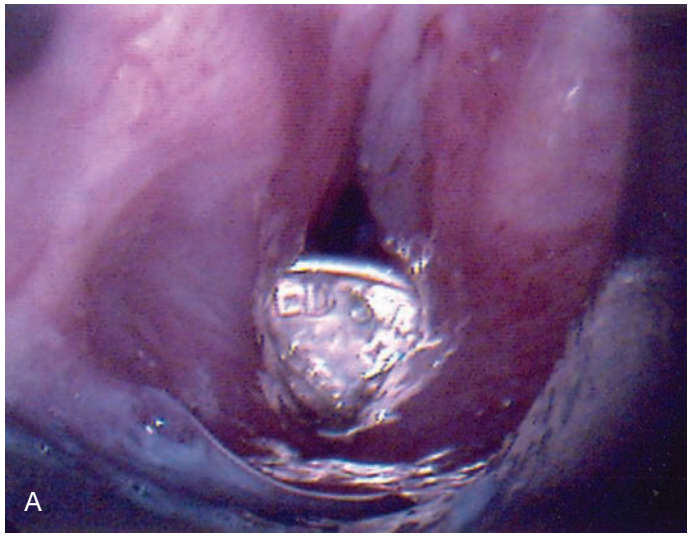
The trachea divides into two mainstem bronchi.[7] The right mainstem bronchus is shorter, straighter, and larger in diameter than the left mainstem bronchus. This explains why right mainstem foreign bodies are more common than left mainstem foreign bodies. The mainstem bronchi divide into three lobar bronchi on the right and two on the left. The lobar bronchi divide into segmental bronchi. There are, usually, 10 segmental bronchi on the right, and 8 on the left.[7]

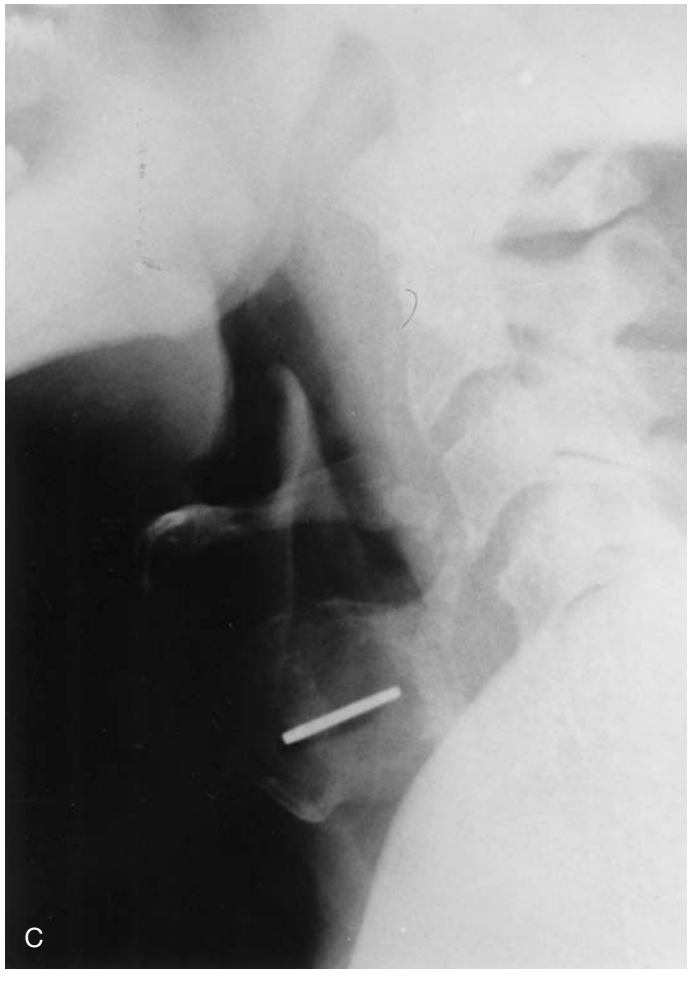
Airway foreign bodies commonly become lodged in one of three locations: the larynx, the trachea, or the bronchi. Laryngeal foreign bodies account for 4% to 5% of airway foreign bodies.[8] Laryngeal foreign bodies have a mortality rate of 45% due to complete airway obstruction.[9] Approximately one-third of survivors of transient airway obstruction suffer from hypoxic encephalopathy.

Most choking victims are able to generate a forceful cough to expel an airway foreign body. Some patients are unable to relieve the obstruction themselves. The use of the Heimlich maneuver has further decreased mortality.[10] **It should be emphasized that the relief of an airway obstruction should only be attempted if signs of a complete airway obstruction are observed.[11] Only perform oral cavity finger sweeps if a foreign body is seen within the oral cavity.[11] Immediate intervention is not only unnecessary, but may be potentially dangerous if a patient is able to breathe, speak, or cough.[12]**

Laryngeal foreign bodies can present with only mild or moderate respiratory distress. They may be located, or wedged, between the laryngeal ventricles, the true vocal folds, or the immediate subglottis (**Figure 174-1A**). Plain radiographs of the neck will detect radiopaque foreign bodies (**Figures 174-1B & C**). Flexible awake fiberoptic laryngoscopy allows visualization of the larynx and supraglottic structures.

Tracheal foreign bodies account for 9% and bronchial foreign bodies account for 81% of airway foreign bodies.[8] The classic diagnostic triad of a tracheobronchial foreign body consists of the sudden onset of paroxysmal coughing, wheezing, and diminished breath sounds on the affected side. However, these symptoms may only be present in 50% of cases. Approximately 33% of airway foreign bodies are neither observed nor suspected.[13] Tracheal foreign bodies may present with audible biphasic or expiratory stridor. Audible expiratory wheezing is more likely associated with a





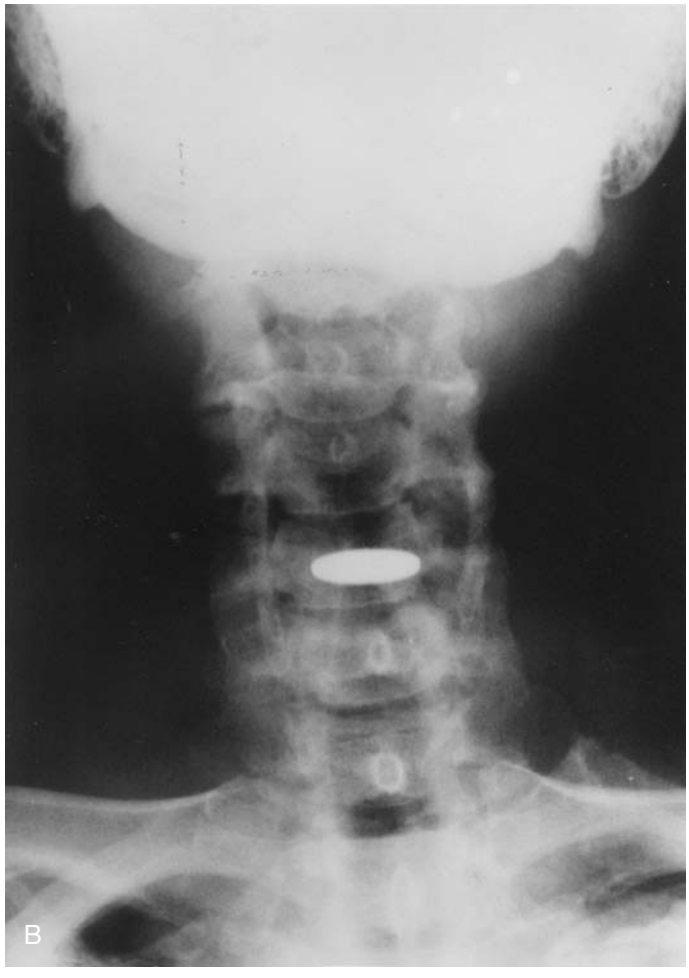


FIGURE 174-1. Laryngeal foreign body. **A.** Coin lodged within the laryngeal ventricles resulting in a partial airway obstruction. **B.** Anteroposterior neck radiograph. **C.** Lateral neck radiograph.

main bronchus obstruction. Tachypnea and cyanotic episodes may occur, generally when larger obstructing objects are present. Small foreign bodies may travel distally to a secondary bronchus and produce the more subtle symptoms of mild wheezing, cough, pneumonia, or fever. No abnormalities are found in up to 39% of patients.[4] It is estimated that only 70% of patients with a foreign body aspiration seek treatment within the first week of the aspiration.[14]

The most common airway foreign bodies are food items and toys. Peanuts account for nearly 40% of tracheobronchial foreign bodies[15] (**Figure 174-2**). Other common foreign bodies include plastic toys, pins, tacks, watermelon seeds, sunflower seeds, nails, screws, carrots, and popcorn. More than 80% of airway foreign bodies are radiolucent and can be difficult to diagnose. The most common radiologic findings are identified using both inspiratory

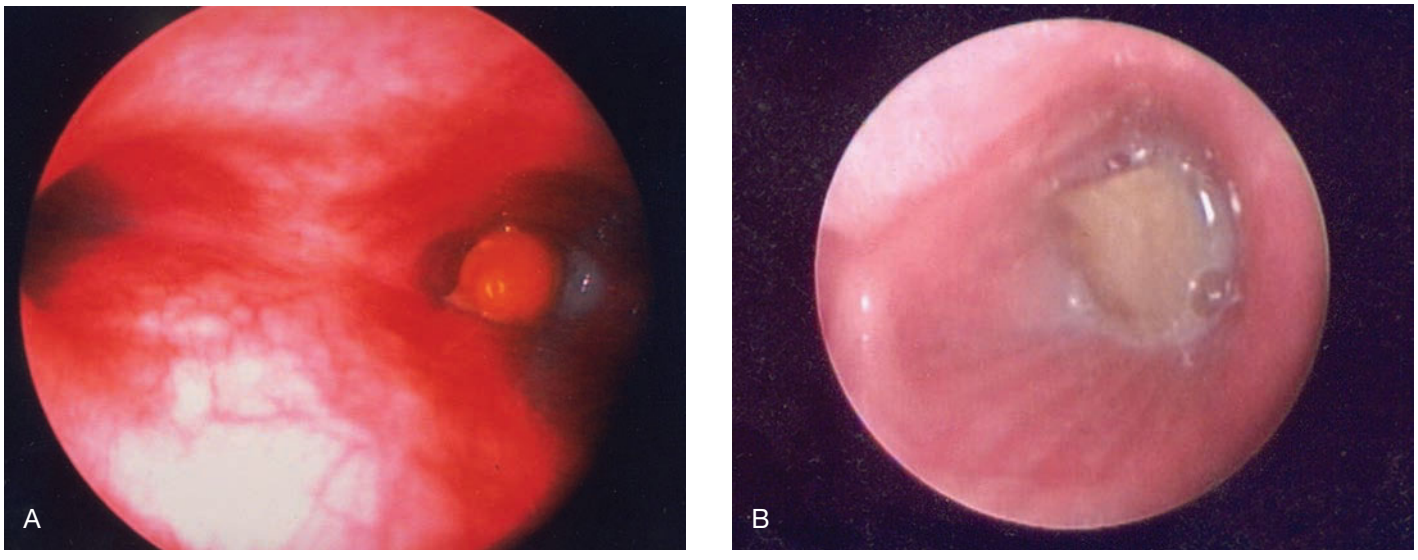


FIGURE 174-2. Endoscopic view of a peanut in the right main-stem bronchus. **A.** Endoscopic view from just superior to the carina. Note that both mainstem bronchi are visible. **B.** Close-up view of the foreign body.

and expiratory chest radiographs. This can be in the form of a check valve with postobstructive hyperinflation and mediastinal shift to the contralateral side (**Figure 174-3**). It may also be seen in the form of a ball valve with atelectasis, collapse of the distal airways, and mediastinal shift to the ipsilateral side. Pneumonia can be present in 9% of cases, generally when the foreign body has been present for weeks or months. Chest radiographs can be normal in up to 11% to 20% of patients with tracheobronchial foreign bodies.[4]

Suspect an airway foreign body based upon the history, physical examination, and radiologic findings. **However, the diagnosis is not always clear-cut. It is the responsibility of the Emergency Physician suspecting an airway foreign body to confer with the appropriate specialist and to strongly suggest endoscopy consisting of laryngoscopy and bronchoscopy.** Endoscopy remains the gold standard to rule in or rule out an airway foreign body.

INDICATIONS

The indications for airway endoscopy must take into account the patient's history, physical examination, radiologic findings, and the suspected location of the foreign body. An accurate history is of the utmost importance in the diagnosis of foreign body aspiration as the remainder of the assessment, physical examination, and radiographic studies can be deceptively unremarkable. The characteristic history consists of an incipient choking or gagging episode. Caretakers often describe subsequent coughing spells when the event was witnessed. Aspiration must be assumed if the patient was eating peanuts, seeds, or beans during the episode. All witnessed aspirations with nuts or nondissolvable food matter require endoscopy and removal if the foreign material is identified.

CONTRAINDICATIONS

The majority of patients presenting to the Emergency Department with airway foreign bodies are in stable condition. This allows time to adequately access the patient and formulate the best possible treatment plan. Infants and children with airway foreign bodies require an institution with the capability for comprehensive pediatric care. This includes a Physician who is experienced with



FIGURE 174-3. Chest radiograph of a patient with a left mainstem bronchus foreign body and a check valve-type of obstruction. Marks delineate the trachea and the mainstem bronchi.

airway endoscopy and foreign body retrieval in children, a facility with pediatric endoscopic equipment, pediatric anesthesia capabilities, and pediatric intensive care capabilities. This often will require transfer to a specialized pediatric center. Attempting removal of airway foreign bodies in a less-than-adequate environment can be catastrophic for the patient and is not advised. This same philosophy applies to adult airway endoscopy and to having qualified personal who are experienced in this area.

Follow basic life support protocols, including the section on a choking victim, in the rare situation of an acutely obstructed airway. Any patient with a suspected laryngeal foreign body or impending airway obstruction requires emergent endoscopy and control of the airway in the Operating Room, if possible. If urgent endoscopy is not possible and a laryngeal foreign body is suspected, direct laryngoscopy in the Emergency Department and removal of a visualized foreign body with a McGill forceps can be attempted. A cricothyroidotomy or percutaneous transtracheal jet ventilation may be required as a lifesaving measure for a laryngeal foreign body if attempts at resuscitation and/or removal are unsuccessful. However, these two procedures are unlikely to be beneficial if the foreign body is located in the distal tracheal or bronchi. **If urgent endoscopy is not available, and a lifesaving measure is required due to total airway obstruction of a distal tracheal or bronchial foreign body, orotracheal intubation with the tube positioned into one of the mainstem bronchi may be lifesaving. Based on the facility and the situation of total airway obstruction, ECMO could also be lifesaving.**

EQUIPMENT

Emergency Department Equipment

- Intubation equipment
- Percutaneous transtracheal jet ventilator
- Cricothyroidotomy kit
- Suction source, tubing, and catheter
- Magill forceps
- Laryngoscope with a variety of blades or a video laryngoscope
- Topical anesthetic spray
- Fiberoptic nasopharyngoscope

OPERATING ROOM EQUIPMENT

The proper equipment must be selected based upon the patient's age and size, as well as the suspected composition of the foreign body. Laryngoscopes are selected to allow visualization of the larynx and the passage of a bronchoscope. Rigid, ventilating bronchoscopes with fiberoptic telescopes provide optimal visualization. This allows direct access to the airway, excellent visualization, continuous administration of anesthetic agent and oxygen, and a conduit for the introduction of instruments (forceps) to retrieve the foreign object. Multiple sizes of laryngoscopes and bronchoscopes are essential to have available in the operating room. Numerous extraction instruments (of different sizes and shapes) must be available and include smooth, toothed, cupped, angled, open mouth, and optical forceps. The optical forceps allow a magnified and direct view through the forceps improving visualization and ease of foreign body removal.

PATIENT PREPARATION

Timing of endoscopy and airway foreign body retrieval must be based upon each individual patient. Do not waste time if impending airway obstruction exists. Immediately notify and mobilize an Anesthesiologist, Otolaryngologist, and the Operating Room, as this is an emergent situation. It is appropriate to wait for NPO status to be present and the stomach empty prior to proceeding to the Operating Room if the diagnosis of an airway foreign body is highly suspected and the patient is stable. This is considered a timely approach and may take up to 6 hours for children or 8 hours for adults. Waiting this time in the stable patient decreases the risk of aspiration and further compromising the situation. It is also appropriate to wait, in a stable patient, in order to assemble the appropriate and best nursing and anesthesia team to care for the patient. Using personnel who are unfamiliar with endoscopy can create a compromised and stressful situation.

TECHNIQUES

EMERGENCY DEPARTMENT TECHNIQUES

The foreign body airway obstruction protocol based upon the Pediatric Basic Life Support textbook treats conscious infants (younger than 1 year of age) with four back blows while the infant is in a prone position on the rescuer's forearm, face down, and the head lower than the trunk. This is combined with four rapid chest thrusts (as in infant CPR), if the obstruction persists, while the infant is supine with the head lower than the body.[11] Treat unconscious infants by opening the airway and attempting rescue breathing based on basic life support protocols.[11] Treat children and adults with the standard Heimlich maneuver, using gentle thrusts in smaller children to decrease the likelihood of injury to the abdominal organs. Finger sweeps to remove a foreign body in the oral cavity should only be performed if the foreign body is directly visualized. Blind finger sweeps are not recommended as they can further impact the foreign body and obstruct the airway.

It is always best not to manipulate the airway or attempt intubation in a stable patient with an airway foreign body and who is moving air and breathing. The airway is best controlled in the Operating Room at the time of the actual foreign body removal. Once the airway is manipulated a foreign body can become dislodged, turning a partial airway obstruction into a complete airway obstruction. If this occurs in the Operating Room, the bronchoscopy equipment is available for urgent use by the endoscopist if needed.

Attempt orotracheal intubation in the Emergency Department if the airway obstruction progresses rapidly and the patient cannot ventilate. Intubation can be used to force the foreign body into one mainstem bronchus and allow ventilation of the other lung. One-lung ventilation will keep the patient alive until the foreign body can be removed in the Operating Room. Position the laryngoscope to visualize the larynx. If a foreign body is visualized, grasp the foreign body with a McGill forceps and remove it. If no foreign body is visualized, intubate the patient. Insert and advance the endotracheal tube as far as it will advance if the foreign body is not visualized or unable to be grasped. If the endotracheal tube will not pass, try a smaller size tube. Withdraw and position the endotracheal tube with the tip above the carina to optimize ventilation. As an alternative, properly insert and position the endotracheal tube above the carina then advance a bougie through the endotracheal tube in an attempt to move the foreign body distally. **Always be prepared to perform a cricothyroidotomy or transtracheal jet ventilation.** Transtracheal jet ventilation allows for short-term oxygenation, is temporary, and may allow time for safe transport to the Operating Room so that endoscopy and foreign body retrieval can be performed in a more controlled environment with appropriate equipment at hand. Refer to Chapters 11, 25, and 24 regarding the details of orotracheal intubation, cricothyroidotomy, and transtracheal jet ventilation, respectively.

Direct laryngoscopy and bronchoscopy in a child or adult with an airway foreign body is a dangerous situation. The procedure may result in a partial airway obstruction becoming a complete airway obstruction. **Always have a cricothyroidotomy tray immediately available.** All equipment must be selected, assembled, and ready for use.

It is possible to remove foreign bodies located within the hypopharynx in the Emergency Department. Typical foreign bodies that may be removed include pieces of food and fishbones. **The patient must be stable and in no risk of airway compromise.** Obtain anteroposterior and lateral soft tissue radiographs of the neck to localize, if possible, the foreign body. The use of CT scans to attempt to identify potential fish or chicken bones that may be lodged in the pharynx, hypopharynx, or esophagus is an option in the stable patient. Perform indirect laryngoscopy to identify the foreign body and its location. Refer to Chapter 173 regarding the complete details of laryngoscopy. Obtain intravenous access.

Place the patient in full monitoring (i.e., pulse oximeter, cardiac monitor, noninvasive blood pressure cuff). Apply a topical anesthetic spray to the oropharynx and the base of the tongue. Place the patient supine. Administer a small dose of an intravenous sedative if required. Slowly and gently insert a #3 Miller laryngoscope blade. An alternative to a traditional laryngoscope, if available, is a video laryngoscope. The video laryngoscope may provide a better field of view with less manipulation. **Do not immediately insert the laryngoscope blade all the way.** Stop frequently to lift the laryngoscope and look for the foreign body. This slow insertion and frequent looks will prevent the laryngoscope blade from pushing the foreign body further into the airway. Elevate the patient's tongue and jaw. Grasp the foreign body with a McGill forceps. Withdraw the McGill forceps followed by the laryngoscope.

OPERATING ROOM TECHNIQUES

The procedure begins with the induction of general anesthesia. It cannot be overemphasized that anesthesia should only be administered by an Anesthesiologist who is competent and comfortable with the situation. Pediatric patients require an Anesthesiologist with pediatric airway experience if the patient is stable. Full monitoring and mask induction allow the patient to maintain spontaneous respiration. Muscle relaxants are avoided as they can induce complete airway obstruction.

The Otolaryngologist begins the procedure. Place the patient supine with a shoulder roll to position the airway. Insert the laryngoscope into the larynx. Expose the larynx by elevating the laryngoscope. Topical anesthetic is applied to the larynx to avoid laryngospasm. The bronchoscope with telescope is then passed under direct vision through the mouth and into the laryngeal introitus. Ventilation can continue via a port on the scope. The foreign body is visualized. Forceps are inserted through the scope and used to grasp the foreign body. Small objects can be removed directly through the scope, whereas larger objects require simultaneously removing the bronchoscope along with the forceps and foreign body. The bronchoscope is passed again, after removal of the foreign body, to identify any mucosal injury or second foreign body that may occur in as many as 5% of patients.[4] If purulent secretions are noted, a culture may be obtained and antibiotics administered appropriately.

A specific type of foreign body, such as a tack or sharp object, may become lodged in the larynx or upper trachea. Extraction with the forceps using standard endoscopic techniques may not be possible. Patients may require a tracheotomy and an open approach (laryngotomy) to remove the foreign body.

ALTERNATIVE TECHNIQUE

The use of a flexible fiberoptic bronchoscope to retrieve bronchial foreign bodies may be acceptable for Physicians who are well trained with this technique. The mainstay of tracheobronchial foreign body retrieval remains to be rigid bronchoscopy.

AFTERCARE

After the retrieval of an airway foreign body, most patients should be breathing spontaneously. An endotracheal tube may rarely, in the presence of significant laryngeal or tracheobronchial edema, need to remain in place temporarily. This would require admission to an intensive care unit. Humidified oxygen is helpful to keep the airway moist and prevent mucous crusts from forming. A postprocedural radiograph will help to determine any subcutaneous air, air in the soft tissues, a pneumothorax, or any changes to the lung fields following the extraction.

All patients who have undergone foreign body removal require at least a few hours of airway observation in a monitored setting. Racemic epinephrine treatments and intravenous Decadron can be administered as needed. Discharge from the hospital is acceptable when the patient is breathing comfortably and no longer in danger of airway compromise. Some patients may be discharged home the same day, while others may require multiple days of airway support and observation.

In cases where a bronchial foreign body has been present for a prolonged period of time, granulation tissue and severe inflammation can form around the foreign body making removal difficult or impossible. It may be necessary to treat the patient with intravenous steroids and antibiotics for 48 hours, with or without intubation, followed by a repeat bronchoscopy and a repeat attempt to remove the foreign body.

COMPLICATIONS

Complications from the foreign bodies themselves include hypoxia leading to cerebral anoxia if not identified. Intraoperative complications can occur in the hands of an inexperienced endoscopist or even an experienced endoscopist who loses control of a foreign body in the airway and is faced with obstruction or respiratory arrest. Cardiac arrhythmias can occur from hypoxia or direct pressure on the left main-stem bronchus. Postoperative problems can include laryngeal or tracheobronchial edema from the foreign body or the instrumentation of the airway. Mucosal irritation can instigate a tracheitis or bronchitis. Pneumonia can develop. Pneumomediastinum has been reported in as many as 13% of aspirations and a pneumothorax slightly less frequently.[16]

A foreign body pulled up from a main stem bronchus can become dislodged in the larynx or trachea and cause a complete airway obstruction. A foreign body in the hypopharynx can be pushed distally and result in a total airway obstruction. The foreign body needs to be quickly removed, pushed back down into one of the mainstem bronchi to allow ventilation of at least one lung, or a surgical airway performed. Failure to react appropriately in this situation can result in asphyxiation and death.

SUMMARY

Airway foreign bodies pose a diagnostic and therapeutic challenge. The initial encounter in the Physician's office, clinic, or the Emergency Department must uncover any historical fact, physical abnormality, or radiographic abnormality that may lead to a definitive or presumed diagnosis of an airway foreign body. Endoscopy

must be performed by a skilled team to allow safe and efficient removal of the foreign body. Hypopharyngeal foreign bodies may be safely removed in the Emergency Department by a trained Emergency Physician.

175 Peritonsillar Abscess Incision and Drainage

Eric F. Reichman, Kellie D. Hughes, and Jehangir Meer

INTRODUCTION

A peritonsillar abscess is the most common deep infection of the head and neck encountered in young adults in the Emergency Department.[1] The incidence is approximately 45,000 cases per year.[2] This infection can occur in all age groups, although it is a relatively rare before the age of 5 years. The highest incidence occurs in adults 20 to 40 years of age. There remains a fair amount of controversy in the literature regarding the optimal antibiotic choice and the mechanism of drainage. The objective for the Emergency Physician remains to make an accurate diagnosis, to institute appropriate care, and to arrange timely follow-up.

ANATOMY AND PATHOPHYSIOLOGY

Knowledge of oropharynx anatomy is imperative. The anatomy of the oral cavity is relatively simple (**Figure 175-1**). The peritonsillar abscess can be found posterolateral to the palatine tonsil and posterior to the palatoglossal fold (or arch). **Note the close proximity of the internal carotid artery and the facial artery to the peritonsillar abscess (Figure 175-2). Use extreme care to not penetrate too deeply and lacerate these arteries.**

Most patients will have had symptoms for approximately 4 days by the time abscess formation has occurred. The most common symptoms include fever, sore throat, dysphagia, muffled voice (the "hot potato" voice), and trismus. Physical examination will reveal a nonexudative pharyngitis in the majority of cases, soft palate edema, a bulging prominent tonsil, and uveal deviation away from the abscessed tonsil (**Figure 175-3**). The differential diagnosis includes intratonsillar abscess, peritonsillar cellulitis, infectious mononucleosis, leukemias, odontogenic infections, and aneurysms of the internal carotid artery.

Intraoral ultrasound (US) for a peritonsillar abscess has been performed since the 1990s. It was first described in the Otolaryngology literature and subsequently in the Emergency Medicine literature. The first case series of patients whose peritonsillar abscesses were drained under US guidance was described by Blaivas and colleagues.[3] Since that time, US guidance has been shown to have a high degree of sensitivity (85% to 92%) and specificity (80% to 100%).[4,5] US offers the advantage of confirming the presence of an abscess prior to aspiration attempts as well allowing visualization of important neighboring structures (e.g., the internal carotid artery). Some patients with a peritonsillar abscess may be misdiagnosed with cellulitis and not undergo drainage. The use of US can prevent this. A significant proportion of patients (10% to 24%) have false-negative results on blind aspiration because the peritonsillar abscess can be multilocular and its location can vary.[4,6,7] US will identify the location of the abscess to limit the number of false-negative aspirations.

The peritonsillar abscess has been attributed to progression and direct extension of an acute exudative pharyngitis. More recent work has described a group of salivary glands, Weber's glands, located in the supratonsillar space as the actual site of bacterial invasion and subsequent abscess formation.[8,9] The glands clear the tonsillar area of debris and assist with the digestion of food particles trapped in

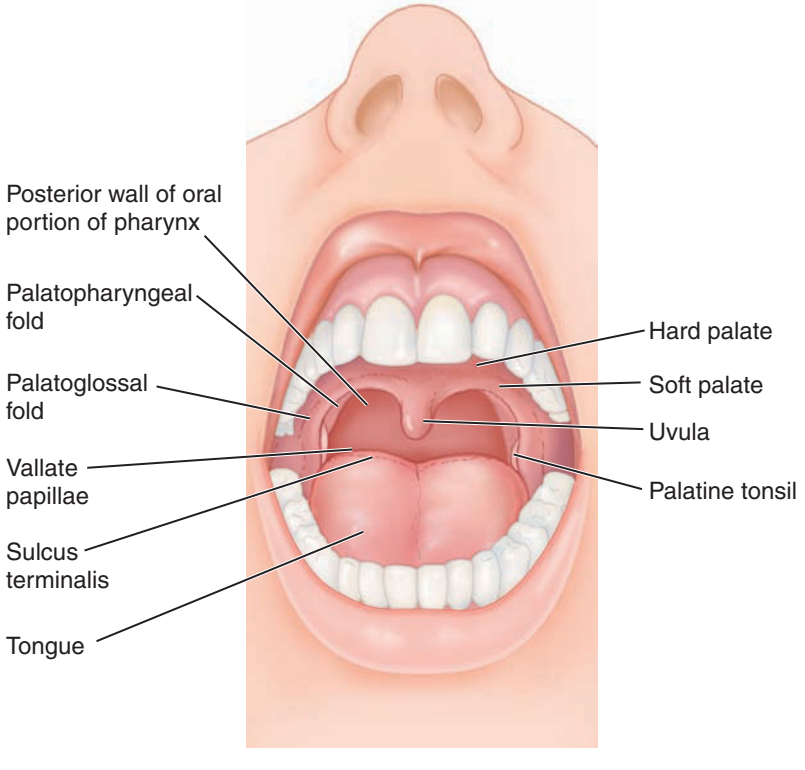


FIGURE 175-1. Anatomy of the oropharynx as seen through the open mouth.

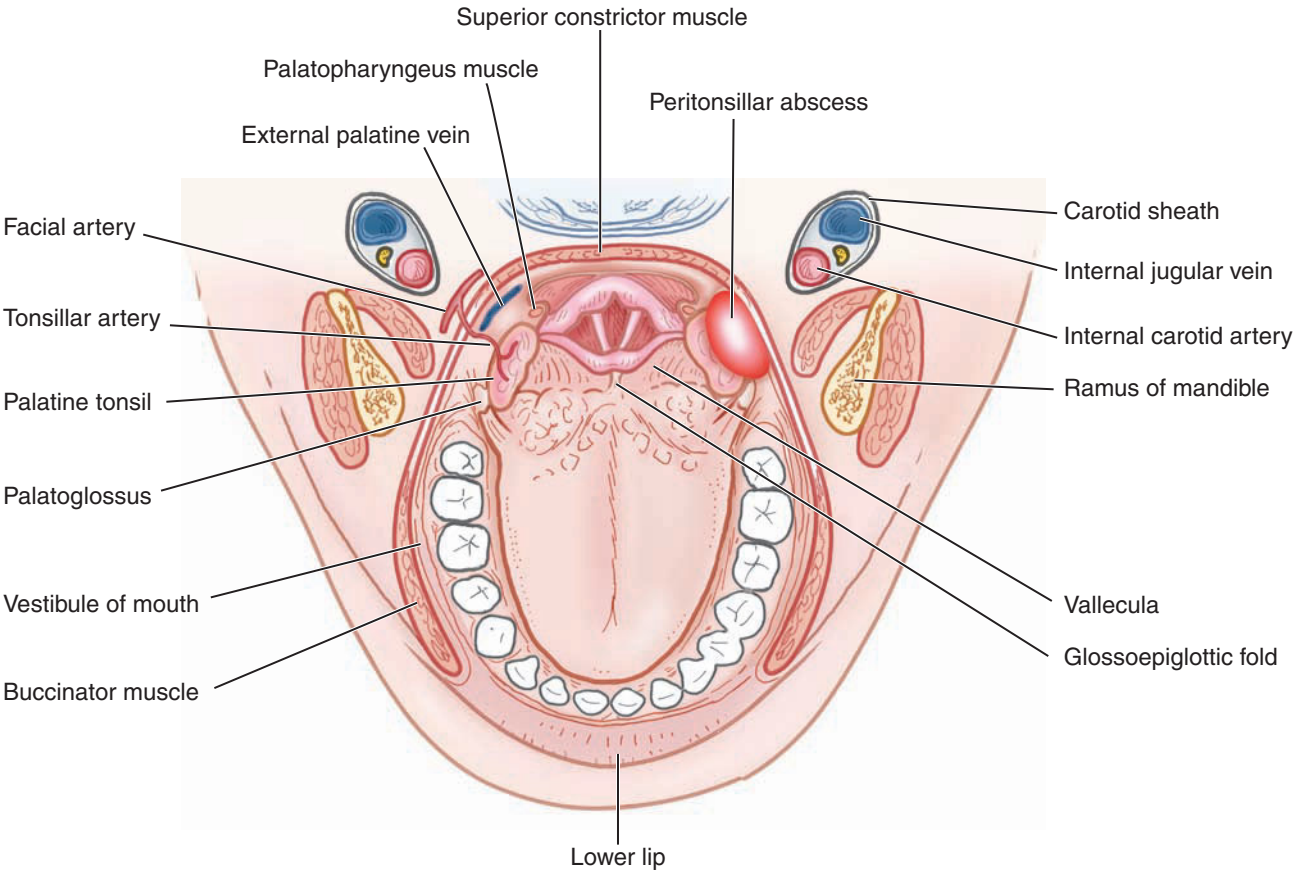


FIGURE 175-2. Horizontal section through the mouth and oropharynx. Note the close proximity of the peritonsillar abscess to the internal carotid artery and the facial artery.

the tonsillar crypts. If the Weber's glands become inflamed, a local cellulitis can develop.[9] The bacterial inoculum results in tissue necrosis and pus formation typically located between the tonsillar capsule and the lateral pharyngeal wall and/or the supratonsillar space. Progression of pus formation and cellulitis within the supratonsillar space results in a gradual involvement of the surrounding musculature, particularly the internal pterygoids, leading to spasm and trismus.

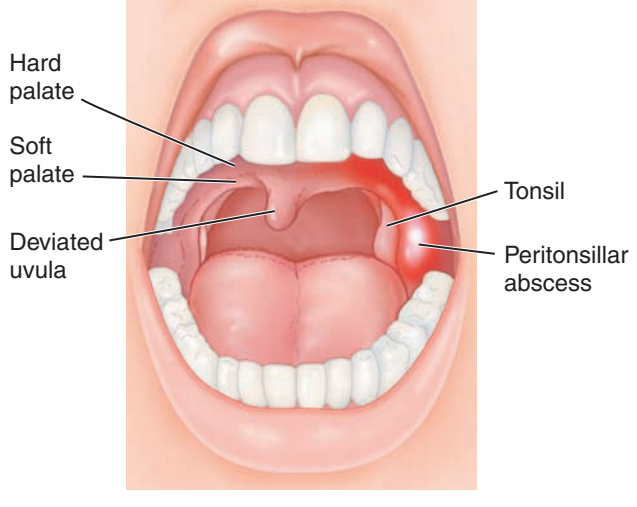


FIGURE 175-3. A peritonsillar abscess. The abscess displaces the tonsil forward and medially. The uvula is deviated toward the contralateral side.

Most peritonsillar abscesses are caused by a mixed profile of aerobic and anaerobic organisms.[10] The most common aerobic isolate found on culture remains group A beta-hemolytic streptococci.[1,9–11] The most common anaerobic species are peptostreptococcus, prevotella, and Fusobacterium.[1] Other isolates include *Staphylococcus aureus*, *Bacteroides fragilis*, and *Bacteroides melaninogenicus*. There is an increasing prevalence of beta-lactamase producing organisms.[11]

Treatment options for a peritonsillar abscess have undergone a significant amount of debate in the literature. Treatment requires appropriate antibiotic selection and removal of purulent fluid. Techniques of fluid removal range from simple or single aspiration of the abscess, repeated aspirations, and incision and drainage. Patients treated with aspiration alone have success rates ranging from 85% to 100%.[2,12,13] The cure rates for simple aspiration versus incision and drainage are similar.[14–18] The overall recurrence rate is less in patients undergoing incision and drainage.[2,12,13]

INDICATIONS

All peritonsillar abscesses require either aspiration or incision and drainage. The gold standard to diagnose a peritonsillar abscess remains the collection of pus through needle aspiration or the identification of a peritonsillar fluid collection using US. The decision regarding the drainage technique is left to the Emergency Physician's preference and, when possible, in consultation with an Otolaryngologist.

US may be used to confirm the presence of a peritonsillar abscess, to guide needle aspiration of a confirmed peritonsillar abscess, and/or rescue a failed blind needle aspiration. The use of US can confirm the presence of a cellulitis with no underlying abscess. It will also confirm that the "mass" is not an aberrant internal carotid artery.[19]

CONTRAINDICATIONS

There are no absolute contraindications to draining a peritonsillar abscess. Patients with severe trismus limiting visibility and access may require intravenous analgesics and muscle relaxants, procedural sedation, or intraoperative drainage. Consult an Otolaryngologist for all patients who are coagulopathic, taking oral anticoagulants, or with a known bleeding disorder. These patients are at risk for significant bleeding and associated complications. Admit children to the hospital for intravenous antibiotics, incision and drainage under general anesthesia, and possible tonsillectomy. The procedure should be avoided in patients who are uncooperative, unable to follow instructions, unable to sit upright, and those that are very young to prevent iatrogenic complications.

EQUIPMENT

General Supplies

- #11 scalpel blade on a handle
- Curved hemostat
- Frazier suction catheter
- Suction source and tubing
- Tongue depressors
- Topical anesthetic spray (Cetacaine, lidocaine, tetracaine, or benzocaine)
- Syringe, 3 or 5 mL
- 25 or 27 gauge needle, 2 inches long
- Local anesthetic solution with epinephrine
- 10 mL syringe
- 18 gauge needle
- Culturettes or culture bottles
- Headlamp or adjustable overhead light source
- Gloves
- Face mask with an eye shield
- Gown
- Oral rinse solution, hydrogen peroxide or Peridex

Us Guidance

- US machine
- High frequency, endocavitary US probe
- Sterile US gel
- US probe cover

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed informed consent for the procedure. Ensure that the patient has a thorough understanding of the postprocedural care instructions and follow-up requirements.

Position the patient sitting in an upright multipositional procedure chair. Alternatively, place the patient sitting upright on a gurney with the back elevated. Prepare the wall suction unit to ensure it is working. Apply suction tubing and a suction catheter to the suction source. The Emergency Physician should wear gloves, a gown, and a face mask with eye protection. This protective wear will prevent against becoming exposed or contaminated with oral secretions or abscess contents during the procedure if the patient coughs.

The use of good lighting cannot be overemphasized. Apply a headlamp if one is available. An alternative is an overhead adjustable light source. Position the light so that it is aimed in the patient's mouth. The overhead light often hits the examiner in the head, casts shadows, is too bright for the patient's eyes, and is also difficult to properly position because both of the Emergency Physician's hands must be used for the procedure. An additional alternative is to use the bottom half of a vaginal speculum with a fiberoptic light source.[25] This requires an assistant to position and hold the speculum against the tongue and apply downward pressure.

Incision and drainage must be preceded by adequate anesthesia to the abscess site. Determine the most fluctuant region of the abscess. Anesthetize this area. Spray topical anesthetic over the abscess (**Figure 175-4A**). Dry the mucosa overlying the peritonsillar abscess with a gauze square. Arm a 3 mL syringe with a 25 or 27 gauge needle. Inject 1 mL of local anesthetic solution containing epinephrine through the area of topical anesthesia and just under the mucosal surface (**Figure 175-4B**). Allow 3 to 5 minutes for the anesthetic to work.

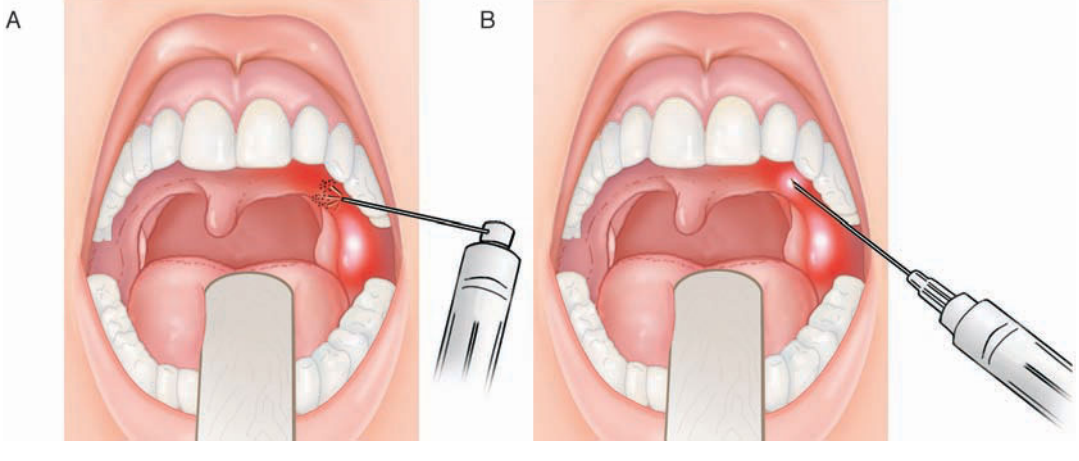
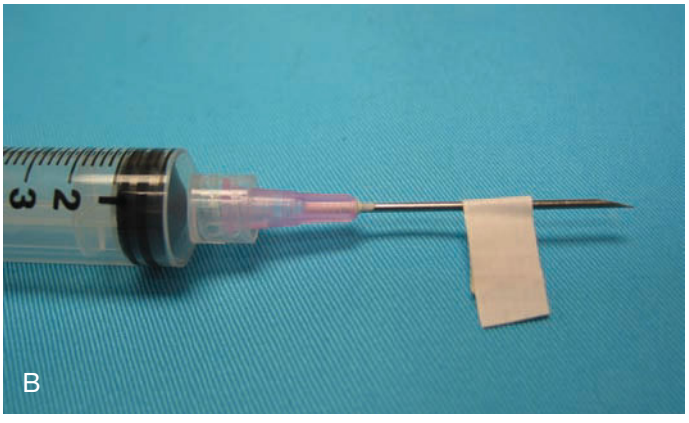


FIGURE 175-4. Anesthesia techniques. **A.** Topical spray anesthesia. **B.** Infiltrative anesthesia.





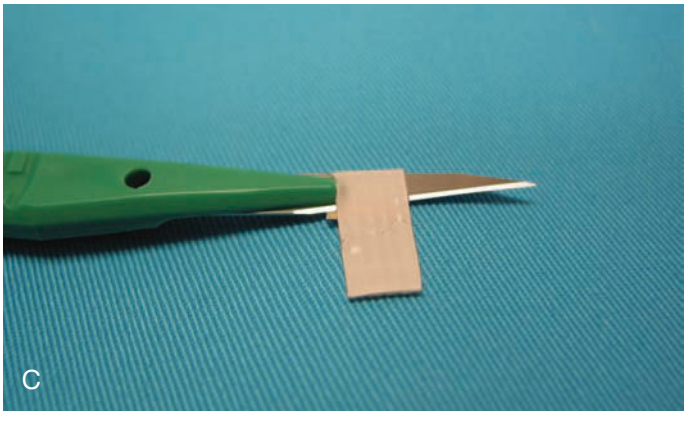


FIGURE 175-5. Safety techniques to prevent injury to the internal carotid artery. **A.** The needle cover is cut and placed over the needle as a guard. **B.** Tape applied to an 18 gauge needle. **C.** Tape applied to a #11 scalpel blade.

TECHNIQUES

ASPIRATION

Identify the area of maximal fluctuance at the upper pole of the abscess. Anesthetize the area as described previously. Prepare the equipment. Apply an 18 gauge needle onto a 10 mL syringe. **A smaller needle may not allow thick pus to be aspirated.** Break the seal of the syringe. Trim the needle cap and place it over the needle to act as a depth gauge (**Figure 175-5A**). The needle should project only 1 cm from the distal end of the needle cap. Alternatively, apply a piece of tape onto the needle to mark a point 1 cm from the tip of the needle (**Figure 175-5B**). The guard (cap or tape) serves as a marker for the maximum allowable depth to insert the needle during the procedure. **Limiting of the depth of insertion of the needle will prevent injury to the carotid artery that is located approximately 1.5 to 2 cm posterior and lateral to the tonsil.**

Depress the tongue with a tongue depressor held in the nondominant hand (**Figure 175-6A**). Insert the prepared needle attached to the syringe into the upper pole of the abscess, into the point of maximal fluctuance (**Figures 175-6A & B**).[14,17,20,21] Hold and advance the needle parallel to the floor and directly posterior.

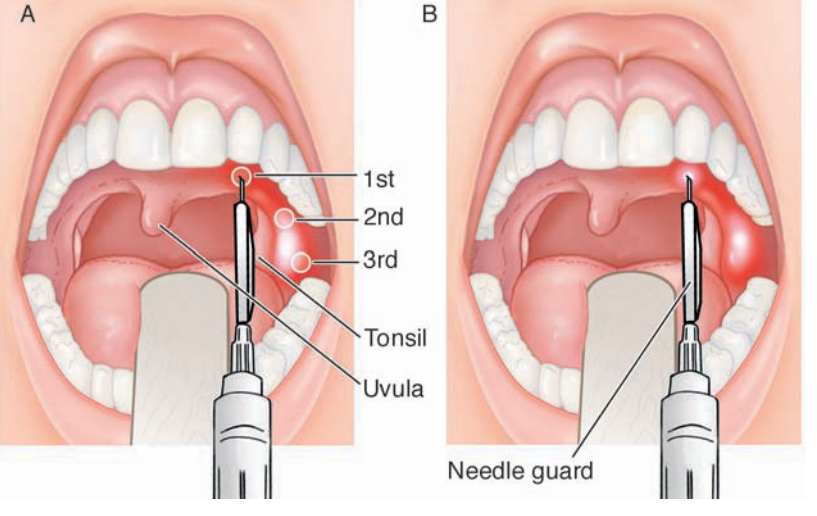


FIGURE 175-6. Needle aspiration of a peritonsillar abscess. **A.** Recommended sites for needle aspiration. **B.** Aspiration in the first area.

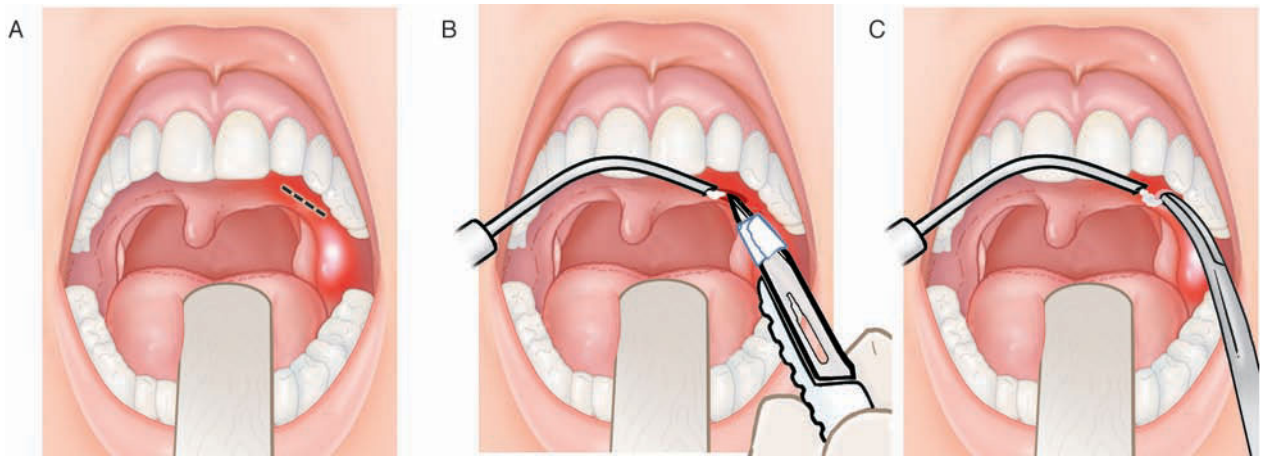


FIGURE 175-7. Incision and drainage of a peritonsillar abscess. **A.** The incision site is also the same site for the first aspiration. **B.** Incision with a #11 scalpel blade. Note the tape marking the maximum insertion depth of the scalpel blade. Suction any bloody or purulent fluid that escapes from the incision. **C.** Hemostat gently inserted to break any loculations.

Do not direct the needle laterally where it can injure the carotid artery. Aspirate while advancing the needle. Approximately 85% to 90% of abscesses occur in the upper pole of the tonsil.[14,17] If purulent fluid is obtained, continue to aspirate and remove as much purulent material as possible. Obtain a culture and sensitivity of the aspirated material. Allow the patient to rinse and spit several times with Peridex solution or half-strength hydrogen peroxide solution.

If the initial aspirate is negative, reattempt the procedure by inserting the needle into the middle pole and then the inferior pole of the abscessed tonsil until purulent material is obtained (**Figure 175-6A**). **A completely negative aspiration, while more consistent with a tonsillar cellulitis, does not rule out the existence of an abscess.** Gentle palpation will reveal fluctuance when an abscess if present.

INCISION AND DRAINAGE

It is recommended to always perform a needle aspiration prior to the incision and drainage technique. Aspiration will localize the collection of pus and allow a more accurate incision and drainage. **A negative aspiration at all three sites (Figure 175-6A) is a contraindication for an incision and drainage procedure.** It may be too early and an abscess has not yet formed. A negative aspiration at all three sites suggests that the patient has a tonsillar cellulitis requiring oral antibiotics, gargles with hydrogen peroxide, and follow-up in 24 hours for reevaluation.

Identify the area of maximal fluctuance at the upper pole of the abscess. Anesthetize the area as described previously. Prepare the equipment. Place a piece of tape on the #11 scalpel blade so that only 0.75 to 1 cm is exposed (**Figure 175-5C**). Place the Frazier suction catheter near the incision site. Insert the scalpel blade to make a horizontal stab wound to a maximum depth of 1 cm in the same area noted for the aspiration technique (**Figures 175-7A & B**). The Frazier suction catheter will remove any blood and purulent material to prevent the patient from aspirating. **The depth of the stab should be no more than 1 cm. Extend the length of the incision to a maximum of 1.0 to 1.5 cm.**

Insert a curved hemostat into the wound (**Figure 175-7C**). Gently spread apart the jaws of the hemostat to break up any loculations in the abscess. Continue to simultaneously suction the area during the procedure. Packing of the abscess cavity is not required. Obtain a culture and sensitivity of the purulent material. Allow the patient to rinse and spit several times with Peridex solution or half-strength hydrogen peroxide solution. Leave the suction in the patient's hand so they can use it as needed.

US GUIDANCE

Anesthetize the area as described previously. Prepare the equipment. Place sterile US gel on the transducer surface of the US probe. Apply the US probe cover. Take care to avoid trapping air bubbles between the cover and the US probe, as they can seriously degrade the image. Apply sterile US gel over the covered US probe transducer surface.

Gently insert the US probe into the patient's oral cavity. Direct the US probe to the peritonsillar area and until it rests lightly against the posterior pharynx (**Figure 175-8**). Maintain the US probe in a transverse orientation to maximize visualization of the posterior pharynx. Note the location of the palatine tonsil, a small oval structure with low-level echoes, and the internal carotid artery (**Figure 175-9**). A peritonsillar abscess can have variable appearances on US. They usually are heterogeneous, cystic, and



FIGURE 175-8. Placement of the endocavitary US probe inside the oral cavity and directed against the peritonsillar area.

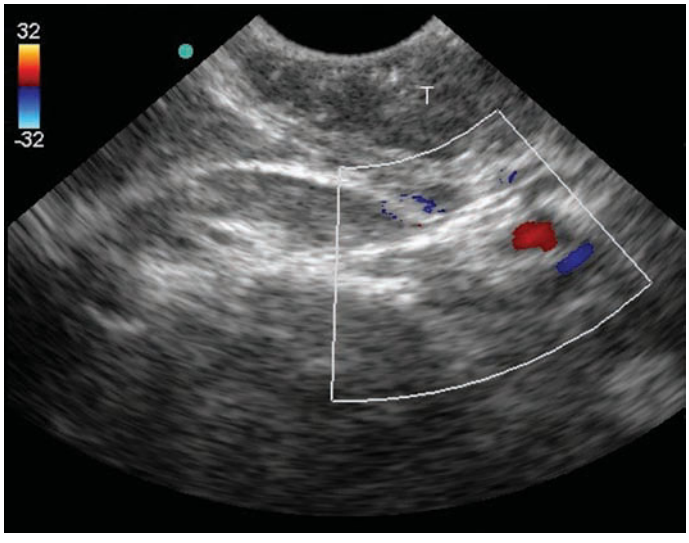


FIGURE 175-9. Transverse color Doppler scan of the normal posterior pharynx. The tonsil (T) is visible on the top of the image. The internal carotid artery is noted by its red color Doppler signal.



FIGURE 175-10. Intraoral ultrasound image. The needle (*arrows*) is inserted into the peritonsillar abscess (A). The tonsil (T) is visible on the top of the image. The internal carotid artery is not visualized in this image.

adjacent to the tonsil (**Figure 175-10**). The carotid artery usually lies 5 to 20 mm posterolateral to the tonsil. Note the depth and location of the abscess.

After the presence of a peritonsillar abscess is confirmed and its location mapped, proceed using the previously described techniques for aspiration or incision and drainage. Alternatively, perform a needle aspiration under real-time US guidance. Use the long axis approach to direct the needle into the peritonsillar abscess (**Figure 175-10**).

ASSESSMENT

Incision and drainage will result in significant relief of the patient's pain and trismus. Allow the patient to rinse and spit with either Peridex solution or half-strength peroxide solution. Observe the patient for any evidence of continued bleeding or upper airway symptomatology. Assess the patient's ability to tolerate oral fluids prior to discharge.

AFTERCARE

Discharge the patient with oral antibiotics and analgesics. Penicillin used to be the antibiotic of choice. The emergence of beta-lactamase-producing organisms has required a change in antibiotic choice.[10] Use clindamycin, or a second or third generation cephalosporin, to treat peritonsillar abscesses due to their polymicrobial coverage.[9,10] If penicillin is used, many Otolaryngologists will add either clindamycin or metronidazole due to the increasing incidence of penicillin-resistant organisms.[2,22] Nonsteroidal anti-inflammatory drugs will adequately control any pain and fever. Consider the administration of 3 mg/kg, to a maximum of 250 mg, of methylprednisolone to decrease pain and inflammation.[23]

Recommend to the patient to follow a soft diet and drink plenty of fluids during the first 48 hours after the intervention. Instruct the patient to gargle with half-strength hydrogen peroxide or Peridex after each meal, at a minimum, and several other times per day. Arrange follow-up within 48 hours, or sooner if they do not improve. Instruct the patient to return to the Emergency Department immediately if they develop bleeding, shortness of breath, difficulty swallowing, drooling, or have any concerns.

Admission is generally required for patients who appear toxic, pediatric patients, dehydrated patients, immunocompromised patients, recurrent abscesses, and for patients who are unable to tolerate oral fluids. These patients require observation for 23 hours and intravenous antibiotics.

COMPLICATIONS

There are few complications associated with the management of a peritonsillar abscess. Potential complications include aspiration pneumonitis, airway obstruction, hemorrhage, or extension of infection into deep tissue of the neck. Aspiration pneumonitis or lung abscess can occur secondary to abscess rupture.[9] Protect against aspiration of purulent material and subsequent pulmonic infection by having the patient sit upright during the procedure and using suction as the abscess is opened. Making an incision that is too large or too deep can injure the carotid artery (or a carotid artery aneurysm) which could result in prolonged bleeding or hemorrhage. Always limit the depth of the needle or scalpel insertion.

The use of US to locate and assist in the drainage of a peritonsillar abscess is associated with several pitfalls. Failure to recognize the internal carotid artery can be catastrophic for the patient. Always note the relationship of the tonsil and the peritonsillar abscess to the internal carotid artery.[24] The internal carotid artery lies posterolateral to the tonsil. The use of color Doppler can assist in the identification of the carotid artery and differentiate it from the peritonsillar abscess. US may fail to identify a peritonsillar abscess. Although fluid within a peritonsillar abscess is usually hypoechoic, it can appear isoechoic or hyperechoic.

SUMMARY

A peritonsillar abscess is commonly encountered in the Emergency Department. Diagnosis and treatment result in rapid symptom resolution in the majority of patients. Admission may be required in a few instances for observation and intravenous antibiotics. Appropriate antibiotics after the procedure can prevent a recurrence of the peritonsillar abscess.

176 Dental Anesthesia and Analgesia

Eric F. Reichman

INTRODUCTION

Dental anesthesia techniques are used by Emergency Physicians for a variety of intraoral and extraoral conditions. This includes dental caries, jaw fractures, dry sockets, intraoral hemorrhage, laceration repair, and tooth fractures. These techniques are simple to learn, easy to perform, and provide temporary pain relief for the patient. The Emergency Physician can provide pain-free intraoral manipulations, extraoral manipulations, facial manipulations, and simple pain control until the patient receives definitive evaluation and treatment by a Dentist or Oral Surgeon. The fundamental principles of dental anesthesia and anatomy will be discussed so that the Emergency Physician will feel knowledgeable and comfortable performing dental anesthetic techniques.

ANATOMY AND PATHOPHYSIOLOGY

An understanding of the anatomy of the fifth cranial nerve is essential to performing dental nerve blocks[1] (**Figure 176-1**). The fifth cranial nerve is also referred to as CN V or the trigeminal nerve. It is the largest cranial nerve. It is a mixed cranial nerve containing primarily sensory fibers to the skin of the face and scalp, the nasal cavity, and the oral cavity. The motor fibers innervate the muscles of mastication.

The trigeminal nerve originates in the brainstem as a small motor root and a large sensory root. These roots fuse as they leave the brainstem. The trigeminal nerve travels forward into the middle cranial fossa where it expands into a large and crescent-shaped trigeminal ganglion. The trigeminal ganglion divides to give rise to the three divisions of the trigeminal nerve: the ophthalmic nerve (V_1), the maxillary nerve (V_2), and the mandibular nerve (V_3) (**Figure 176-1**). Each of these nerves leaves the middle cranial fossa through its own foramen.

OPHTHALMIC NERVE

The ophthalmic nerve is the smallest branch of the trigeminal nerve. It travels forward in the lateral wall of the cavernous sinus and enters the orbit via the superior orbital fissure. It provides sensory innervation to the forehead, scalp, upper eyelid, cornea, nasal cavity, sinuses, and the orbit. This nerve is not discussed further because it does not innervate any oral or dental structures.

MAXILLARY NERVE

The maxillary nerve is purely sensory. It travels forward in the lateral wall of the cavernous sinus and exits the cranial vault via the foramen rotundum into the pterygopalatine fossa. It then enters the

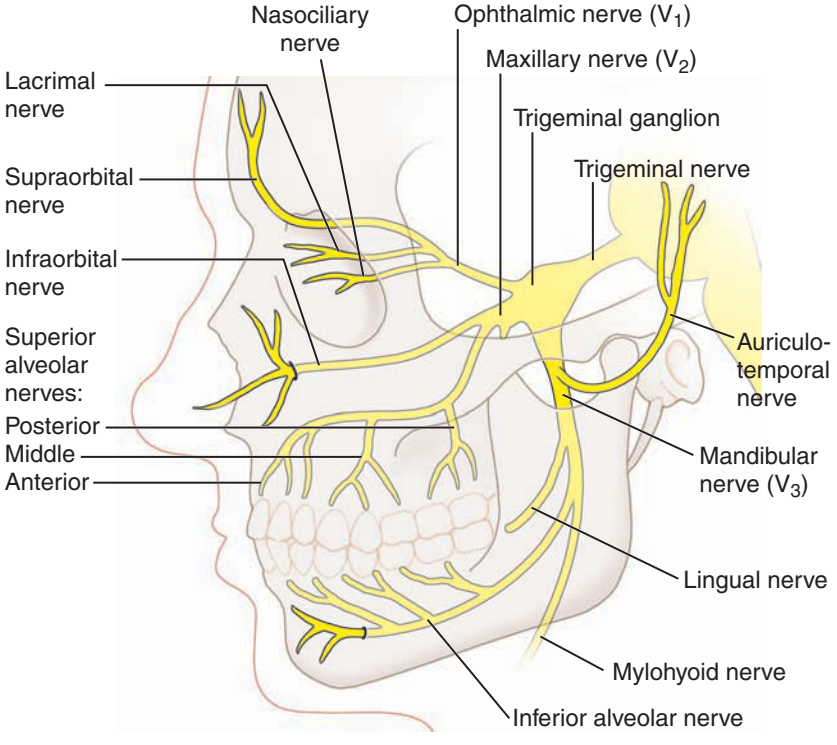


FIGURE 176-1. The anatomy of the trigeminal nerve.

orbit through the inferior orbital fissure to continue on as the infraorbital nerve and emerge on the face. The infraorbital nerve terminates as a sensory nerve to the lower eyelid, upper cheek, nose, and upper lip. The infraorbital nerve gives off the anterior superior alveolar nerves prior to its termination. These nerves supply the maxillary sinus, the maxillary incisors, the maxillary canine teeth, and the maxillary premolar teeth. The anterior superior alveolar nerve occasionally crosses the midline to supply the contralateral maxillary incisors.

The maxillary nerve forms numerous branches in the pterygopalatine fossa. The zygomaticofacial and zygomaticotemporal nerves are cutaneous to the face and temple. The nasal and nasopalatine nerves supply the nasal cavity and floor of the nasal cavity. The nasopalatine nerve exits the nasal canal through the midline incisive foramen, just posterior to the central incisors. It provides sensory innervation to the anterior hard palate and associated soft tissues. The greater palatine nerve exits the greater palatine foramen to provide sensory innervation to the posterior two-thirds of the hard palate. The lesser palatine nerve exits the lesser palatine foramen and provides sensory innervation to the soft palate. The greater and lesser palatine nerves exit 1 cm medial to the junction of the second and third molar on the hard palate. The middle superior alveolar nerve provides sensory innervation to the premolars, and occasionally the canine and the first molar teeth. The posterior superior alveolar nerve provides sensory innervation to the molars and, occasionally, the premolars.

MANDIBULAR NERVE

The mandibular nerve is the largest division of the trigeminal nerve. It is the only division of the trigeminal nerve to contain motor fibers. The mandibular nerve exits the middle cranial fossa via the foramen ovale. It provides branches to the meninges and the small muscles of the palate and the medial pterygoid muscle. It divides into a small anterior division and a large posterior division.

The anterior division of the mandibular nerve is primarily motor. It innervates the muscles of mastication (i.e., masseter, temporalis, and lateral pterygoid). The sensory portion of the anterior division is the buccal nerve. This nerve travels between the two heads of the lateral pterygoid muscle, under the masseter muscle, and emerges from the anterior border of the masseter muscle. It travels forward to innervate a small and variable portion of the skin of the cheek. It primarily innervates the mucous membranes of the cheek.

The posterior division of the mandibular nerve is purely sensory. It divides into the auriculotemporal, inferior alveolar, and lingual nerves. The auriculotemporal nerve supplies sensory innervation to the skin of the auricle, external auditory canal, scalp, and temporomandibular joint. It conveys postganglionic parasympathetic fibers to the parotid gland.

The lingual nerve descends into the mouth and travels along the lateral surface of the tongue. It supplies sensory innervation to the anterior two-thirds of the tongue and the floor of the mouth. The lingual nerve receives, near its origin, and conveys the chorda tympani from the facial nerve. The chorda tympani provides taste sensation to the anterior two-thirds of the tongue and preganglionic fibers to the submandibular ganglion for the submandibular and sublingual glands.

The inferior alveolar nerve descends immediately posterior and adjacent to the lingual nerve. It enters the upper one-third of the ramus of the mandible, posterior to the lingula, to enter the mandibular canal. It provides sensory innervation to the mandible, the mandibular teeth, and the adjacent mucous membranes. The inferior alveolar nerve gives origin to the mental nerve. The mental nerve exits the mental foramen located on the outer surface of the mandible between the first and second premolars. It supplies sensory innervation to the lower lip, the skin of the chin, and the mucous membrane of the chin.

INDICATIONS

Dental nerve blocks can be performed to provide temporary relief of pain. They are often used to provide relief from alveolar ridge fractures, dental caries, dry sockets, mandible fractures, and tooth fractures. Nerve blocks can be performed prior to painful intraoral procedures such as incision and drainage of dental abscesses and laceration repair to the cheek, lips, oral mucosa, and tongue. Nerve blocks do not distort the local anatomy, when compared to infiltration of the surrounding soft tissue with local anesthetic solution, and allow better approximation of the wound edges during suturing. Nerve blocks are an excellent alternative if narcotic analgesics are contraindicated or to be avoided. Local anesthetic solutions containing epinephrine can be utilized to provide longer pain relief and vasoconstriction along the nerve distribution (**Table 176-1**).

CONTRAINDICATIONS

The two absolute contraindications to dental anesthesia include a known hypersensitivity to the anesthetic agent and gross distortion of the anatomic landmarks required to perform the nerve

TABLE 176-1 Local Anesthetic Solutions Commonly used in Dental Anesthesia Procedures

Anesthetic solution	Proprietary name	Time of onset (minutes)	Pulpal duration of action (minutes)	Soft tissue duration of action (minutes)	Maximum dose (mg)*	Maximum adult or pediatric weight-based dose (mg/kg)
1% procaine	Novocaine™	6–10	10	15–90	500	7.0
1% procaine with epinephrine		6–10	15	15–120	600	9.0
2% lidocaine	Xylocaine™	2–5	10	30–45	300	4.5
2% lidocaine with epinephrine		2–5	60	180–300	500	7.0
3% mepivacaine	Carbocaine™	5	5–10	90–120	400	6.6
2% mepivacaine with epinephrine		5	45–60	120–140	400	6.6
4% prilocaine	Citanest™	3–5	10–60	60–240	400	6
4% prilocaine with epinephrine		3–5	60–90	180–480	400	6
4% articaine with epinephrine	Septocaine™	1–3	45–75	180–300	500	7
0.5% bupivacaine	Marcaine™	5	60–90	240–280	90	1.3
0.5% bupivacaine with epinephrine		5	90–120	240–720	90	1.3

*Do not exceed this quantity if the maximum weight-based dose is larger than this number.

block. Other relative contraindications include an uncooperative patient, such as an anxious adult, scared child, or any patient with altered mental status. These patients place themselves and the Emergency Physician at significant risk for injury. It may be most prudent to abort the procedure and perform procedural sedation and analgesia (or general anesthesia in the operating room) to ensure the safety of the patient and the Emergency Physician.

The needle used to inject local anesthetic solution should not traverse infected tissue. Injection of the local anesthetic solution into or through infected tissue is also a relative contraindication. These processes may result in spread of the infection into other adjacent tissues or tissue planes. It is possible to cause bacteremia when injecting into infected tissues. Local anesthetic solutions are less effective when injected into areas of infection or inflammation. An infection that tracks along a nerve and into a bone of the face and/or skull is extremely difficult to treat. Evaluate the risks and benefits of injecting through infected tissue and attempt an alternative method of anesthesia if possible.

EQUIPMENT

- Nonsterile gloves
- Antiseptic mouth rinse, any of the following:
  - Hydrogen peroxide
  - Ethanol (7%) with chlorhexidine (0.5%)
  - Povidone iodine solution
  - 0.12% chlorhexidine or Peridex solution
- 4 × 4 gauze squares
- Cotton-tipped applicators
- Aspirating dental syringe (**Figure 176-2**)
- Local anesthetic solution (**Table 176-1**)
- Syringes, 1 and 3 mL
- Suction source and tubing
- Yankauer suction catheter
- Topical anesthetic (e.g., viscous lidocaine, viscous benzocaine, or aerosolized benzocaine)
- Overhead light source or headlamp
- 22 to 27 gauge needles, 2 inches long

The above-listed supplies are required to provide dental anesthesia. They are contained in every Emergency Department. An aspirating dental syringe and anesthetic cartridges, if available, are ideal to perform the nerve blocks (**Figure 176-2**). Standard 1 to 3 mL syringes armed with a 25 or 27 gauge, 2 inch long needle will work as a substitute. The aspirating dental syringe allows better control of the syringe and the ability to simultaneously aspirate and insert the needle with one hand. This allows the nondominant hand to be used to identify landmarks, retract the cheek or tongue, adjust the light source, and/or use the suction catheter. Many local anesthetic solutions are available in 1.8 mL carpules that fit into the dental aspirating syringe. The carpules are available with the local anesthetic solution, and also with or without a vasoconstrictor (usually epinephrine). A dental or multipositional procedure chair would be preferred to the use of a standard cart or gurney.[2,3] Unfortunately, this may not be available in many Emergency Departments.

Numerous injectable agents are available to provide anesthesia (**Table 176-1**). The most commonly used agents are lidocaine and lidocaine without epinephrine (1:100,000). Longer acting agents are commonly available in the Emergency Department (e.g., bupivacaine and mepivacaine, with and without epinephrine) when a prolonged period of anesthesia is required. Avoid using long-acting



FIGURE 176-2. The aspirating dental syringe and local anesthetic cartridges.

local anesthetic agents if the tongue (i.e., inferior alveolar or lingual nerve blocks) or mucosa (i.e., buccal nerve block) is anesthetized, especially in children, to prevent the patient from biting the area and causing injury.

A relatively new device is the Accupal (Accupal, Little Rock, AR). It is an injection preparation tool that prepares the gums before the anesthetic needle is inserted. The Accupal vibrates and produces ultrasonic tissue stimulation to reduce pain sensation at the needle injection site. The Accupal is usually not available in the Emergency Department.

Numerous jet injectors for the delivery of local anesthetic agents are commercially available. These devices inject the local anesthetic solution under pressure and in a fine stream into the soft tissues without the use of a needle. The small volume of injected solution and its superficial penetration into the soft tissues only anesthetizes the soft tissues and not the teeth. Thus, jet injectors cannot be used to anesthetize teeth. They can be used to provide topical anesthesia.

PATIENT PREPARATION

Perform a thorough history and a directed physical examination, dependent on the clinical situation, in any patient undergoing dental anesthesia. Give special attention to the past medical history, past surgical history, current medications, and any history of allergic or adverse reactions to an anesthetic agent. A patient with severe systemic disease may be better served by rescheduling the procedure after appropriate consultation or referral. This will clarify functional reserve and treatment limitations.[2,3] Any patient with cardiac valvular disease, congenital heart anomalies, artificial heart valves, or other indications should receive antibiotic prophylaxis to help prevent bacterial endocarditis caused from transient bacteremia. Please refer to Chapter 177 for more complete details of antibiotic prophylaxis.

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain an informed consent for the specific

technique to be performed. A formal consent may exist depending upon the institution in which one practices. Some physicians desire a formal signed and dated consent form. Other physicians choose to chart: "All the risks, benefits, and complications were described and discussed with the patient. They understood the procedure described and gave verbal consent for the procedure." This is physician and institution dependent. Place the patient in a well-lighted environment. Reassurance often alleviates a patient's anxiety regarding injections or manipulations and puts them at ease.[2]

Prepare the mucosa at the injection site. Completely dry the mucosa with gauze squares. Apply an antiseptic solution (e.g., 7% ethyl alcohol (ETOH) with 0.5% chlorhexidine solution, diluted povidone iodine, 0.12% chlorhexidine solution, or hydrogen peroxide) to the working area with a cotton ball or gauze square for 15 seconds. Alternatively, the patient can swish 0.12% chlorhexidine mouth rinse or hydrogen peroxide for 30 seconds and then spit it out.

Apply a topical anesthetic agent (e.g., viscous lidocaine or benzocaine with a cotton-tipped applicator, or 20% benzocaine spray) for added patient comfort. **It is not recommended to use TAC (tetracaine, adrenalin, and cocaine) or other topical anesthetic combinations that are used for cutaneous laceration repair on mucosal surfaces.** Their use may lead to significant absorption and systemic toxicity.

TECHNIQUES

The general procedure of a dental nerve block will be described. The specific details are contained within each nerve block described below. Identify the anatomic landmarks required to perform the nerve block. Clean the mucous membrane at the injection site with a gauze square. Apply an antiseptic solution. Apply a topical anesthetic and allow it to work for 2 to 3 minutes. Reidentify the anatomic landmarks. Insert a 25 or 27 gauge needle into the appropriate area to deliver the local anesthetic agent. **If the patient experiences paresthesias, do not inject the local anesthetic solution. Paresthesias signify that the tip of the needle is within the nerve bundle.** Withdraw the needle 1 to 2 mm and allow the paresthesias to resolve. This usually takes 5 to 20 seconds. Inject the local anesthetic solution. Allow up to 10 minutes for the local anesthetic solution to take effect. Some Dentists prefer to apply pressure to the area immediately next to the site of the anesthetic injection with a cotton-tipped applicator. This aids in distracting the patient from the pain of injection. Other Dentists "jiggle" the mucous membrane to and fro rapidly as they simultaneously introduce the needle.[2,3]

SUPRAPERIOSTEAL INFILTRATION (FIELD BLOCK)

This technique is commonly used in dentistry. Excellent anesthesia can be achieved with this technique when it is used to anesthetize a branch of the anterior or middle superior alveolar nerve.[3,4] This technique deposits local anesthetic agent against the periosteum of the alveolar ridge adjacent to a tooth (**Figure 176-3A**). The local anesthetic agent then infiltrates through the periosteum, the cortical plate of the maxilla, and the medullary bone to anesthetize the nerve root as it leaves the apex of the tooth. This technique works best for teeth with associated thin cortical bone. This includes the maxillary incisor, canine, and premolar teeth. The molars of the maxilla in an adult are less likely to be anesthetized with this technique as the cortical bone in which they lie is relatively thick and a poor conduit for the anesthetic. Supraperiosteal infiltration is also a poor technique for anesthesia of mandibular teeth in the adult patient for the same reasons. In children, the cortical bone of the maxillary molars and the mandible is thin and may allow this technique to be effectively utilized to anesthetize a tooth.

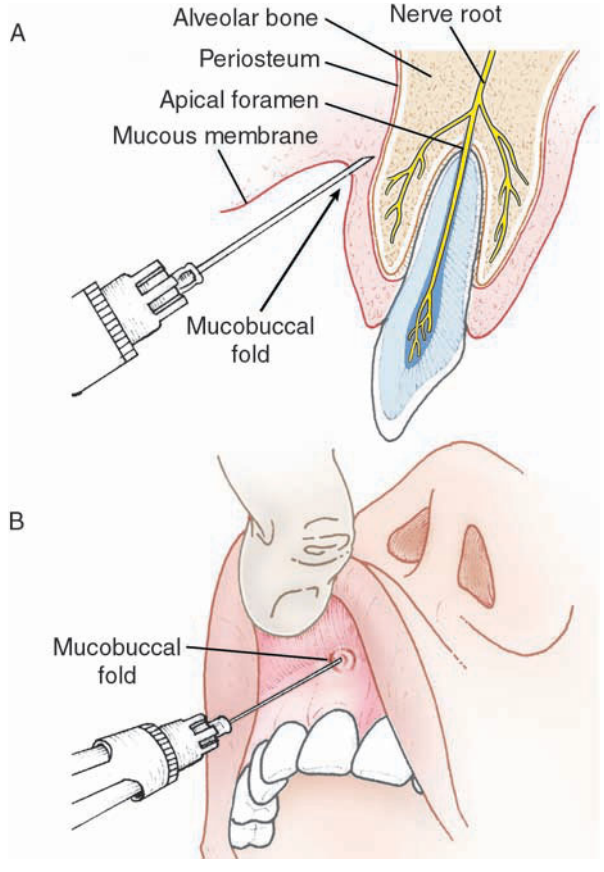


FIGURE 176-3. Supraperiosteal infiltration of local anesthetic solution. **A.** Illustration of the correct needle position. **B.** Elevate the upper lip and insert the needle through the mucobuccal fold.

Anatomy The anterior superior alveolar nerve provides sensory innervation to the ipsilateral medial and lateral incisors, canine, and sometimes the first premolar teeth. The middle superior alveolar nerve provides sensory innervation to the ipsilateral premolars, canine, and first molar teeth.

Patient Positioning Place the patient recumbent in a dental chair with their neck extended 45°. Alternatively, position the patient sitting upright with their back and head firmly set against an examination chair or table.

Landmarks Use the nondominant hand to grasp and pull the upper lip outward and upward (**Figure 176-3B**). Identify the mucobuccal fold above the tooth to be anesthetized.[3]

Needle Insertion and Direction Clean, prep, and apply a topical anesthetic agent to the mucobuccal fold above the tooth to be anesthetized. Firmly grasp the upper lip. Pull it outward and upward to tighten the tissues and allow a clear identification of the maxillary mucobuccal fold (**Figure 176-3B**). Insert a 27 gauge needle through the mucobuccal fold over the center of the tooth to be anesthetized (**Figure 176-3B**). Aim the tip of the needle toward the maxilla. Advance the needle 1.0 to 1.5 cm until it contacts the maxilla (**Figure 176-3A**). Withdraw the needle 1 mm. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 1 to 2 mL of local anesthetic solution.

Remarks The anesthetic will be deposited in a nonoptimal location if the needle is too deep or too shallow. It may take as long as 10 minutes to achieve anesthesia as the local anesthetic solution diffuses through the cortical bone and to the nerve root. **Be careful when using this technique for anesthesia of the incisor or canine**

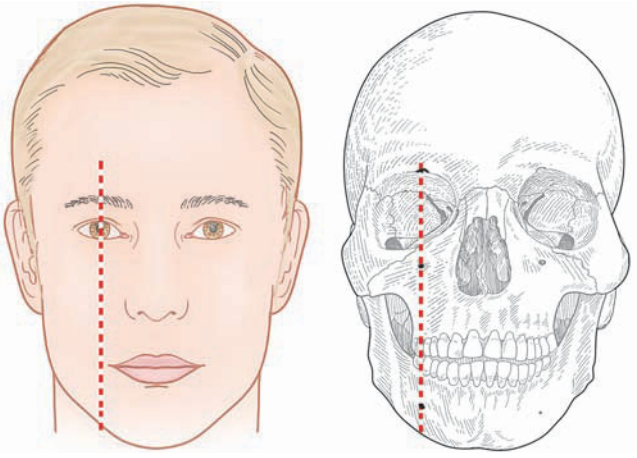


FIGURE 176-4. The supraorbital foramen, infraorbital foramen, and the mental foramen all lie along a straight line drawn through the pupil in the midposition.

teeth because advancing the needle too far may breach the nasal cavity or maxillary sinuses.

INFRAORBITAL NERVE BLOCK

Anatomy The infraorbital nerve is the terminal branch of the maxillary nerve. It exits the maxilla via the infraorbital foramina and supplies sensation to the ipsilateral upper lip, cheek, lateral nose, and lower eyelid. It may be blocked by either an extraoral or intraoral approach.

Patient Positioning Place the patient recumbent in a dental chair with their neck extended 30°. Alternatively, position the patient sitting upright with their head and back against an examination chair or table with their neck extended 30°. Instruct the patient to slightly open their mouth.

Landmarks Identify the infraorbital foramen by palpation. It is located below the infraorbital ridge in the midpupillary line (**Figure 176-4**). The midpupillary line is a line drawn in the sagittal plane (vertical) through the pupil while the patient is staring straight ahead.

Needle Insertion and Direction (Extraoral Approach) Identify the infraorbital foramen as above. Clean and prep the skin over the infraorbital foramen. Instruct the patient to close their eyes. Insert a 25 or 27 gauge needle through the skin overlying the infraorbital foramen (**Figure 176-5**). Advance the needle to just beneath the

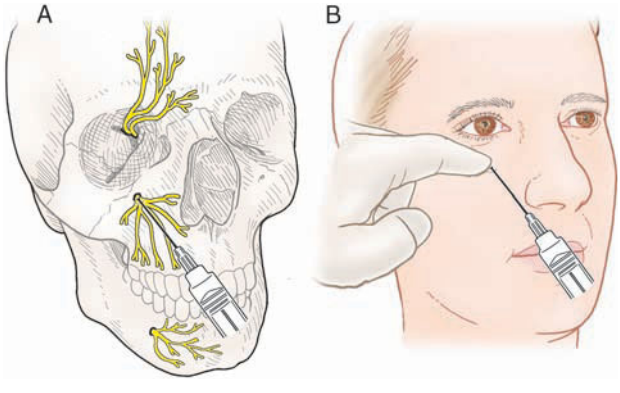


FIGURE 176-5. The extraoral approach to the infraorbital nerve block. **A.** Location of the nerve. **B.** Insertion of the needle.

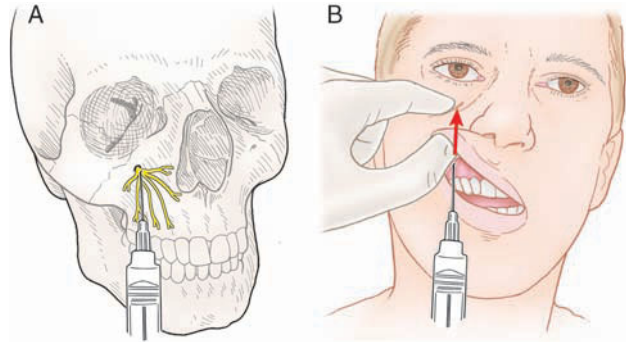


FIGURE 176-6. The intraoral approach to the infraorbital nerve block. **A.** Location of the nerve. **B.** Insertion of the needle.

subcutaneous tissue. **Do not enter the infraorbital canal as this may damage the nerve.** Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 1 to 2 mL of local anesthetic solution. Massage the area over the infraorbital foramen for a few seconds to ensure optimal infiltration.

Needle Insertion and Direction (Intraoral Approach) Clean, prep, and apply a topical anesthetic agent to the mucosa opposite the first maxillary premolar. Place the nondominant index finger over the infraorbital foramen (**Figure 176-6**). Retract the upper lip using the nondominant thumb. Identify the mucobuccal fold above the first premolar. Insert a 25 or 27 gauge needle through the mucobuccal fold. Advance the needle toward the nondominant index finger situated over the infraorbital foramen (**Figure 176-6B**). Stop advancing the needle when the tip is felt beneath the index finger. The estimated depth of penetration of the needle tip is 1.0 to 1.5 cm in an older child or an adult and 0.5 to 1.0 cm in a younger child. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 1 to 2 mL of local anesthetic solution.

Remarks **Be careful not to penetrate too deeply when performing the intraoral approach.** The infraorbital venous plexus may be disrupted and result in a hematoma. The globe may also be accidentally penetrated. Avoid these complications by positioning the nondominant index finger over the infraorbital foramen and using it to palpate and track the advancing needle tip. The intraoral approach is the preferred technique.

NASOPALATINE NERVE BLOCK

Anatomy The nasopalatine nerve provides sensory innervation to the anterior one-third of the hard palate (**Figure 176-7A**). It exits the maxilla via the incisive foramen in the midline and 0.5 cm posterior to the central incisors.

Patient Positioning Place the patient recumbent in a dental chair with their head extended 45°. Alternatively, place the patient supine with a rolled sheet beneath their shoulder blades to assist in neck extension. Instruct the patient to fully open their mouth.

Landmarks The incisive foramen lies in the midline and approximately 5 mm posterior to the central incisors of the maxilla. Overlying the incisive foramen is the incisive papilla, a soft tissue elevation.

Needle Insertion and Direction Clean, prep, and apply a topical anesthetic agent to the mucosa on the anterior one-third of the hard palate. Identify the incisive foramen by first identifying the incisive papilla. Insert a 27 to 30 gauge needle, with the bevel facing the hard palate, from a position immediately lateral to the edge of the incisive papilla (**Figure 176-7B**). Advance the needle

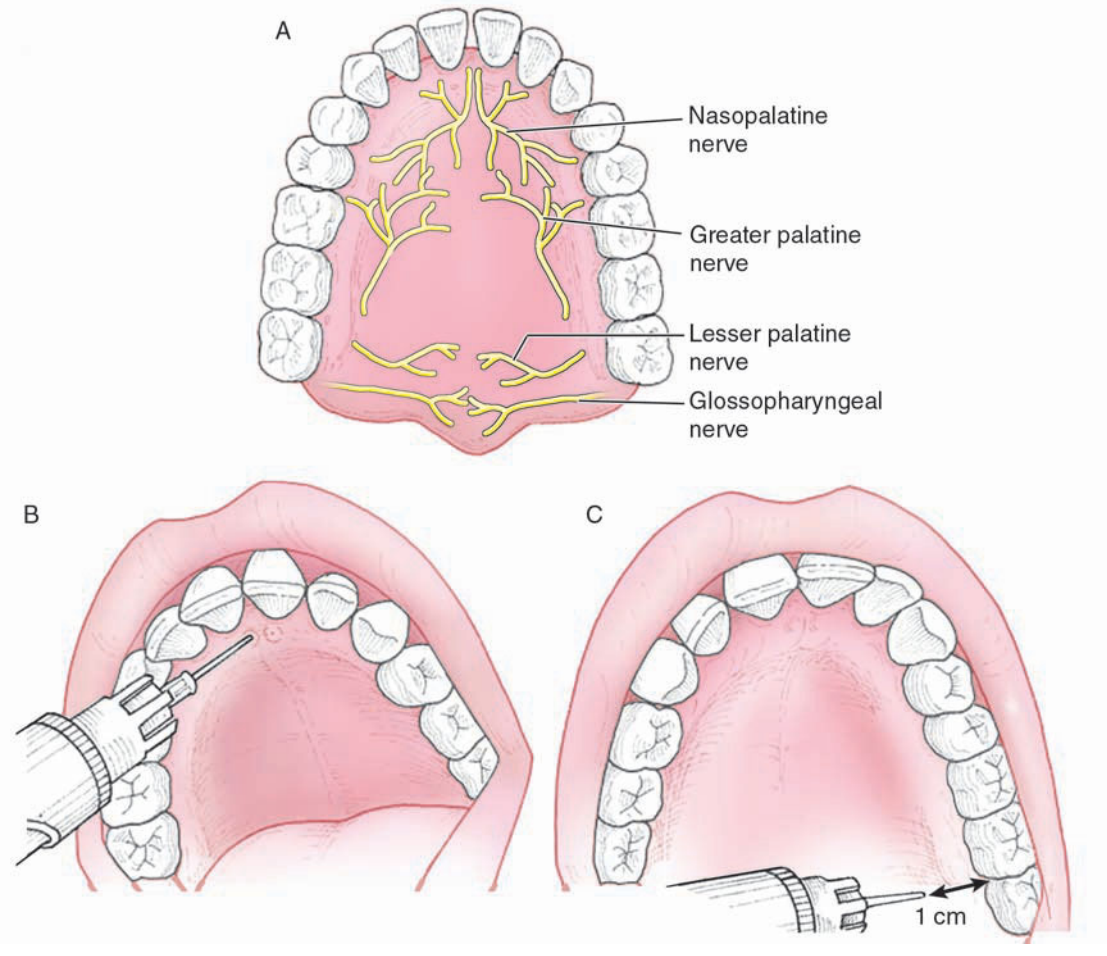


FIGURE 176-7. Anesthesia of the palate. **A.** Sensory innervation of the palate. **B.** Nasopalatine nerve block. **C.** Greater palatine nerve block.

3 to 4 mm toward the midline or until bone is identified. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 0.25 to 0.35 mL of local anesthetic solution. The area surrounding the injection site will blanch upon deposition of the local anesthetic solution.[2,3]

Remarks This is a particularly painful injection due to the adherent nature of the mucosa to the underlying hard palate. Topical anesthetics will provide adequate preinjection anesthesia. Some clinicians use a cotton-tipped applicator or a blunt instrument to put pressure on the incisive papilla for 30 seconds prior to and during the injection.[3] This seems to defer the attention of the patient and make the injection more bearable. **Be careful not to penetrate too deeply with the needle and enter the incisive foramen.** Insertion into the incisive foramen will cause severe pain. **Injection into the incisive foramen can result in permanent nerve damage.**[2,3] The mucosa of the hard palate receives its blood supply from the hard palate. Injection of more than 0.4 mL will elevate the mucosa from the hard palate and result in mucosal necrosis. This block may be performed to repair lacerations of the mucosa of the anterior hard palate.

GREATER PALATINE NERVE BLOCK

Anatomy The greater palatine nerve provides sensory innervation to the ipsilateral posterior two-thirds of the hard palate (**Figure 176-7A**). It enters the oral cavity via the greater palatine foramen. The greater palatine foramen lies between the second and third maxillary molar and approximately 1 cm onto the hard palate.

Patient Positioning Place the patient recumbent in a dental chair with their head extended 45°. Alternatively, place the patient supine with a rolled sheet beneath their shoulder blades to assist in neck extension. Instruct the patient to fully open their mouth.

Landmarks The greater palatine foramen lies 1 cm medial to the gingival junction of the second and third maxillary molar (**Figure 176-7C**).

Needle Insertion and Direction Clean, prep, and apply a topical anesthetic agent to the hard palate adjacent to the second and third maxillary molars. Insert a 27 to 30 gauge needle 1 cm medial to the junction of the second and third maxillary molars (**Figure 176-7C**). Ensure that the tip of the needle is held at 90° to the curve of the palate. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 0.25 to 0.35 mL of local anesthetic solution. The area surrounding the injection site will blanch upon deposition of the local anesthetic solution.[2,3]

Remarks This block may be performed to repair lacerations of the mucosa of the hard palate. The mucosa of the hard palate receives its blood supply from the hard palate. Injection of more than 0.4 mL will elevate the mucosa from the hard palate and result in mucosal necrosis. The position of the lesser palatine foramen is 2 to 4 mm posterior to the greater palatine foramen. The lesser palatine nerve provides sensory innervation to the soft palate and uvula. If anesthetized, as it often is when blocking the greater

palatine nerve, the patient may experience a feeling of dysphagia or throat closure. Reassurance is usually adequate to alleviate the patient's anxiety until the anesthesia wears off.

POSTERIOR SUPERIOR ALVEOLAR NERVE BLOCK

Anatomy The maxillary nerve exits the skull via the foramen rotundum. It then courses anteriorly into the pterygopalatine fossa and divides into its constituent branches. The posterior superior alveolar nerve provides sensory innervation to the maxillary molar teeth and their associated mucosal tissues.

Patient Positioning Place the patient semirecumbent in a dental chair with their head extended 30°. Alternatively, place the patient sitting upright with their head and back firmly against the examination chair or table and their head extended 30° to 45°. Instruct the patient to fully open their mouth.

Landmarks Pull the buccal mucosa laterally and identify the inferior-most posterior portion of the zygoma. It lies posterior, lateral, and superior to the third maxillary molar. The pterygomaxillary fissure lies posterior, medial, and superior to the vestibule between the third maxillary molar and the posterior zygoma. The pterygopalatine fossa can be reached by following the pterygomaxillary fissure superiorly and medially.[2,3]

Needle Insertion and Direction Clean, prep, and apply a topical anesthetic agent to the recess posterior and lateral to the maxilla. Insert the nondominant index finger between the maxillary molars and the cheek (**Figure 176-8A**). Palpate the zygomatic process of the maxilla with the index finger. Rotate the index finger 180° so that the pad is against the patient's cheek (**Figure 176-8B**). Apply outward pressure to move the cheek away from the teeth. Place the needle along the middle of the nail plate of the index finger. Aim the needle and syringe along the index finger (**Figure 176-8B**). The needle and syringe should be aimed posteriorly, superiorly, and medially (**Figure 176-8C**). Insert and advance the needle 2.5 cm along the index finger. If the needle contacts bone, withdraw the needle completely and direct it more laterally.[2,3] Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 3 mL of local anesthetic solution.

Remarks Bend the needle 30° at the hub to assist in achieving a medial direction of the needle. **Do not bend the needle more than 30° as the needle may fracture. It is extremely important to never change the direction of a needle once it is inserted.** This is associated with an increased risk of needle breakage requiring an operative procedure to recover the needle segment. **Never force the needle.** The needle is inappropriately positioned if it is meeting resistance. Abort the procedure, reidentify the landmarks, and reattempt the procedure.[2,3] Occasionally, the first molar is only partially anesthetized by this block. Consider supplementation of this block with a supraperiosteal infiltration of the first molar.

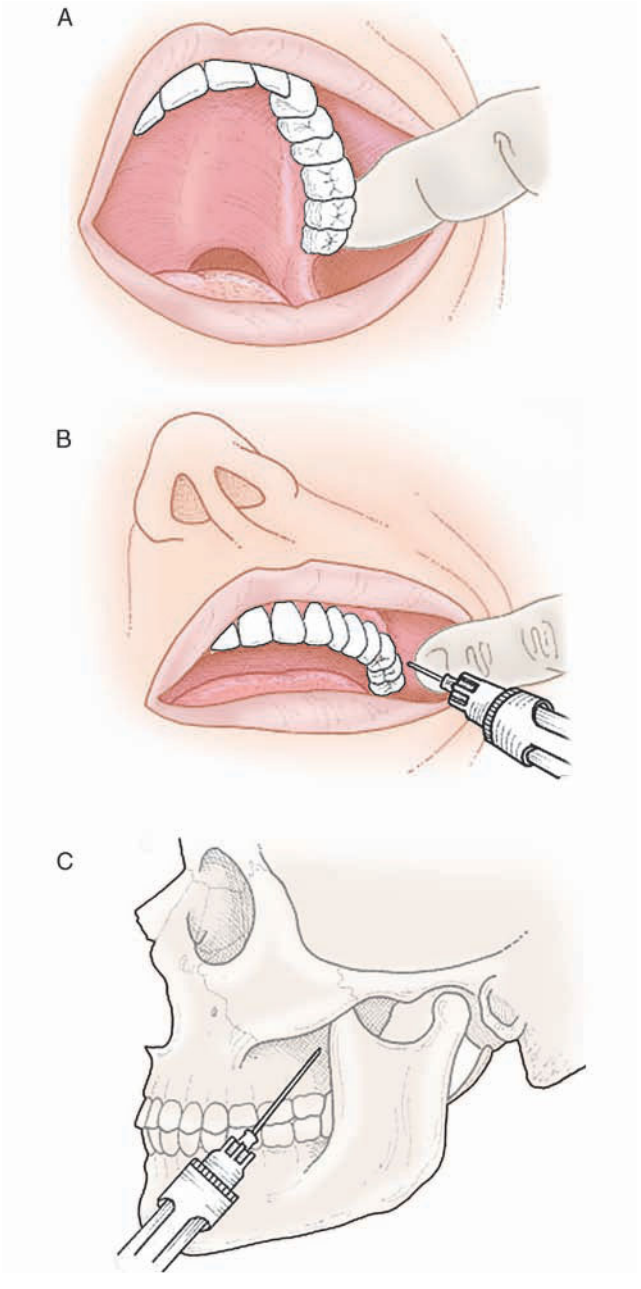


FIGURE 176-8. The posterior superior alveolar nerve block. **A.** The nondominant index finger is inserted and positioned. **B.** The cheek is retracted. **C.** The proper direction for insertion and advancement of the needle.

MENTAL NERVE BLOCK, INTRAORAL APPROACH

Anatomy The mental nerve is one of the two terminal divisions of the inferior alveolar nerve. It provides sensory innervation to the ipsilateral skin and mucosa of the lower lip and chin. It exits the bony mandible at the mental foramen.

Patient Positioning Place the patient recumbent in a dental chair. Alternatively, place the patient sitting upright or supine with their head against the examination table and in the neutral position. Instruct the patient to slightly open their mouth.

Landmarks The mental foramen lies in the same plane as the infraorbital foramen and the midpupillary line (**Figure 176-4**). The mental foramen is located approximately 1 cm beneath the gum line, between the first and second premolar.

Needle Insertion and Direction Clean, prep, and apply a topical anesthetic agent to the oral mucosa overlying the mental foramen. Grasp the lower lip with the nondominant hand. Pull it outward and downward (**Figure 176-9**). Insert a 27 gauge needle into the mucobuccal fold between the first and second premolar (**Figure 176-9**). Advance the needle medially until it contacts the mandible. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 1.5 to 2.0 mL of local anesthetic solution.

Remarks The mental nerve block, as the infraorbital nerve block, has an intraoral and an extraoral approach. The extraoral approach will not be discussed as it is more painful and there is no benefit to its use over the intraoral approach. A description of the extraoral

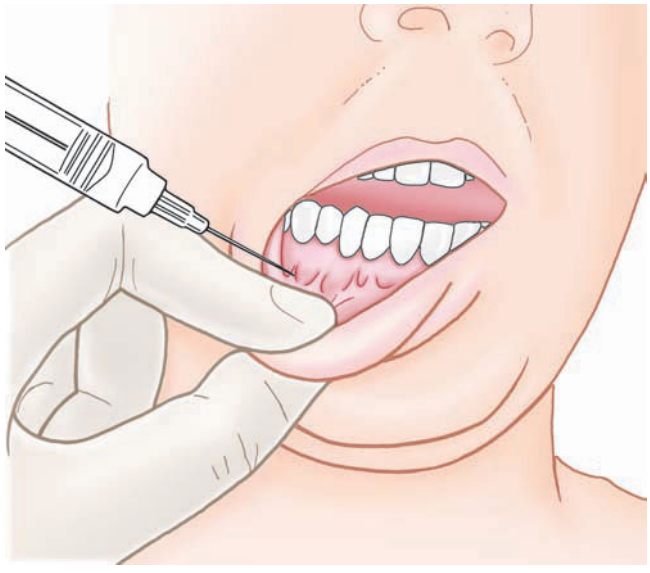


FIGURE 176-9. The intraoral approach to the mental nerve block.

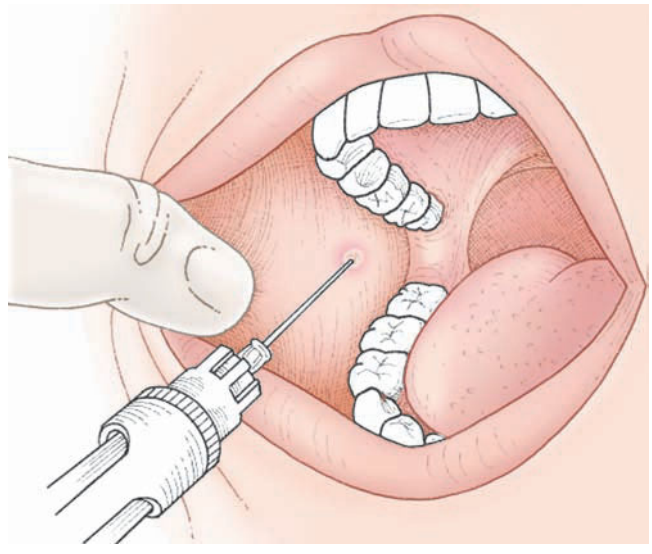


FIGURE 176-10. The buccal nerve block.

approach to the mental nerve block is found in Chapter 126. A near midline lower lip or chin injury may necessitate bilateral mental nerve blockade due to the midline crossover from each of the mental nerves.[2]

BUCCAL NERVE BLOCK

Anatomy The buccal nerve is one of the main branches of the mandibular nerve. It travels down the medial aspect of the ramus of the mandible, anterior to the inferior alveolar neurovascular bundle. It crosses from the medial mandible into the soft tissue of the cheek at the level of the occlusive plane. It supplies the sensory innervation to the mucous membrane of the cheek and vestibule.[1] It innervates, to a variable degree, a small patch of skin over the cheek.

Patient Positioning Place the patient recumbent in a dental chair with their head extended 30°. Alternatively, place the patient sitting with their head and back firmly against an examination chair or upright table with their head extended 30° to 45°. Instruct the patient to fully open their mouth.

Landmarks Visually identify the third mandibular molar. Palpate the anterior border of the ramus of the mandible. The buccal nerve traverses the anterior border of the ramus of the mandible, posterior and slightly lateral to the third molar at the level of the occlusive plane.

Needle Insertion and Direction Clean, prep, and apply a topical anesthetic agent to the oral mucosa over the anterolateral border of the ramus of the mandible. Place the thumb of the nondominant hand on the inner surface of the cheek. Pull the cheek outward. Insert a 27 gauge needle 1 mm lateral to the anterior border of the ramus of the mandible and at the level of the occlusal plane (**Figure 176-10**). Advance the needle 3 to 4 mm into the soft tissues. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 2 mL of local anesthetic solution.

Remarks Buccal nerve blocks are used when extensive intraoral manipulation is anticipated, when buccal manipulation or repair is required, or for the incision and drainage of an abscess. It provides additional patient comfort. The block is nearly always performed as an adjunct to an inferior alveolar, maxillary, or posterior superior alveolar nerve block.[3]

INFERIOR ALVEOLAR NERVE BLOCK

Anatomy The lingual and inferior alveolar nerves are two of four branches of the mandibular nerve. The nerves initially travel together and inferiorly on the medial side of the mandibular ramus (**Figure 176-11A**). The lingula is a palpable bony landmark immediately anterior to the mandibular foramen. The inferior alveolar nerve courses posterior to the lingula and enters the mandibular canal via the mandibular foramen. It continues to travel anteriorly within the mandible to provide sensory innervation to the body of the mandible, the mandibular teeth, and the overlying oral mucosa. One of the terminal branches of the inferior alveolar nerve is the mental nerve. The inferior alveolar nerve may be blocked by the classic, open-mouth approach or the closed-mouth approach.

Patient Positioning Place the patient in a dental chair with their head neutral, such that the occlusive surface is parallel to the floor. Alternatively, place the patient sitting upright in an examination chair or on a gurney with their head positioned firmly against the back of the gurney or chair. Instruct the patient to fully open their mouth. Perform the open-mouth approach if the patient can fully open their mouth. Perform the closed-mouth approach if the patient has trismus or cannot fully open their mouth.

Landmarks Identify by palpation the anterior border of the ramus of the mandible within the mouth, the coronoid notch within the mouth, and the posterior border of the ramus of the mandible externally (**Figure 176-11B**). Approximately equidistant from these two points lie the lingual and the inferior alveolar nerves. Palpate the lingula of the ramus of the mandible. It is a bony projection on the medial surface of the ramus of the mandible and 1 cm above the occlusive plane.

Needle Insertion and Direction (Open-Mouth Approach) Clean, prep, and apply a topical anesthetic agent to the inner surface of the ramus of the mandible. Stand opposite the side to be blocked. Place the thumb of the nondominant hand on the anterior border of the ramus of the mandible. Move the thumb posteromedially to identify the lingula. Place the index finger of the nondominant hand against the extraoral border of the mandibular ramus, just above the angle of the mandible. Grasp the ramus between the thumb and

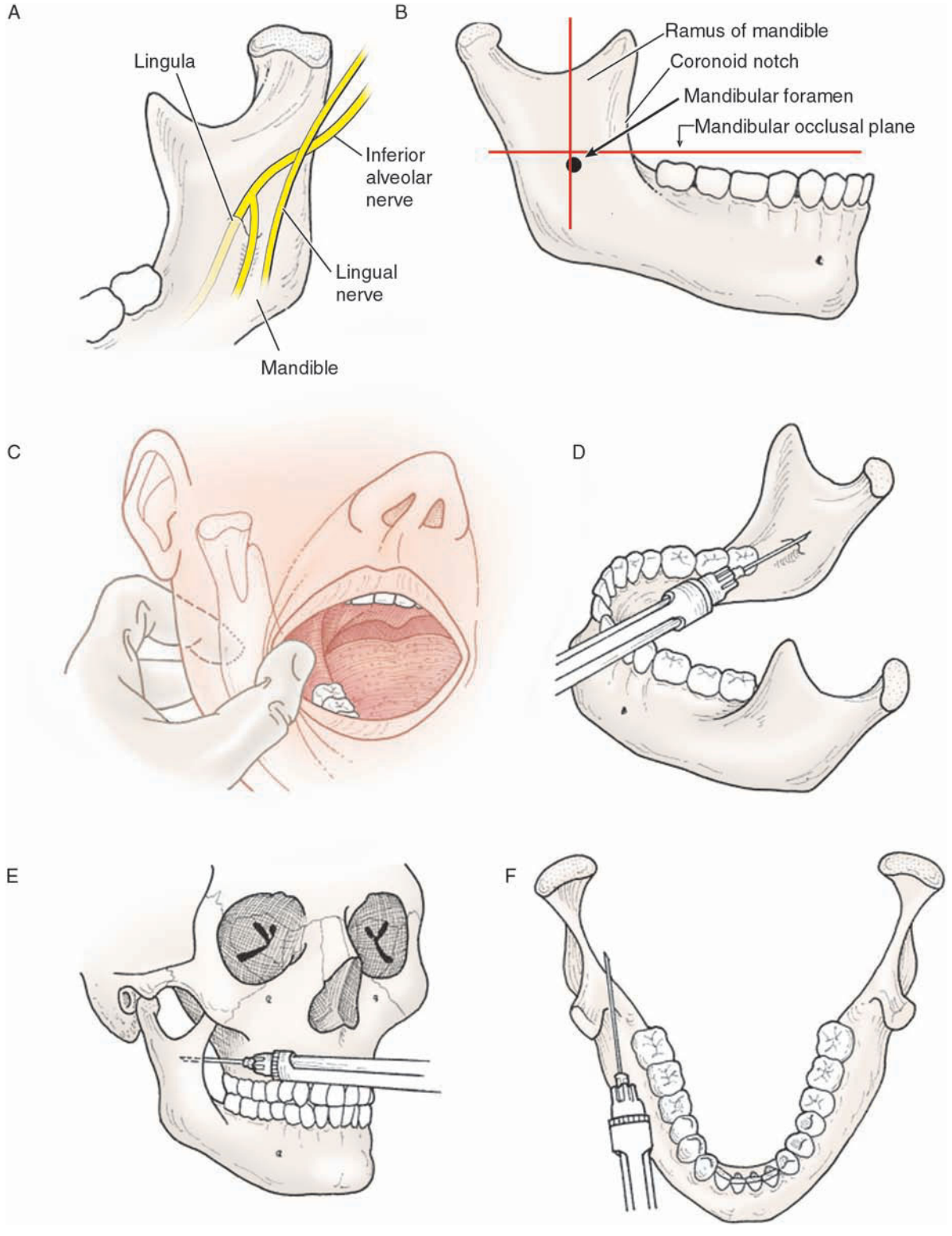


FIGURE 176-11. The inferior alveolar nerve block. **A.** The course of the inferior alveolar nerve and the lingual nerve along the ramus of the mandible. **B.** The anatomy of the external surface of the mandible. **C.** Positioning for the open-mouth approach. **D.** Proper needle insertion and direction for the open-mouth approach. **E.** The closed-mouth approach. **F.** Superior view of the closed-mouth approach demonstrating the proper needle direction.

the forefinger (**Figure 176-11C**). Pull the cheek outward using the nondominant thumb as a lever. Place a 27 gauge, 2 inch needle on a 3 mL syringe that contains local anesthetic solution. A 5 mL syringe is too large for this approach. A syringe smaller than 3 mL will not carry enough anesthetic.

Introduce the needle from the opposite side (**Figure 176-11D**). Align the tip of the needle toward the lingula with the barrel of the syringe between the contralateral first and second premolars (**Figure 176-11D**). Hold the syringe parallel to the occlusal plane and 3 to 4 mm above the premolars. Insert the needle into the oral

mucosa just superior and posterior to the lingula. Advance the needle until the tip contacts the ramus of the mandible. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 2 mL of local anesthetic solution.

The above technique is optimal if the operator is right-handed and a right-sided inferior alveolar block is attempted. If the operator is right-handed and attempting a left-sided inferior alveolar nerve block, it is still necessary to stand opposite the side to be anesthetized with the syringe in the dominant hand. Place the nondominant arm over and around the patient's head so that the thumb of the nondominant hand can contact the anterior border of the mandibular ramus and the index finger can grasp the posterior border above the angle of the mandible. The remainder of the technique is the same.

Needle Insertion and Direction (Closed-Mouth Approach) This method can be used when the patient cannot fully open their mouth due to an abscess, edema, mandible fractures, trismus, or if the mandible is wired-closed to the maxilla. This approach deposits the local anesthetic solution superior to the site of the classic, open-mouth approach. The local anesthetic solution will descend, due to gravity, to bathe the inferior alveolar nerve and provide adequate anesthesia.

Place the nondominant thumb on the inner surface of the cheek. Pull the cheek outward. Place a 27 gauge needle on a 3 mL syringe that contains local anesthetic solution. Place the needle and syringe parallel to the occlusal plane and aligned along the junction of the maxillary molars and their gingiva (**Figure 176-11E**). Direct the needle just medial to the ramus of the mandible (**Figures 176-11E & F**). Advance the needle 3 cm through the mucosa. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 2 mL of local anesthetic solution.

Remarks **It is crucial that the tip of the needle contacts the mandible in the open-mouth approach.** The needle is usually advanced 0.5 to 1 cm before the mandible is encountered. The needle is most likely inappropriately placed and deposition of anesthesia will not produce the desired results if the mandible is not encountered. Remove the needle, reidentify the appropriate anatomic landmarks, and reattempt the procedure if the mandible is not encountered. The buccal, inferior alveolar, and lingual nerves must be blocked on one side to achieve complete anesthesia of the hemimandible. Facial nerve paralysis can occur if the needle is inserted too far posterior and enters the capsule of the parotid gland. This paralysis is usually transient and resolves as the anesthetic wears off.

LINGUAL NERVE BLOCK

Anatomy The lingual nerve is a branch of the mandibular division of the trigeminal nerve. It travels with the inferior alveolar nerve until the inferior alveolar nerve enters the mandible. The lingual nerve leaves the medial aspect of the mandibular ramus and penetrates the posterior tongue at the level of the occlusive plane, just medial to the third mandibular premolar. It courses anteriorly to provide sensory innervation to the anterior two-thirds of the tongue, the floor of the mouth, and the lingual mucous membrane.[1]

Patient Positioning Place the patient in a dental chair with their head neutral, such that the occlusive surface is parallel to the floor. Alternatively, place the patient sitting upright in an examination chair or on a gurney with their head firmly against the back of the gurney or chair. Instruct the patient to fully open their mouth.

Landmarks Identify the lingual side of the second mandibular molar. The injection site is 1 cm medial to the second mandibular molar.

Needle Insertion and Direction Approach the patient from the contralateral side. Move the tongue upward or toward the contralateral side with a tongue blade. Insert a 27 gauge, 2 inch needle into the mucosa 1 cm medial to the second mandibular premolar (**Figure 176-12**). Advance the needle posteriorly 1 cm. Aspirate to confirm that the tip of the needle is not within a blood vessel. Inject 1.0 to 1.5 mL of local anesthetic solution.

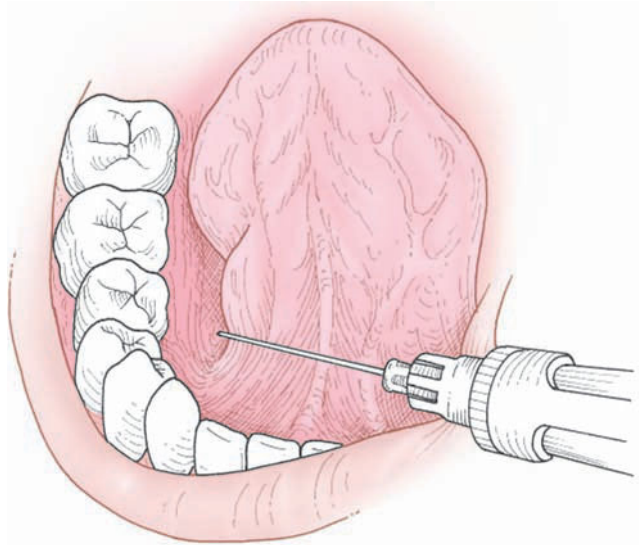


FIGURE 176-12. The lingual nerve block.

Remarks The inferior alveolar nerve and the lingual nerve can be, and usually are, blocked simultaneously during an inferior alveolar nerve block. The lingual nerve, however, can be blocked in an isolated fashion. Perform an isolated lingual nerve block only when the initial combined block has failed or for isolated tongue lacerations.[1,3] This is an optimal block for tongue laceration repair. However, bilateral lingual nerve blocks may be necessary.

ASSESSMENT

Anesthesia is usually achieved within 5 minutes of the injection. However, depending upon the particular injection and the local anesthetic used, anesthesia can be achieved anywhere from 20 seconds to 10 minutes. The block was properly performed if the patient experiences anesthesia. Repeat the block if anesthesia is not achieved by 10 minutes.

AFTERCARE

The aftercare of dental anesthesia is minimal. Reexamine the area of the local anesthetic injection before the patient is discharged to ensure that a hematoma has not developed. **Instruct the patient to use caution as there is no sensation in the area anesthetized.** Encourage them to refrain from meals, chewing gum, hot beverages, aggravated scratching, placing foreign bodies in the mouth, or anything that may cause injury to the anesthetized area. Parents must be informed to discourage children from testing the anesthetized area by biting or chewing. Many Dentists and Physicians place a cotton roll, or rolled 2 × 2 gauze, between the area anesthetized and the teeth to provide added protection from a self-inflicted bite injury.[2,3]

COMPLICATIONS

Any patient receiving dental anesthesia has the potential to develop complications. The key is to have knowledge of these complications and be prepared to deal with them should they occur. Most severe complications will declare themselves in a rapid fashion. These severe complications include intravascular injection of local

anesthetic, allergic reactions to the local anesthetic, cardiovascular toxicity, neurologic toxicity, seizures, and unintentional overdosage. Allergic reactions can occur from the latex vial/carpule seal or the preservative in the local anesthetic.[5] These complications can be avoided by aspiration before injection, obtaining an appropriate history of prior anesthesia, and cautious calculation of anesthetic dosages, respectively.[2–4]

Late complications of dental anesthesia include hematomas, neuropathy, infection, and trismus.[2,3] Hematomas after dental anesthesia occur after the inadvertent puncture of an artery or vein. Arterial hematomas enlarge more rapidly and are usually more painful than venous hematomas. They can cause a significant facial deformity. Hematomas following dental anesthesia are usually of little significance, require no intervention, and resolve spontaneously with time. A proper preprocedural history should determine if the patient is using anticoagulants or blood thinners, has a real or potential bleeding disorder, or had adverse bleeding complications from previous procedures. Treatment initially involves applying cold packs. Heat in the form of an externally placed heating pad should be used to help disintegrate the clot after 24 hours.[2,3]

A peripheral neuropathy can occur in the form of prolonged anesthesia, paresthesias (burning or itching sensation), hyperesthesias (increased sensitivity to noxious stimuli), and dysesthesias (painful sensation to non-noxious stimuli). This may be a result of direct damage to the nerve from traumatic needle insertion, hemorrhage or hematoma within the nerve sheath, deposition of local anesthetic into a foramen or canal causing pressure injury to the nerve, or chemical injury to the nerve.[6,7] Reduce the risk of causing a neuropathy by avoiding injections into a foramen, using a small gauge needle, and withdrawing the needle slightly before injection if the patient should feel a shock or paresthesias with needle insertion.[2,3] While many nerve injuries are temporary and will resolve with time, some can be permanent.[7]

Infection due to dental anesthesia is rare, but does exist. Follow several simple measures to minimize potential infections. Never inject through an infected area. Doing so may carry bacteria through facial planes into deeper compartments. Refrain from multiple injections (needle misadventures) as this increases the risk of iatrogenic infection. This is easily resolved by appropriately identifying the anatomic landmarks prior to needle insertion.

Needle breakage can occur as a result of manufacturing defects or operator imprudence. **To prevent needle breakage, never exert force against resistance.** Resistance signifies that the tip of the needle is against bone or a tooth. Withdraw the needle and reattempt insertion if this occurs. **Never advance the needle to the hub.** The greatest percentage of needle breaks occur when the needle is inserted to the hub.[2,3] **Never redirect the needle after it is inserted through the skin or mucosa.** This puts abnormal force on the needle and potentiates breakage. The needle may inadvertently be in an undesired anatomic location. Withdraw the needle completely, identify the appropriate anatomic landmarks, and reinsert the needle. Do not bend the needle as this can weaken it and make it more prone to breakage. If a needle breaks, grasp the fragment with a forceps or hemostat and remove it from the soft tissue. If the needle fragment is not palpable with an instrument, consult a Dentist or Oral Surgeon for possible removal. The consultant may choose to see the patient in the Emergency Department, see the patient in their office within 24 to 48 hours, or leave the needle fragment in place and not remove it.

SUMMARY

Dental anesthetic techniques are easy to learn, simple to perform, and effective in providing temporary pain relief. The required equipment is readily available in every Emergency Department. Consider using local anesthetic agents that contain epinephrine because they provide significantly longer analgesia than those without epinephrine. A rapidly performed local anesthetic injection goes a long way toward patient satisfaction.

177 Dental Abscess Incision and Drainage

Daniel J. Ross

INTRODUCTION

Patients frequently present to the Emergency Department complaining of a "toothache". The common causes of toothache pain are multiple.[1] Similarly, there are multiple etiologies for a dental abscess (**Table 177-1**). Distinguishing the type of dental abscess can have an impact upon treatment decisions, prognosis, and patient morbidity.[2–5] The accurate diagnosis and proper treatment of these maladies require that the Emergency Physician has a basic understanding of dental anatomy, pathophysiology, and simple dental treatment protocols. Many of these conditions can be managed initially through the Emergency Department. The prudent Emergency Physician must have a clear understanding that these infections can rapidly become complicated and may require timely consultation or referral.

ANATOMY AND PATHOPHYSIOLOGY

Teeth are essentially composed of three layers (**Figure 177-1**). These layers, from the outside working inward, are the enamel, the dentin, and the pulp. The dentin and pulp are living tissues that are sensitive to noxious stimuli. The crown is covered with enamel, while the root is covered with a substance known as cementum. Cementum helps attach the tooth to the surrounding alveolar bone via the periodontal ligament (PDL). The neurovascular supply enters the pulp through the apical foramen at the root apex. The pulp contains only pain transmitting neuronal fibers, while the PDL contains both pain-sensitive and pressure-sensitive fibers.[7] Dental abscesses arise when bacteria penetrate the normal anatomic and physiologic barriers of the tooth and surrounding structures. This can lead to a localized collection of purulence contained within the tooth (pulpal abscess), or around the apex of the tooth (periapical abscess) (**Figure 177-2**). Alternatively a dental abscess may localize to the supporting structures of the tooth (periodontal abscess) or strictly to the adjacent soft tissues (pericoronitis) (**Figure 177-2**).

PULPAL OR PERIAPICAL ABSCESSES

Dental abscesses often arise from pulpal necrosis secondary to dental caries or a defective restoration.[1,3,4,6,7] Dental caries is commonly known as dental decay or "cavities". This is the direct destruction

TABLE 177-1 Common Etiologies for a Dental Abscess

Cysts that become infected
Gingival infections
Mixed periodontal/periapical infections
Periapical infections
Periodontal infections
Postoperative infections
Root fracture that becomes infected

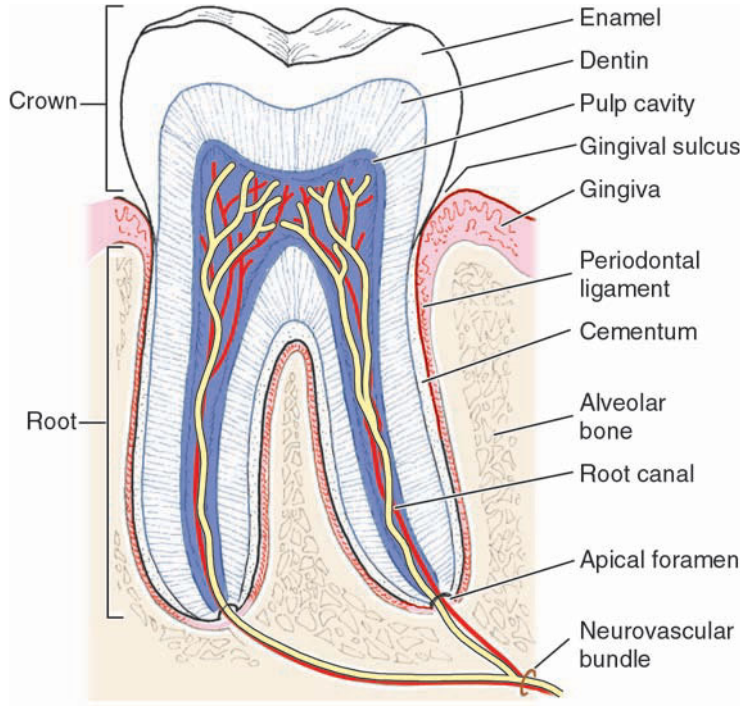


FIGURE 177-1. The anatomy of a tooth.

of the tooth substance by the acidic bacterial products of normal oral flora. A carious tooth may not initially be painful. The products of inflammation eventually reach the dental pulp as the disease process progresses and the tooth will become sensitive.[1–3,7–9] This is known as pulpitis. Patients will report nonlocalizable and intermittent symptoms. This process may initially be reversible by routine dental treatment (e.g., a filling), but the pulp will rapidly necrose and die if it becomes infected. If the infectious process is allowed to continue, products from the necrotic pulp may escape the confines of the tooth via the apical foramen and begin to involve the PDL and surrounding alveolar bone. This is known as a periapical abscess, and makes the infected tooth easily localizable by patient complaints of spontaneous or constant sensitivity, and/or tenderness to gentle percussion.[1–3,5–7,9] The infection could likely be halted at this stage of the pathophysiologic process with a "root canal," which is essentially an incision and drainage procedure performed on the inside of a tooth by an Endodontist.[6,7]

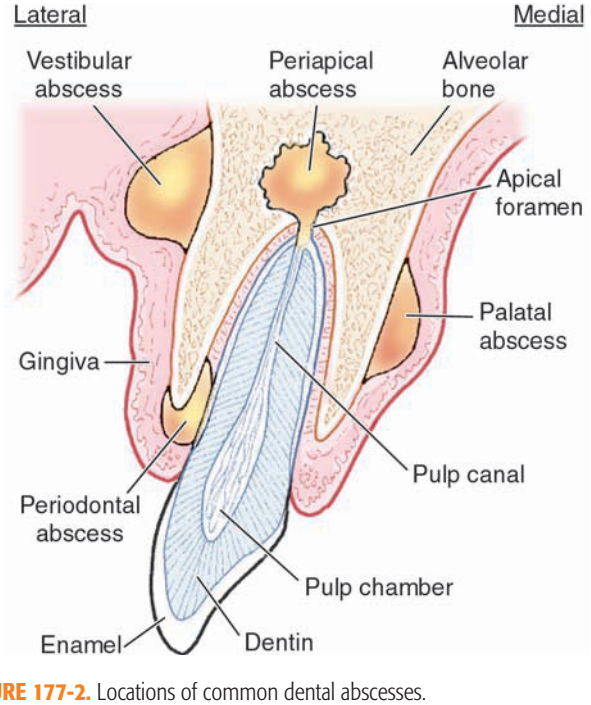


FIGURE 177-2. Locations of common dental abscesses.

If left unchecked, however, the bacterial products of a periapical infection and the host's immune response to it can lead to a progressive destruction of the dental supporting tissues, including the alveolar bone. At this point the tooth will become increasingly mobile. The infection will follow the path of least resistance as it penetrates through the alveolar bone into the surrounding soft tissues.[6,7] It may perforate laterally to form a vestibular abscess (**Figure 177-3A**). Alternatively, it may perforate medially to form a palatal or lingual abscess (**Figure 177-3B**). Further spread will be dictated by the proximity of the muscle attachments and fascial planes.[3,5–7,9–11] The appropriate treatment for an abscessed tooth depends on the extent of infection. It may include endodontic treatment, incision and drainage, extraction, or a combination of these.[6,7] An incision and drainage procedure is warranted if the infectious process extends outside the alveolar bone and involves the soft tissues.[5,6,7,9,10]

The extension of infectious products outside the root apex can lead to a multitude of clinical signs throughout the head and neck. Swelling, erythema, warmth, fluctuance, and spontaneous drainage of purulence via a sinus tract or fistula may be seen intraorally or extraorally. A localized or generalized cellulitis may be present. There is often a foul breath odor.[1,5,6,10] One or more of the numerous named fascial spaces of the head and neck may become involved via direct extension.[3,5–8,10–16] Systemic symptoms may become involved including fever, malaise, anorexia, and leukocytosis.[5,6,8,10,12] Structures immediately adjacent to the oral cavity may become involved. This can result in trismus, reactive sinusitis, lymphadenopathy, osteomyelitis, cavernous sinus thrombosis, airway compromise, and/or a brain abscess.[3,11–16]

Dental infections extending into any of the fascial compartments of the head and neck are dangerous, can rapidly progress, and are

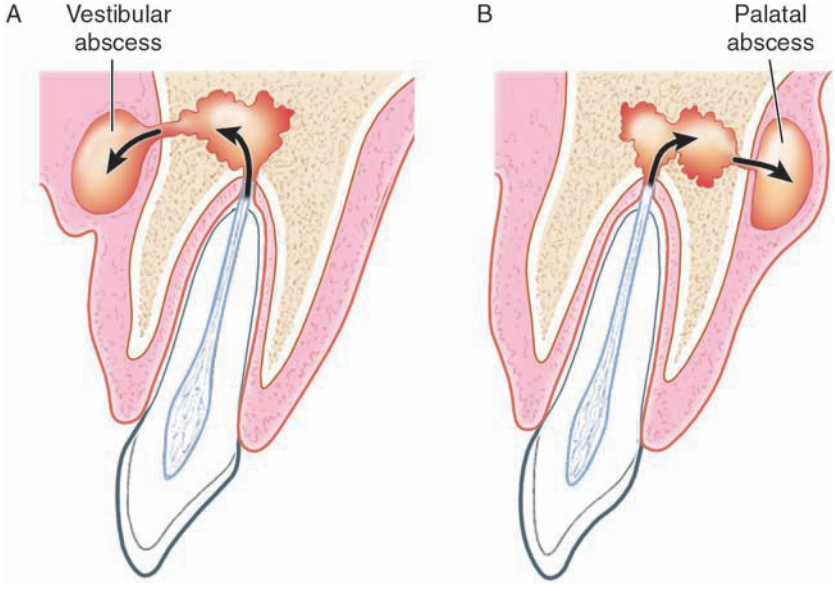


FIGURE 177-3. The spread of a dental abscess. A pulpal abscess progresses to a periapical abscess that perforates the alveolar plate. **A.** Labial or buccal perforation leads to a vestibular abscess. **B.** Palatal or lingual perforation leads to a palatal or lingual abscess, respectively.

considered complicated infections.[3,5–7,10,12–16] Patients typically have a toxic appearance with systemic signs and symptoms. They often present with dysphagia, dysphonia, or dyspnea. The classic example is Ludwig's angina or a concurrent bilateral involvement of the sublingual, submental, and submandibular spaces. This represents an immediate threat to the airway.[11,13,15,16] Infectious extensions into the lateral pharyngeal, retropharyngeal, and prevertebral spaces are rare and can lead to disastrous complications such as aspiration, mediastinitis, and airway compromise. A retropharyngeal space measuring greater than 3 to 5 mm on lateral soft tissue neck radiographs or CT scans is indicative of airway compromise.[10] **Consider rapid and aggressive management with prompt surgical consultation, broad-spectrum antibiotics, and early airway intervention in patients who are suspected of manifesting any of these processes.[3,8,10–15]**

PERIODONTAL ABSCESSES

Poor dental hygiene and poor nutrition lead to local inflammation of the tissues surrounding and attaching the tooth to its socket, allowing bacterial penetration. Early periodontal disease is isolated to the gingiva and known as gingivitis.[5,17] Alveolar bone may be destroyed as the disease progresses, leading to gingival pockets and tooth mobility.[1,5,18] Food debris or plaque may become trapped within these pockets and create a localized infection known as a periodontal abscess.[4,5,17] Periodontal disease is very common in pregnant women.

Patients may complain of bleeding, foul odor, bad taste, loose teeth, pain, or swelling. The physical examination reveals gingival tissue that may be erythematous or necrotic and bleed easily. Heavy accretions of dental plaque and calculous may be present. An abscess may present as a focal swelling, tooth mobility, pain on percussion, and purulence that is expressible from the gingival sulcus.[1,5,17,18] It may be impossible, with current dental caries, to differentiate a periapical abscess from a periodontal abscess without radiographs.[3,5] In fact, both lesions may occur together.[18] A periodontally diseased tooth may be so mobile that it cannot be salvaged and requires extraction.[5]

True periodontal abscesses rarely spread beyond the local dentoalveolar structure and rarely require an urgent referral.[3,4] Treat an isolated periodontal abscess with dental anesthesia, incision and drainage, and dilute peroxide (1:5 solution or 5%) or chlorhexidine rinses. Prescribe oral antibiotics for evidence of spread, if there is a delay to definitive care, or for systemic manifestations.[1,3–5,18] Appropriate antibiotics include penicillin, clindamycin, or erythromycin. Refer patients with these lesions to a Dentist within 24 to 48 hours for definitive follow-up care to avoid recurrence.[1,3,5]

PERICORONITIS

Inflammation can occur around the crown of any erupting tooth and is common around impacted teeth, especially the third molars.[1,3,4,19] This condition is known as pericoronitis. It is often exacerbated by the impaction of food under the soft tissue. Progression of the primary process or overzealous treatment can easily lead to extension of the infection posteriorly to multiple contiguous spaces, including the retropharyngeal space.[1,3,19,20] Simple cases are easily managed in the Emergency Department. Always maintain a very low threshold for consultation and referral of patients with complicated presentations.

Treatment of pericoronitis may include dental anesthesia, direct saline irrigation, warm saltwater rinses, dilute peroxide or chlorhexidine rinses, and oral analgesics. The presence of swelling, trismus, and inflammation may be severe enough to warrant a course of oral antibiotics.[1] Some authors advocate antibiotic coverage in essentially all cases.[1,10,19,21] Definitive treatment requires the completed eruption or extraction of the tooth. Refer the patient to a Dentist or Oral Surgeon for follow-up and definitive care within 24 to 48 hours.

INDICATIONS

The indications for dental abscess incision and drainage include a periapical or periodontal abscess with clinical evidence of alveolar penetration and soft tissue spread.[9,10] Some authors recommend incision and drainage for purely cellulitic processes.[4,5,11] **Extraoral incision and drainage is indicated only for dental infections progressing toward inevitable spontaneous extraoral drainage.[3,10] Drain all other dental abscesses intraorally.**

CONTRAINDICATIONS

A review of the current literature reveals no direct contraindications to the incision and drainage of a dental abscess. Maintain a low threshold for consultation and referral to a surgical specialist for

TABLE 177-2 Prophylactic Regimens for Endocarditis in Patients Undergoing Dental or Oral Surgical Procedures[23,*]

Situation	Antibiotic choice	Adult dose	Pediatric dose[†]
Standard general prophylaxis and able to take oral medications	Amoxicillin	2000 mg PO	50 mg/kg PO
Standard general prophylaxis and unable to take oral medications	Ampicillin	2000 mg IV or IM	50 mg/kg IV or IM
	or		
	Cefazolin	1000 mg IV or IM	50 mg/kg IV or IM
	or		
	Ceftriaxone	1000 mg IV or IM	50 mg/kg IV or IM
Penicillin allergic patient able to take oral medications	Clindamycin	600 mg PO	20 mg/kg PO
	or		
	Cephalexin or Cefadroxil[‡]	2000 mg PO	50 mg/kg PO
	or		
	Azithromycin or Clarithromycin	500 mg PO	15 mg/kg PO
Penicillin allergic patient unable to take oral medications	Clindamycin	600 mg IV or IM	20 mg/kg IV or IM
	or		
	Cefazolin[‡]	1000 mg IV or IM	50 mg/kg IV or IM
	or		
	Ceftriaxone[‡]	1000 mg IV or IM	50 mg/kg IV or IM

*Administer the antibiotics 30 to 60 minutes prior to the procedure.
[†]The pediatric, weight-based dose should not exceed the adult dose.
[‡]Do not use cephalosporins in a patient with a history of a penicillin allergy and any of the following: anaphylaxis, angioedema, respiratory difficulties, urticaria, or unknown reactions.

any patient with rapidly progressing infections, difficulty breathing, difficulty swallowing, fascial space involvement, temperature greater than 101 °F (38.3 °C), white blood cell count greater than 10,000, severe trismus (manifested by mandibular opening less than 10 mm or inability to adequately visualize the hypopharynx), a toxic appearance, compromised host defenses, or who are children.[3,6,10,22]

EQUIPMENT

- #15 scalpel blade on a handle
- #11 scalpel blade on a handle
- Povidine iodine or chlorhexidine solution
- Minnesota retractor
- Wieder tongue retractor
- Frazier suction catheter
- Suction source and tubing
- Needle driver
- Hemostat
- Suture, 4-0 and 5-0 silk
- Gelfoam
- 0.25 inch wide Penrose drain
- Light source, overhead or headlamp

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain dental radiographs if the infection is from a dental source.[5,6,10] Obtain an informed consent for the procedure. Provide adequate anesthesia; ideally in the form of a dental block. Obtain a separate informed consent for the dental block. **Direct infiltration into the area of purulence does not achieve adequate anesthesia and risks spreading the infection by inoculation.**[3,5] Dental blocks may require augmentation with direct infiltration anterior and posterior to the abscess. Anesthetize the areas adjacent to the abscess last to avoid seeding. Refer to Chapter 176 for a complete discussion of dental analgesia and anesthesia. The application of procedural sedation may be required if adequate local anesthesia is not possible.[10] Refer to Chapter 129 for the complete details regarding procedural sedation and analgesia.

Prophylaxis to prevent infective bacterial endocarditis should be addressed in the appropriate patients prior to incision and drainage of a dental abscess in accordance with the policy put forth by the American Dental Association. Further information and specific antibiotic regimens can readily be found at the website of either the American Heart Association or the American Dental Association (**Table 177-2**).[23,24]

TECHNIQUES

SIMPLE INTRAORAL INCISION AND DRAINAGE

There are two techniques for intraoral incision and drainage. The first technique is to make a simple stab incision with a #11 scalpel blade in the area of greatest fluctuance and in the area that best facilitates dependent drainage (**Figure 177-4A**). **Do not make the incision more than 1 cm in length.** Gently insert a closed, curved hemostat into the incision (**Figure 177-4B**). Gently spread the jaws of the hemostat in several different directions to break up any loculations (**Figure 177-4C**). Express and suction any remaining purulence. Insert a sterile rubber drain cut from a 0.25 inch wide Penrose drain or from a sterile surgical glove (**Figure 177-4D**). Place one to two silk sutures through the drain and the oral soft tissues. This will ensure that the drain does not fall out and result in premature closure of the incision or aspiration of the drain.

The second technique for simple intraoral incision and drainage differs only in the location of the incision. Make an incision with a #15 scalpel blade at the alveolar crest within the gingival sulcus, scalloping around the teeth. Extend the incision one tooth medial and distal to the tooth in question or the area of the abscess. Gently elevate the attached gingiva from the bone with a blunt instrument. Continue the blunt dissection until the abscess cavity is penetrated. This typically occurs just within the level of unattached gingiva. The remainder of the procedure is as described above. This technique affords some mechanical advantages to the operator and is well tolerated by the patient postoperatively. It can be performed in both arches, buccally, palatally, and lingually. It is often useful for draining a periodontal abscess.

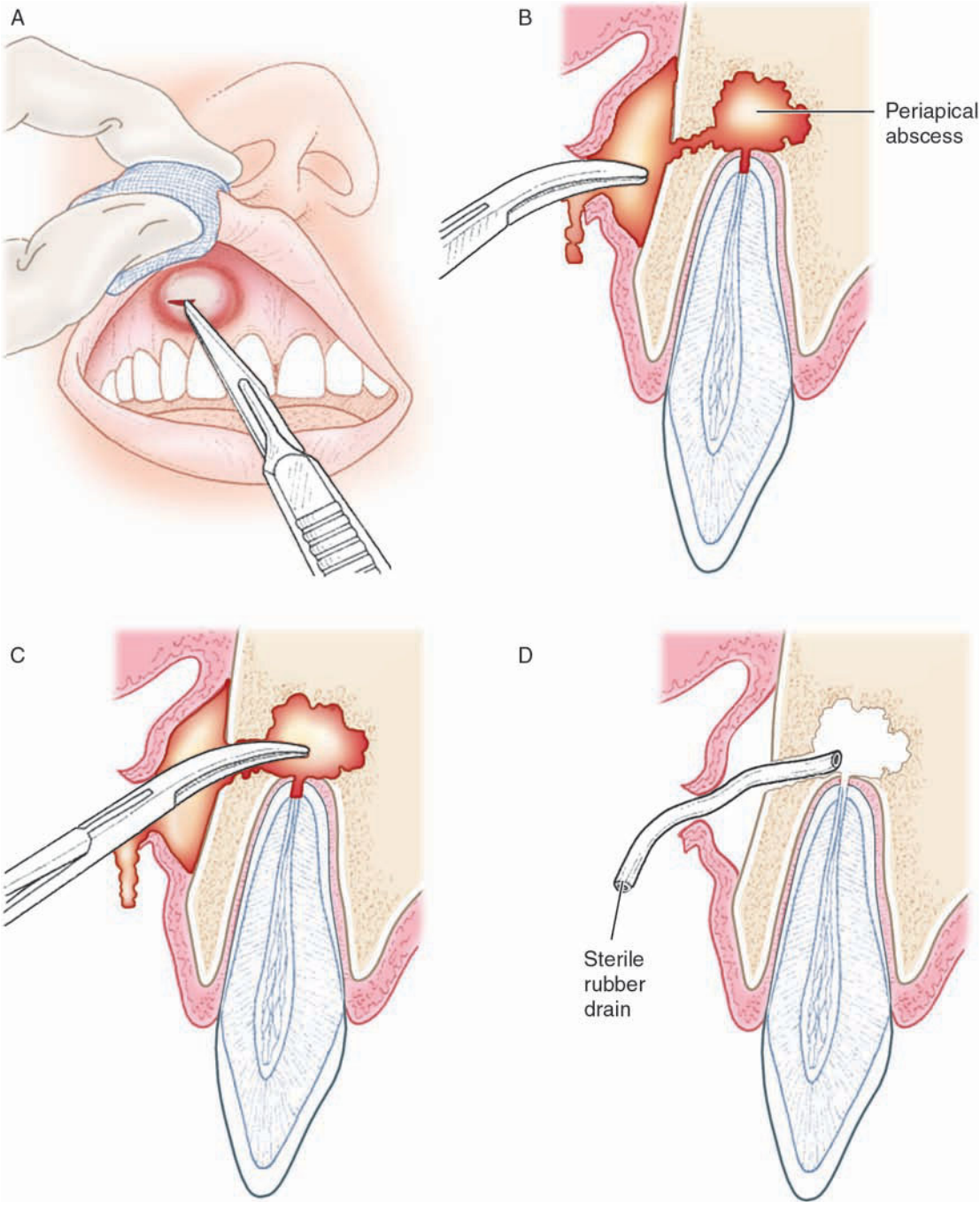


FIGURE 177-4. Incision and drainage of a periapical abscess that has extended into a vestibular abscess. **A.** Make a stab incision with a #11 scalpel blade. **B.** Insert a hemostat into the incision. **C.** Advance the hemostat into the abscess cavity to lyse any adhesions. **D.** Place a sterile drain into the abscess cavity.

EXTRAORAL INCISION AND DRAINAGE

Extraoral incision and drainage is indicated when a dental infection appears to be progressing toward inevitable spontaneous extraoral drainage.[10] This procedure requires more attention and skill because of the numerous underlying vital structures and the possible cosmetic consequences.[3,10] Make every effort to avoid extraoral incision and drainage.[3] Consider consulting a Dentist or Oral Surgeon before performing an extraoral incision and drainage.

Extraoral incision and drainage differs from the intraoral approach.[3,10,11] **Advise the patient that they will almost certainly have a visible scar after the incision heals.[3,10]** Extraoral incision and drainage requires the use of aseptic technique. Prepare the area with povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to isolate a field. Perform local subcutaneous infiltrative anesthesia of the skin. Use a separate needle and syringe for any intraoral anesthetic techniques.

Make a 1.0 to 1.5 cm long incision with a #15 scalpel blade in an area of healthy skin, proximal to the site of expected breakdown and in a location that facilitates dependent drainage (**Figure 177-5**). Extend the incision into the subcutaneous tissues. This is another critical difference from the intraoral technique. Insert a hemostat to penetrate and drain the abscess cavity. Spread the hemostat in several directions to break up any loculations. The remainder of the procedure is performed as described as above. Scarring with extraoral incisions is virtually universal.

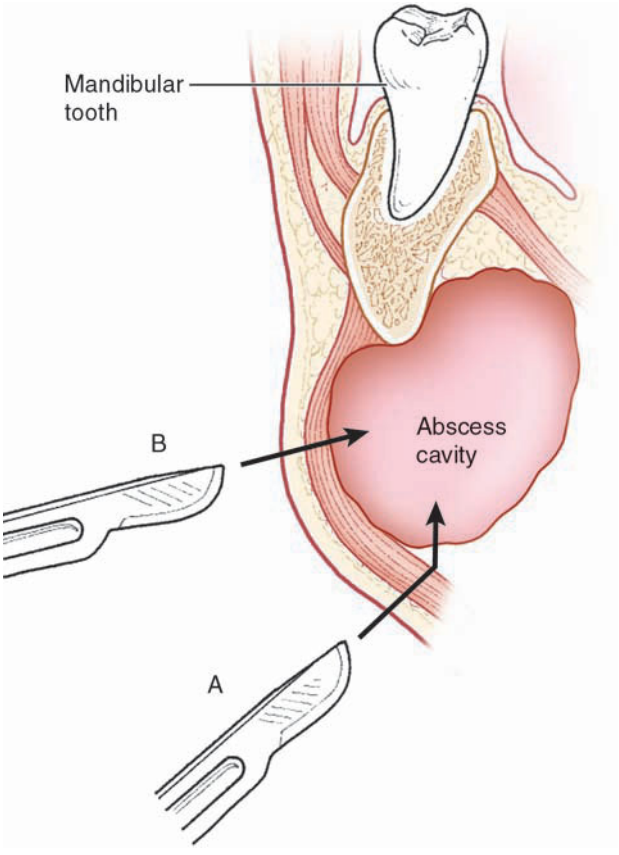


FIGURE 177-5. Extraoral drainage of a dental abscess. Choose a location that has healthy skin and that will allow dependent drainage.

PEDIATRIC CONSIDERATIONS

Facial infections in children tend to develop and progress more rapidly. They are more likely to present with systemic signs and symptoms.[25] Facial infections in children are also more likely to be associated with complications, such as dehydration or bacteremia.[25] Unlike adults, the anatomic location of a facial infection in a child can be a more useful guide in determining its source and management.[25] In general, upper face infections tend to be more common in children less than 5 years of age and frequently have no identifiable source. Children older than 5 years of age more commonly have lower face infections and typically have an odontogenic or wound-related source.[25] According to the American Academy of Pediatric Dentistry, a child presenting with a facial swelling secondary to a dental infection should receive immediate dental attention.[26] Lastly, in sharp contrast to adults, children with facial infections in either location more frequently respond to antibiotics alone and may not require an incision and drainage procedure.[25]

ASSESSMENT

Basic postoperative assessment includes inspecting the operative site for the minor complications described below. **Assess adequate drain retention. A loose intraoral drain may represent an aspiration risk.** Observe the patient for postprocedural bleeding. It can be controlled with the application of pressure, injection of a local anesthetic agent containing epinephrine, or topical Gelfoam. Wound cultures are not indicated unless the patient is immunocompromised or the infection is recurrent. The wound cultures usually demonstrate mixed oral flora with no predominate organism.

AFTERCARE

The application of warm moist compresses, oral fluids, rest, and good nutrition are mainstays in the treatment of any inflammatory process. Patients may benefit from a soft, bland diet and frequent oral rinses with a warm saltwater solution. All patients require postoperative oral analgesics.[3,5,10,11] Patients with an extraoral incision require dressing changes.[3,5,10,11] Provide the patient with adequate supplies and teaching. Instruct the patient on the application of pressure if postprocedural bleeding occurs.

The use of antibiotics in light of adequate drainage is somewhat controversial. Clear-cut indications for oral antibiotics in orofacial infections include cellulitis, extraoral incision, systemic symptoms, persistent infection, pericoronitis, fascial space involvement, and immunocompromised patients.[4,7,10,16] The prudent Emergency Physician is advised to err on the side of caution while the academics quarrel over antibiotic indications. Penicillin is the drug of choice for the empiric treatment of dental-related infections. Alternatives to penicillin include erythromycin, clindamycin, or a cephalosporin. Clindamycin is the first alternate choice. It is especially useful when anaerobes are suspected or in recalcitrant infections where sensitivities are lacking.[3,5,6,10]

Allow the intraoral drain to remain in place until the swelling has resolved and purulent drainage has ceased. Evaluate the patient for drain removal or advancement in 24 to 48 hours. Prescribe oral antibiotics and analgesics during this time. Refer the patient to a Dentist within 24 hours.

COMPLICATIONS

Minor postoperative pain, swelling, bleeding, drainage, and possibly bruising can be expected following the incision and drainage of a dental abscess. Significant postprocedural bleeding can be controlled with pressure, a vasoconstricting local anesthetic agent, or topical Gelfoam.[5,6,17,18] An incision and drainage tract that communicates freely between the oral cavity and the external face represents a significant complication. Refer these patients to a Plastic or Oral Surgeon.

SUMMARY

The recognition of common dental-related infections such as pericoronitis, periodontal abscesses, and dental abscesses can impact patient prognosis and morbidity. The diagnosis and treatment of these maladies, and their complications, requires knowledge of dental anatomy and pathophysiology. The Emergency Department management of these infections is quick and simple. Refer all patients to a Dentist or Oral Surgeon for definitive care of their teeth.

178 Post-Extraction Pain and Dry Socket (Alveolar Osteitis) Management

Eric F. Reichman

INTRODUCTION

Post-extraction pain, or periosteitis, begins as the local anesthetic agent wears off. The pain begins to diminish, most of the time, within 12 hours. The prescription of nonsteroidal anti-inflammatory drugs will provide analgesia and comfort while the

pain subsides over 1 to 2 days. Narcotic analgesics may occasionally be required for the first 24 to 48 hours.

Pain that develops 2 to 4 days after the tooth extraction most likely indicates a localized alveolar osteitis or a dry socket. A dry socket occurs most commonly with the extraction of the third mandibular molar, but can be associated with any tooth that has been extracted. The pain is quite severe in nature and is localized to the area of the extraction site. The extraction site may emit a foul odor and the patient often complains of a bad taste in their mouth.[1,2] Physical examination may reveal the socket is missing a clot, but this is sometimes difficult to identify. The signs of an infection are absent.

ANATOMY AND PATHOPHYSIOLOGY

The exact etiology or the pathogenesis of a dry socket is not clear.[1–6] It may be multifactorial due to smoking, a localized infection, a poor blood supply, traumatic extractions, a foreign body in the socket, and certain medications. These factors result in an increased level of fibrinolysis of the blood clot in the socket before the clot has had the time to be replaced by granulation tissue. The clot falls out of the socket and exposes the bony surface of the socket to the oral cavity. The exposed bone is extremely sensitive to air, resulting in severe pain.[1–4]

INDICATIONS

The single and utmost therapeutic goal of alveolar osteitis is to relieve the patient's pain during the healing process. This procedure should be performed on all patients with a dry socket.

CONTRAINDICATIONS

There are no contraindications to the management of a dry socket.

EQUIPMENT

- Dental mirror
- 2 × 2 gauze squares
- Scissors
- Dry socket paste or Dressol-X
- Gelfoam
- Irrigating syringe
- Normal saline solution
- Frazier suction catheter
- Suction source and tubing
- Forceps
- Iodoform ribbon gauze
- Eugenol-impregnated ribbon gauze
- Oil of cloves

PATIENT PREPARATION

Explain the risks, benefits, potential complications, and aftercare to the patient and/or their representative. A signed consent is not required for this procedure. Place the patient sitting upright or reclining. A multipositional dental chair is ideal and allows for a variety of positions to visualize the affected tooth. This procedure may be accomplished with no anesthesia. Some may consider performing a dental block to temporarily alleviate the patient's pain and allow the procedure to be accomplished with minimal discomfort, and increase the level of patient satisfaction. If performed, use lidocaine without epinephrine because the procedure is quickly performed and the anesthesia wears off while the patient is still in the Emergency Department. Refer to Chapter 176 for the complete details regarding dental anesthesia and analgesia. Consider obtaining a plain radiograph or panorex to rule out a retained root tip or foreign material in the socket.

TECHNIQUES

Identify the defective tooth. Gently and thoroughly irrigate the socket with warm normal saline and low-level suction to remove any debris. Use a forceps to pack dry socket paste into the socket. Dry socket paste is composed of balsa wood fragments saturated with eucalyptol and looks like chewing tobacco. Completely fill the socket with the dry socket paste. The patient will experience almost instant pain relief if a dental block was not performed. Place a piece of Gelfoam on top of the dry socket paste. Compress the Gelfoam and dry socket paste into the socket. Instruct the patient to bite down against a 2 × 2 gauze square placed over the socket for 5 to 10 minutes. Dressol-X may be used instead of dry socket paste if available.

Unfortunately, few Emergency Departments stock dry socket paste or Dressol-X. An alternative is ribbon gauze or Gelfoam impregnated with eugenol, iodine, or oil of cloves. Ribbon gauze tends to dry out and fall out sooner than commercially available dry socket paste. Use a forceps to pack the socket completely with the impregnated ribbon gauze (**Figures 178-1A to C**) or Gelfoam. Place a piece of plain Gelfoam on top of the socket (**Figure 178-1D**). Compress the plain Gelfoam and the underlying impregnated ribbon gauze or impregnated Gelfoam into the socket. Instruct the patient to bite down against a 2 × 2 gauze square placed over the socket for 5 to 10 minutes.

ASSESSMENT

The patient should experience almost immediate pain relief after the socket is packed. If a dental block was performed, allow the local anesthetic to wear off to ensure the patient's pain truly has resolved.

AFTERCARE

The patient may be discharged immediately after the procedure, or after the local anesthetic has worn off. Nonsteroidal anti-inflammatory drugs are usually adequate to provide analgesia. Narcotic analgesics are not needed nor required. Arrange follow-up as soon as possible with the Dentist or Oral Surgeon who performed the extraction procedure. The dressing must be replaced daily, or as needed, until the patient is pain free. Instruct the patient to begin a soft diet, to not ingest extremely hot or cold substances, and to not play with the packing with their tongue. **Instruct the patient to also not suck anything, use a straw, gargle, spit, or smoke.** All these activities will produce negative pressure within the oral cavity and remove the clot from the extraction site.

The decision to prescribe antibiotics to cover the oral flora is physician dependent. There is no literature to support or refute this practice. Consult the Dentist or Oral surgeon who extracted the tooth. Oral penicillin VK (500 mg QID) is the preferred antibiotic if they are prescribed. Clindamycin (300 mg QID) is an alternative for patients allergic or intolerant to penicillin.

COMPLICATIONS

There are no complications associated with this procedure. A potential complication is the aspiration of the material used to pack the socket. This has never been reported in the literature. The packing may fall out and result in the patient's pain recurring. Instruct the

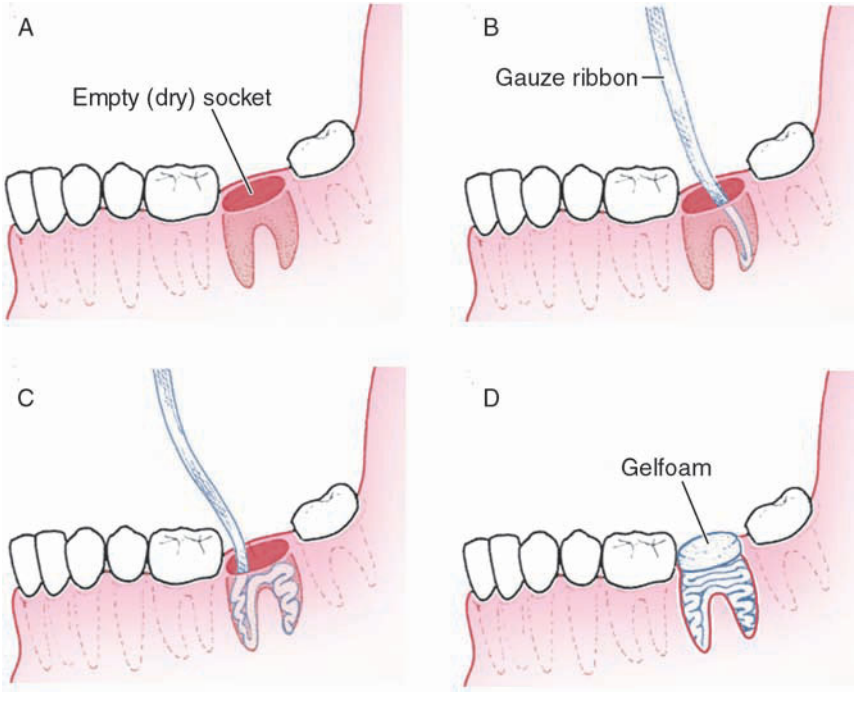


FIGURE 178-1. Packing a dry socket with ribbon gauze. **A.** The empty socket. **B.** Pack the socket starting inferiorly and working upward. **C.** Completely fill the socket. **D.** Apply Gelfoam over the socket and the ribbon gauze.

patient to return to the Emergency Department if the packing falls out prior to their follow-up appointment.

SUMMARY

A dry socket can be extremely painful. Packing an empty socket is easy, quick, simple, and provides the patient with significant relief. The packing needs to be changed daily for several days and then less frequently after that, until the patient is free of pain. Prescribe antibiotics to cover oral flora and analgesics to manage pain.

179 Post-Extraction Bleeding Management

Eric F. Reichman

INTRODUCTION

Post-extraction bleeding is a common problem after the removal or extraction of a tooth. It is often seen in the Emergency Department in the late evening or night when the patient is unable to contact their Dentist. Bleeding that occurs within a few hours of the extraction is often due to the wearing off of the vasoconstrictor effect of the local anesthetic solution used for anesthesia. The application of direct pressure over the bleeding site by having the patient bite down on a folded piece of moist gauze almost always controls post-extraction bleeding. Many patients, however, will report that they have been doing this prior to coming to the Emergency Department and require additional assistance.

ANATOMY AND PATHOPHYSIOLOGY

A careful history may reveal that the patient inadvertently caused the extraction site to bleed by drinking through a straw, spitting, gargling, or smoking. All these activities will produce negative pressure within the oral cavity and remove the clot from the extraction site. Ask the patient if they are touching the extraction site with their tongue, causing a mechanical disruption of the clot. Obtain information about any significant medical history, any history of bleeding, and current medications. This includes use of aspirin products, anticoagulants, broad-spectrum antibiotics, alcohol, and antineoplastic medications. These all may contribute to prolonged bleeding. Ask about the symptoms and examine for the signs of liver disease, hypertension, or hematologic disorders.[1,2] Post-extraction bleeding may be a sign of an underlying and undiagnosed coagulopathy.

INDICATIONS

All post-extraction bleeding must be managed carefully and methodically. The techniques are easy to perform, simple, and straightforward.

CONTRAINDICATIONS

There are no contraindications to the management of post-extraction bleeding.

EQUIPMENT

- 2 × 2 gauze squares
- Irrigating syringe
- Dental mirror, optional
- Local anesthetic solution containing 1:100,000 epinephrine
- 23 to 25 gauge, 1.5 inch needle
- 5 mL syringe
- Silk or plain gut sutures, 4-0 or 5-0
- Absorbable gelatin sponge (Gelfoam)
- Oxidized regenerated cellulose (Surgicel)
- Topical thrombin

- Suture set
- Dental forceps
- Tea bag
- Bone rongeur
- Bone wax
- Headlamp
- Yankauer suction catheter
- Suction source and tubing
- Silver nitrate matchsticks
- Electrocautery unit

PATIENT PREPARATION

Explain the risks, benefits, potential complications, and aftercare to the patient and/or their representative. Document this discussion in the medical record. A signed consent form is usually not required for these procedures. Consider obtaining a radiograph of the affected area to rule out a retained root or a bony spur.

Position the patient to visualize the extraction site. Place the patient in a multipositional dental chair, if available, or on a gurney. Do not place the patient in a chair as they may become presyncopal and require being placed supine to prevent injury. An overhead light source or a headlamp is ideal to illuminate the field. Suction any blood and oral secretions from the mouth. Visualize the extraction site for any signs of bleeding. Thoroughly irrigate the site with warm saline and remove all clots with the aid of suction. It may be necessary to perform a dental block if the patient complains of pain upon irrigation. Refer to Chapter 176 for the complete details regarding dental anesthesia and analgesia.

TECHNIQUES

The management of post-extraction bleeding is simple. Numerous methods to control the bleeding have been described and tested (**Table 179-1**). These techniques are often performed in a sequential manner as described below. The techniques may, of course, be performed in any order, depending on the physical examination and physician preference.

MECHANICAL PRESSURE

Place saline-moistened 2 × 2 gauze squares over the socket. Instruct the patient to apply firm pressure by biting down on the gauze for 20 minutes. Instruct the patient to maintain pressure for 20 minutes despite initial bleeding. Place the suction catheter, intermittently, into the vestibule of the mouth to remove any blood and secretions. The application of pressure will control most post-extraction bleeding. It may be necessary to perform a dental block, if not performed during the irrigation phase, if the patient cannot bite down due to pain.

TABLE 179-1 Methods to Control Post-Extraction Bleeding

Absorbable dressing into socket and mechanical pressure with gauze squares
Absorbable dressing into socket and stitch gingival tissue closed
Cauterize bleeding granulation tissue
Cauterize or stitch bleeding blood vessels
Gingival infiltration with local anesthetic containing epinephrine
Mechanical pressure with gauze squares
Moist tea bag and pressure
Rongeur or apply bone wax to bone spurs
Stitch gingival tears

TEA BAG APPLICATION

Place a saline-moistened tea bag in the socket if mechanical pressure does not control the bleeding. The tannins in the tea leaves will assist with the coagulation process. Instruct the patient to bite down on the tea bag for 15 minutes.

ABSORBABLE DRESSINGS

The two most commonly used absorbable dressings are Gelfoam and Surgicel. Gelfoam is an absorbable gelatin sponge that is readily available and inexpensive. It forms a scaffold for the formation of a blood clot. Surgicel is composed of oxidized and regenerated cellulose. It promotes coagulation better than Gelfoam and can be packed into the socket under pressure. Unfortunately, Surgicel results in delayed healing of the socket and its use should be reserved for persistent bleeding or when Gelfoam is not available.

Place an absorbable dressing (Gelfoam or Surgicel) in the socket if the extraction site continues to bleed.[1–3] The author prefers to use Gelfoam because it is easier to manipulate and it is absorbed more rapidly than Surgicel. Work the Gelfoam in your fingers until it resembles the shape of the socket. Insert the Gelfoam into the socket and compact it with a dental forceps. Insert additional pieces of Gelfoam into the socket, as necessary, to obtain a solid mass of Gelfoam filling the socket. An alternative is to pack the socket with Surgicel. Once the socket is packed, apply a 2 × 2 gauze square over the socket. Instruct the patient to bite down for approximately 20 to 30 minutes. The author prefers to place a figure-of-eight stitch using 4-0 or 5-0 silk suture or plain gut suture over the socket (**Figure 179-1**). The suture applies pressure over the socket and ensures that the Gelfoam or Surgicel will not prematurely fall out of the socket. This technique will usually stop most post-extraction bleeding.

Two additional absorbable dressings are topical thrombin and collagen. They are expensive, not usually available in the Emergency Department, and their use should be limited to circumstances where other hemostasis methods have failed. Topical thrombin is made from bovine thrombin. Place a piece of Gelfoam or Surgicel saturated with thrombin into the socket. Thrombin converts fibrinogen to fibrin, bypassing the coagulation cascade, to form a clot within the socket. Collagen is available in multiple forms from a variety of sources. It promotes platelet aggregation and forms a scaffold for the formation of a clot. Pack the socket with collagen and cover it with a piece of Gelfoam. Place a figure-of-eight suture over the thrombin or collagen-filled socket to secure it in place.

The use of chitosan bandages to control battlefield and prehospital hemorrhage has crossed over into the dental realm. Chitosan dental bandages (HemCon Medical Technologies, Portland, OR) have

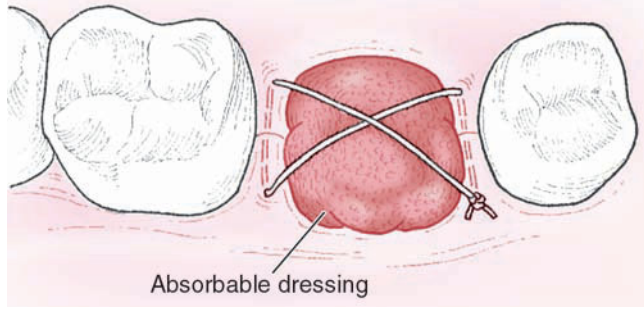


FIGURE 179-1. Pack the socket with Gelfoam followed by a figure-of-eight stitch to control the bleeding.

been designed to control post-extraction hemorrhage. Chitosan is a naturally occurring polysaccharide derived from shellfish. It attracts red blood cells. When placed over the bleeding extraction site, the red blood cells attach to the bandage to form a clot and tamponade the bleeding.

LOCAL ANESTHETIC INFILTRATION

Infiltrate the soft tissue surrounding the socket with local anesthetic solution containing epinephrine if the bleeding is not controlled by the above methods. The most commonly used local anesthetic solutions are lidocaine and bupivacaine. Infiltrate the soft tissues surrounding the socket with the local anesthetic solution until the tissue blanches. This usually requires 2 to 3 mL of the local anesthetic solution. Irrigate the socket. Apply a piece of moist gauze over the socket. Instruct the patient to bite down and to exert pressure on the socket. The patient is often able to bite down much harder on the tissues after the infiltration of the local anesthetic solution.

The effect of mechanical pressure combined with the vasoconstrictive effects of epinephrine control the bleeding. Occasionally, after the vasoconstrictive effect of epinephrine wears off, there is a rebound effect and the persistence of bleeding. This may be prevented by routinely placing Gelfoam or Surgicel into the socket after the bleeding is controlled.

MISCELLANEOUS TECHNIQUES

Reexamine the extraction site if the bleeding is not controlled by the above methods. The source of bleeding may be new granulation tissue, gingival tears, a bone spur, or a partially transected vessel. Cauterization of granulation tissue with silver nitrate or electrocautery will control the bleeding. Handheld, disposable, single-patient use electrocautery units work well but require the patient to be anesthetized. Use a blunt instrument to feel for the presence of a bone spur. This may be a source of significant bleeding. Remove the bone spur with a rongeur or cover it with bone wax to control the bleeding. An exposed and bleeding arteriole or venule can be controlled with cauterization (silver nitrate or electrocautery) or the application of a plain gut suture through the vessel. Suture any tears in the gingiva.

ASSESSMENT

Observe the patient for 30 to 60 minutes after the bleeding has terminated. Do not give the patient anything by mouth (NPO). Reevaluate the socket for signs of bleeding. Continued bleeding requires further attempts at termination.

AFTERCARE

Discharge the patient home after the bleeding has been terminated and a brief observation period. Instruct the patient to avoid any liquids or solids for 2 hours. Stress the importance of not spitting, gargling, drinking through a straw, smoking, using aspirin-containing products, or playing with the site with their tongue. Instruct the patient to apply gauze squares and bite down for 20 minutes if the bleeding returns. They should return promptly to the Emergency Department if the bleeding continues after 20 minutes. Additional instructions should include a soft diet, avoidance of extremely hot or cold substances, avoidance of chewing gum, and avoidance of other such "sticky" foods. Arrange follow-up as soon as possible with the Dentist or Oral Surgeon who performed the extraction.

COMPLICATIONS

There are no documented complications associated with the termination of post-extraction bleeding. The complications are associated with the bleeding itself. Obtain screening labs (e.g., PT, PTT, platelet count, and bleeding times) if hemostasis is not achieved by any of the aforementioned methods. Early consultation with a Dentist or Oral Surgeon and a Hematologist should be considered if the patient is coagulopathic or has a bleeding disorder.

SUMMARY

A careful history and physical examination will often provide the reasons for most post-extraction bleeding that presents to the Emergency Department. Most patients without complicating medical conditions will be easily managed in a simple and systematic manner with a minimal amount of equipment. All patients should follow-up with their Dentist or Oral Surgeon after the bleeding is terminated.

180 Defective Dental Restoration Management

Daniel J. Ross

INTRODUCTION

The field of restorative dentistry is a complex specialty that derives from many disciplines. Patients have often invested considerable time, money, and quite possibly "blood, sweat, and tears" in their dental work. This may be particularly true with the advent of both cosmetic and implant dentistry, which involve long and complicated treatment plans that are often not covered by insurance. A patient's investment in their dental work and the technical complexity of today's dental appliances should not be taken lightly. In fact, the treatment of common dental emergencies was published in the Emergency Medicine Clinics of North America under the heading "Difficult and Advanced Procedures".[1]

The urgent management of an acutely problematic dental restoration can be as simple as relieving discomfort, treating injury and infection, and employing temporizing measures until definitive treatment can be rendered by the appropriate specialist. This requires a basic understanding of dental anatomy, the pathophysiology of various dental states, and their typical treatment modalities.[1,2] It goes without saying that one should also recognize the inherent and all too frequent limitation of treating these problems in the Emergency Department. **The key to the successful emergent or urgent management of an acutely problematic defective dental restoration is stabilization and timely referral with great care to "first, do no harm".**

A few basic principles serve as a useful guide in treating patients with defective dental restorations. First, know your limitations. Dental pain in general, and a defective dental restoration in particular, is rarely if ever, a true emergency.[2–4] Chronic problems should be treated with equal measures of conservatism and reluctance. Refer the patient to a Dentist if you are hesitant to treat or are unfamiliar with an appliance or a presentation. Always consider a secondary or comorbid process. Consider the utility of dental radiographs when in doubt. Never remove a fixed appliance without first discussing it with a specialist, preferably the one who placed it. Save anything

and everything that belongs to the patient, whether it be appliance or tissue, as it may have utility for the definitive treatment.[5,6] Treat pain, inflammation, and evidence of infection. Consider a reversible or temporary solution over all others. Remember to treat a tooth for dental trauma if a restoration is determined to be defective secondary to trauma. Always consider ingestion or aspiration when dealing with a multiply fragmented tooth or appliance. Consider facial, neck, chest, and abdominal radiographs if all fragments cannot be accounted for.[5,7–10] Whenever a patient is actively involved in an ongoing treatment process, it is probably best to do as little as possible. Always use caution and tact when discussing the possibility of a defective dental restoration with a patient. Remember that you are not an expert. The treating specialist may have insight into the patient's current condition that you are unaware of. Attempt to consult before treating. Always arrange follow-up within 24 to 48 hours.

ANATOMY AND PATHOPHYSIOLOGY

Patients frequently present to the Emergency Department with some sort of dental complaint and their primary concern is typically pain related.[1,2,11,12] The perioral tissues are exceptionally sensitive to noxious stimuli. This is particularly true for the oral mucosa, periodontal ligament, dentin, and pulp. This concept is paramount to the effective management of any dental-related complaint. Although a patient's chief complaint may be directed at a particular tooth, be diligent in searching the entire mouth for alternative primary, comorbid, or secondary problems.

A meaningful discussion of the management of defective dental restorations requires a brief outline of the available types of dental appliances. In general, dental appliances are either fixed or removable. Fixed dental appliances are considered permanently attached to the teeth. They include crowns, bridges, implants, some forms of dentures, orthodontic bands and brackets, interdental wiring, and any type of filling (e.g., silver amalgam, gold, porcelain, or tooth-colored composite material). Removable dental appliances are those that are not permanently attached to the teeth and include partial dentures, complete dentures, space-maintenance devices, and other orthodontic devices.

Understanding whether a defective dental device is permanent or removable is often the first step in managing an acutely problematic appliance. Removing a broken or defective removable appliance is a simple and easy solution if it can be done safely and without significantly damaging the appliance. If removal would significantly alter or damage an appliance and there is no other reasonable option but to remove it, document the discussion with the patient and their consent to proceed. This is true whether the appliance is permanent or removable.

Removable dental appliances can predispose patients to several easily treatable mucosal conditions such as ulcerations, abrasions, or mucosal infections.[13,15] Compromised cellular immunity, broad-spectrum antibiotics, low salivary flow, poor oral hygiene, and trauma from poorly fitting dentures can all contribute to oral candidal overgrowth.[13,16] Patients often complain of burning pain. Treat the oral cavity with nystatin or clotrimazole troches. The appliance itself may harbor the organism and must be treated. Instruct the patient to take the appliance out of their mouth for 24 to 48 hours and soak it overnight in a nystatin suspension [5 mL nystatin in 250 mL (8 ounces) of tap water]. Instruct the patient to scrub the denture daily with an approved product to clean it.[13–15]

Oral candidiasis must be differentiated from other mucosal ulcerating conditions such as simple traumatic ulcers, aphthous ulcers, and oral herpes. Herpetic lesions occur on attached mucosa only, whereas aphthous ulcers occur on unattached mucosa.[13–16] Traumatic ulcers, minor aphthae, and major aphthae can be treated with topical corticosteroid ointment, such as triamcinolone, applied with a cotton-tipped applicator. The symptoms associated with herpetic outbreaks can be diminished if treated with acyclovir or a similar antiviral agent.[13–15] Orthodontic or interdental wiring that is impinging upon the oral mucosa may lead to traumatic ulcerations. Apply soft dental wax directly to the irritating appliance to relieve the impingement. This can be easily removed or replaced and is available over the counter at many local pharmacies.

In general, all patients with painful mucosal conditions may benefit from soft and bland diets, frequent use of ice chips for discomfort, and frequent warm saltwater rinses to avoid superinfection.[13,14] A stomatitis cocktail or BMX solution may be helpful for patients with severe mucosal pain. Mix equal amounts of Benadryl (12.5 mg/5 mL), Maalox, and Xylocaine (2% viscous lidocaine). Instruct the patient to swish 30 mL in their mouth for 1 minute and then spit it out.

The repair of broken or defective removable appliances in the Emergency Department is not recommended even though multiple over-the-counter products are available for home use (Figure 180-1).[16] Under the best of circumstances these procedures



FIGURE 180-1. Commercially available home repair kits for the fractured denture.

can be tedious, time consuming, and fraught with complications—even for the trained dental professional.[3] Most importantly, a botched repair attempt can result in patient discomfort, morbidity, and irreversible damage to an otherwise salvageable appliance. **In this light, it seems best to simply recommend removal and a dental referral to the patient seeking care for a broken removable appliance.**[16] Although far less than ideal, a home repair kit may be a viable option for some patients under certain circumstances.

The temporary urgent repair of defective fixed dental restorations by nondental personnel is advocated throughout the literature.[2,3,11,12,14,17–19] Use caution, however, when evaluating a new or recently placed fixed restoration because sensitivity from recent dental procedures can occur due to pulpal or periodontal ligament (PDL) irritation.[20] This may be a normal and expected sequelae of the dental procedure and not necessarily an indication that the restoration is defective.[1,20,21] Trauma from occlusion can result if a new dental restoration is left "too high" and does not fit properly with the opposing dentition.[3,14,18–20] These patients complain of pain with mastication and are sensitive to percussion secondary to PDL irritation. **Do not alter a fixed restoration if it is firmly in place.** Simple temporizing measures include dental blocks (Chapter 176), oral analgesics, a soft diet, and possibly removing the tooth from occlusion by placing a small amount of soft dental wax (or something similar) between the teeth on the opposite side.[3]

Long-standing fixed dental restorations may be defective secondary to microleakage or recurrent decay around the margins of the restoration.[1,20] Estimates suggest that approximately one in three restorations in existence may be defective in some fashion.[20,21] A faulty restoration that sits within or upon a tooth can lead to dentinal exposure regardless of the etiology. Exposed dentin is highly sensitive and prone to further decay. Dentinal sensitivity (also known as reversible pulpitis) is typically nonspontaneous and fleeting.[1,16,18,22] Patients who complain of spontaneous and lasting sensitivity have an irreversible pulpitis that is most likely due to recurrent decay. Sensitivity to percussion is indicative of periapical involvement and suggests the possibility of a periapical periodontitis or an abscess.[1,14,16,18,22]

Evaluate the tooth and its restoration for recurrent decay or a possible dentinal exposure if a patient present complaining of sensitivity associated with a tooth that has a long-standing restoration. **A temporary restoration can easily be fabricated in the Emergency Department if the restoration in question is missing, broken, or easily removed.**

Consideration should be given to a possible pulpal pathology, as outlined above, if a restoration is firmly in place. Provide dental anesthesia, oral analgesics, antibiotics as necessary, and a referral to a Dentist. Refer to Chapter 177 for the details regarding the management of dental abscesses.

INDICATIONS

Replace any previously fixed, permanent or temporary, dental restoration that has completely or partially fallen out or that is easily removed with a dental explorer. Replace any previously fixed, permanent or temporary, crown that has fallen out or is easily removed with a dental explorer and is in the patient's possession.

CONTRAINDICATIONS

Relative contraindications for the placement of a temporary dental filling, or temporarily recementing a crown, include patients who are involved with an extensive ongoing dental treatment plan, have a consulting specialist readily available, are at a significant aspiration risk, or have obvious extensive comorbid or secondary processes including antecedent trauma.

EQUIPMENT

- 10 mL syringe
- 18 gauge angiocatheter
- Normal saline solution
- Local anesthetic solution containing epinephrine
- Dental mirror
- Dental explorer
- 2 × 2 gauze squares
- Sterile cotton rolls
- Dental floss
- Clear nail polish
- Cavit-G
- IRM (zinc oxide and eugenol)
- Dycal (calcium hydroxide paste)
- Copalite (cavity varnish) or clear acrylic nail polish
- Tin foil
- Cotton-tipped applicators
- Discoid-cleoid dental carver
- Articulating paper
- Frazier suction catheters
- Suction source and tubing
- Petrolatum-based lubricant (Vaseline)
- Good overhead lighting or a headlamp

PATIENT PREPARATION

Explain the procedure, its risks, complications, and aftercare to the patient and/or their representative. Obtain an informed consent for the procedure. The simple placement of a temporary filling does not usually require local anesthesia. However, consider the use of a dental block if the patient is uncomfortable. Refer to Chapter 176 for the complete details regarding dental anesthesia and analgesia.

Prepare the patient. Seat the patient in a multipositional procedure chair. Gently irrigate the area with a syringe that contains warm normal saline and is armed with an 18 gauge angiocatheter to remove any food debris. Warm saline is usually less sensitive to the exposed dentin.[1] Gently remove any debris that does not irrigate away with a dental explorer. **Do not attempt to remove any decay because doing so may lead to a complicating pulpal exposure.**[1] Remove the loose portion of the restoration. **Do not remove any firmly fixed portion of the restoration.**

It is mandatory to have a dry field when performing this procedure. Dry the area to be filled with sterile cotton pellets or compressed air. Remember that the tooth may be sensitive.

TECHNIQUES

REPLACING A TEMPORARY OR PERMANENT FILLING

Treatment of defective fillings depends upon the relative size of the defect. There are no specific guidelines of what size (i.e., how many millimeters) the defect must be to perform each of these techniques. Paint small dentinal exposures with calcium hydroxide paste followed by cavity varnish or clear acrylic nail polish to relieve sensitivity.[1,10,14,19] Alternatively, place a simple tin foil dressing over the tooth to act as a bandage following placement of the calcium hydroxide paste.[10,14,19]



FIGURE 180-2. Commercially available home use products for temporary dental filling and crown restoration.

Larger defects require a filling to avoid food impaction and other sequelae. Cavit-G is an excellent choice for temporary filling material, especially in inexperienced hands.[1,10,12,23] This material is premixed, nonirritating, and sets quickly (approximately 30 minutes) upon contact with saliva. IRM, or a mixture of zinc oxide and eugenol, is similar material with the benefit of pulpal sedative properties. The use of IRM is operator dependent and requires a longer setting time.[23] Oddly enough, multiple mixtures of zinc oxide and eugenol are available over-the-counter for home use (Dentemp, Tempanol, Thin Set; **Figure 180-2**).

Cavit-G is recommended for Emergency Department use. Determine whether the missing filling exposes an open endodontically treated root (i.e., root canal). Place a small sterile cotton pellet into the canal prior to placing the filling material if the pulp cavity is exposed.[23] Express a small amount of Cavit-G from the container. Apply it onto the cavity and condense it into the cavity with the moistened end of a cotton-tipped applicator or a dental explorer (**Figure 180-3A**). **A temporary restoration placed by nondental personnel is always better "short" and out of occlusion with the opposing tooth for patient comfort. Work quickly because Cavit-G can set rapidly and it may be difficult to remove once it sets.** Remove any excess Cavit-G with the stick end of the cotton-tipped applicator. Instruct the patient to fully occlude on the new restoration and grind their teeth back and forth in all directions for 5 to 10 minutes. This will form the occlusal aspect of the filling to fit the opposing teeth if it is not made "short".

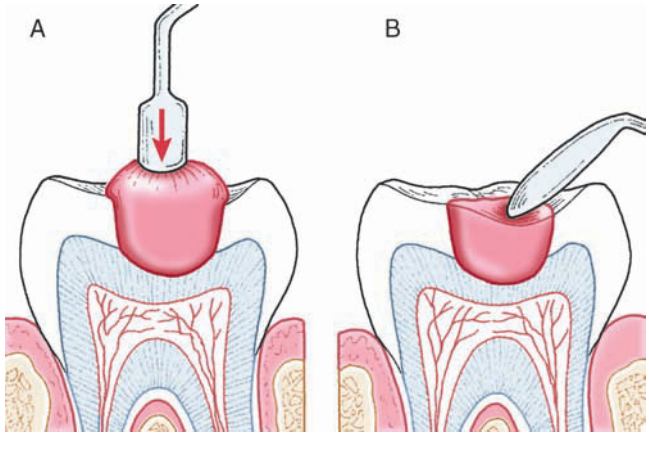


FIGURE 180-3. Application of temporary restorative material. **A.** Pack the material into the defect and condense it with a dental explorer (or a cotton-tipped applicator). **B.** Remove any excess material.

Remove any excess material with the stick end of the cotton-tipped applicator. Use the discoid-cleoid dental carver to remove excess material once it begins to harden (**Figure 180-3B**). Use dental floss to contour a proper embrasure and clear excess material from the gingival tissues. **Use the dental floss in a downward direction only. Never bring the dental floss back up toward the occlusal surface because doing so risks dislodging the new restoration.** Simply pull the dental floss through after one downward pass around the tooth.

REPLACING A TEMPORARY OR PERMANENT CROWN

The patient preparation required for this procedure is essentially the same as that for replacing a temporary filling. However, avoid dental anesthesia if possible to allow better patient proprioception. This will provide the Emergency Physician with a crucial aid in assessing the orientation and occlusion of the final restoration.[1] The same over-the-counter mixtures for repairing a filling may be used to temporarily replace a crown (**Figure 180-2**).

Reapply the crown to ensure that it fits properly. It is often necessary to remove a small amount of the existing cement from within the patient's existing restoration in order to provide an adequate seal and a proper occlusion.[1] This may or may not be possible to do with the discoid-cleoid dental carver. Do not use rotary instruments as these may irreversibly damage the inside of the coping. Reinsert the patient's crown after removing some of the cement to assure a proper fit and proper occlusion. Make an attempt using the alternative technique described below if sufficient preexisting cement cannot be removed and the crown seats properly. Treat dentinal sensitivity as outlined above (i.e., as replacing a filling) if the appliance does not seat at all.

Proceed with this technique if the restoration appears to fit and a small amount of the preexisting cement can be removed from the inside. Prepare the area. Apply a thin layer of petrolatum-based lubricant (i.e., Vaseline) to the mucosal tissues surrounding the tooth to aid in the cleanup. **Do not contaminate the prepared tooth with the lubricant.**

Prepare or mix a thin consistency of zinc oxide and eugenol cement. Place a very small amount of the mixture into the preexisting crown with a cotton-tipped applicator.[3,14,18] Place the crown on the tooth and in the proper orientation. Firmly and fully seat the crown with firm finger pressure. Remove any excess cement material from around the margin of the newly cemented restoration. This may be easier once the material has hardened. Instruct the patient to gently and fully occlude on the restoration. **Ensure proper occlusion.** Ask the patient to provide a subjective report if their occlusion feels like baseline (i.e., does their bite feel funny). Confirm this using articulating paper to ensure that the contact marks are light or minimal. Wipe the petrolatum-based lubricant from the mucosal tissues.

A simpler, alternative, and far more temporary method of replacing a crown involves using Vaseline as the cementing agent.[1] Apply a thin layer of Vaseline to the inside of the coping. It may be necessary to remove a small amount of the preexisting cement. Seat the crown on the tooth in the proper orientation. Ensure proper occlusion. Warn the patient that the crown may come off again and about the risk of aspiration. Instructions may be given to the patient for repeating the procedure at home.

ASSESSMENT

Check the patient's occlusion. It may be necessary to use articulating paper to ensure minimal or no contact with the opposing teeth with the temporary filling. The newly cemented crown restoration must primarily be assessed for proper occlusion. The patient's subjective opinion is invaluable in this regard.

AFTERCARE

Instruct the patient not to eat or chew on their new restoration for at least 1 hour. Additional instructions should include a soft diet, avoidance of extremely hot or cold substances, avoidance of chewing gum, and avoidance of other such "sticky" foodstuffs. They may brush their teeth normally, but should not floss adjacent to the new restoration. Warn them that they may experience some continued sensitivity. Nonsteroidal anti-inflammatory drugs will provide any needed analgesia. Arrange follow-up within 24 to 48 hours.

COMPLICATIONS

Typical complications of replacing a filling include improper occlusion and poor retention of the restoration. The solution for both problems is replacing the restoration. Adjust the occlusion with the discoid-cleoid dental carver. Treat the restoration as a dental restoration that is "too high" if using the discoid-cleoid dental carver is not effective. Treat the tooth as a simple dentinal exposure if a temporary restoration is continually falling out. An unlikely complication would be a pulpal exposure, manifested as minimal bleeding from within the tooth defect.[1,10,12] Manage this as a dental trauma or fractured tooth.

Typical complications for replacing a crown are similar to those listed in replacing a temporary filling. These restorations are often easily removed with a slight twisting motion. A restoration that is seated "too high" should be replaced. Treat the tooth as a simple dentinal exposure if a restoration is consistently "too high".

SUMMARY

Management of the patient with a dental complaint may initially seem intimidating to the Emergency Physician. The recognition and treatment of dental pain, minor defective dental restorations, and painful mucosal conditions can be relatively simple provided a minimal understanding of basic dentistry. Emergency Physicians must be cognizant of the inherent limitations involved in treating these patients in the Emergency Department. Have a low threshold for referral. Pain, inflammation, and infection should always be treated. Refer patients to the appropriate specialist within 24 to 48 hours.

181 Subluxed and Avulsed Tooth Management

Daniel J. Ross

INTRODUCTION

Traumatic dental injuries are a common presentation to the Emergency Department. They can have significant lasting cosmetic, functional, and psychological consequences for the patient. Recent estimates indicate over three quarters of a million annual Emergency Department visits in the United States for dental-related complaints.[1] Nearly 12% of these are related to some form of trauma.[1] Approximately 50% of children will sustain traumatic dental injuries, the majority of these to the permanent dentition.[2–4] Violence of a suspicious nature, such as domestic or child abuse, must always be considered when evaluating dental injuries.

The appropriate Emergency Department management of dental trauma depends heavily upon the type of tooth (permanent vs. primary), the age of the tooth, the time elapsed since the incident, and the extent of the damage. Successful treatment of dental injuries requires a basic understanding of dental anatomy, terminology, and pathophysiology. **The goals of the emergent treatment of dental trauma are to maintain patient comfort and tooth vitality, while ensuring prompt dental follow-up for definitive care.**

ANATOMY AND PATHOPHYSIOLOGY

TOOTH ANATOMY

There are significant differences in the adult and pediatric dentitions that impact their treatment in the Emergency Department (**Figure 181-1**). The pediatric dentition is known as the primary or deciduous dentition and consists of 20 teeth. These include eight incisors, four canines, and eight molars. The adult dentition consists of 32 teeth and is composed of 8 incisors, 4 canines, 8 premolars, and 12 molars. The variable absence of a tooth or the addition of an extra tooth is common in either dentition. The teeth in both the pediatric and adult dentitions erupt in a predictable sequence, albeit with considerable individual variation (**Figure 181-1**). Treatment strategies differ for permanent versus deciduous (primary) teeth as well as by the age of the adult tooth. **Exercise great care when evaluating patients with a "mixed" dentition, roughly between the ages of 6 and 12 years.**

The anatomy of a tooth is rather simple (**Figure 181-2**). The tooth itself consists of a neurovascular pulp surrounded by supportive dentin, which is surrounded by a hard thick crown of enamel. The crown portion lies above the gum line or gingiva. The root portion lies embedded within the alveolar bone of the jaw, anchored by a thin layer of cementum, and the periodontal ligament. The alveolar bone, periodontal ligament fibers, and fragile cementum cell layer taken together are considered a functional unit known as the attachment apparatus. A complete attachment apparatus requires

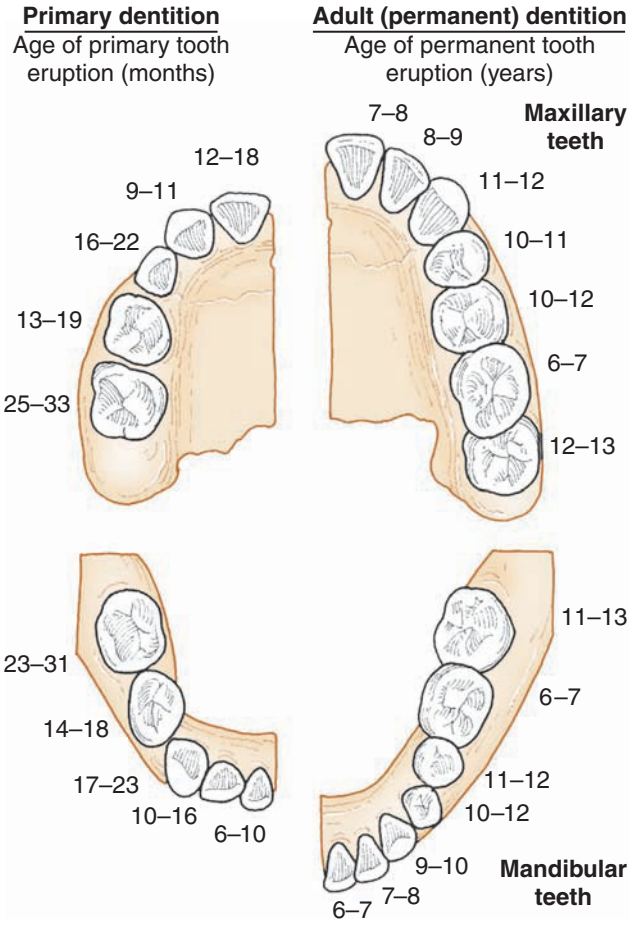


FIGURE 181-1. The normal eruptive patterns of the pediatric and adult dentition.

an intact cementum cellular layer and a fully formed root apex. Immature adult teeth do not have a fully formed apex and necessitate special attention to maintain pulpal viability.[3,5–9]

TOOTH INJURY

Mechanisms of tooth injury include direct trauma (i.e., a blow) or occlusive trauma (i.e., biting on a hard object or a seizure). These mechanisms can result in a spectrum of injury patterns that vary from simple sensitivity to complete tooth avulsion. Crown and root fractures are discussed in Chapter 182. This chapter focuses on the diagnosis and management of dental subluxations and avulsions.

Appropriate treatment of dental injuries requires a thorough history and meticulous examination of the oral cavity, including subsequent radiographs after ruling out more serious injuries. Historically, important points include the age of the patient, the time of the trauma, the mechanism of injury, the location of teeth or tooth fragments, subjective disturbance of bite, and treatments provided since the time of the incident. The physical examination must include an assessment of the extraoral and intraoral soft tissues, bony displacement, missing teeth, crown fractures, pulp exposures, tooth sensitivity, and tooth mobility.

The need for radiographs with dental trauma is worth emphasizing. A tooth that is missing, both by history and physical examination, may be found completely intruded below the gum line, embedded in the perioral soft tissues, floating within the maxillary sinus or stomach, or even aspirated.[10–14] **Obtain facial films if a tooth, or a portion of the tooth, cannot be unequivocally located by history or physical examination. Strongly consider obtaining chest and abdominal radiographs if the tooth, or the portion in question, is not visualized on the facial films.**

CONCUSSED AND SUBLUXED TEETH

Mild injuries to teeth are common and cause concussions and subluxations. Concussed teeth are essentially injured, nonmobile, and nonfractured teeth. These teeth have suffered a direct blow and are sensitive, with no concrete clinical or radiographic

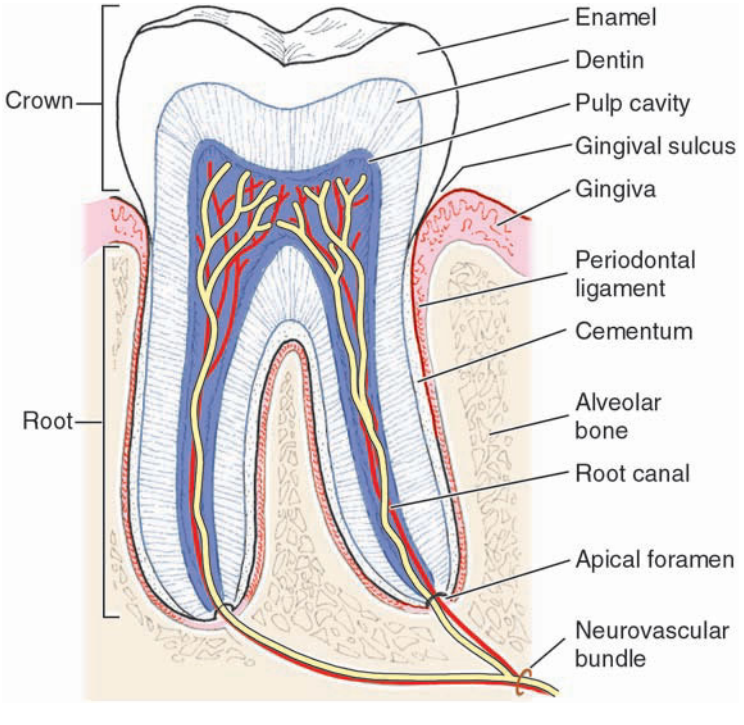


FIGURE 181-2. The dental anatomic unit (i.e., the tooth) and its supporting structures.

evidence of injury. Concussions are often mild injuries to the periodontal ligament with associated inflammation. Subluxed teeth may or may not be sensitive, are not displaced, but are perceptively mobile when manipulated between two cotton applicators or other instruments. Subluxations have definite damage to the periodontal ligament with associated inflammation. Mild gingival bleeding may be present. Both concussion and subluxation imply an injury to the attachment apparatus. Pain control, soft diet instructions, and follow-up with a Dentist are all that is required in the management of most of these injuries. Concussed and subluxed primary and permanent teeth are generally treated in the same manner.[2,7–9,16]

Excessive mobility from a severe subluxation may be irritating, painful, and damaging. These injuries require a temporary splint for relief.[2,3,5–9] Definitive treatment for severely subluxed permanent teeth requires splinting for 2 weeks or more.[9,16] Definitive treatment for severely subluxed primary teeth is extraction.[9,16]

LUXATED TEETH

Luxated teeth are displaced or dislocated from their usual position within the alveolar bone. The periodontal ligament is torn. Luxated teeth are commonly associated with other injuries such as alveolar fractures, root fractures, and gingival lacerations.[2,17] Subcategories of injury within this class are described by the direction of the dislocation. Luxated teeth may be displaced laterally, intruded, or extruded (**Figure 181-3**). Lateral luxations may be mesial, distal, buccal, or lingual in direction. An alveolar fracture is self-evident when several teeth are luxated as a solid segment.

Laterally luxated permanent teeth should be repositioned and temporarily splinted.[7–9] Laterally luxated primary teeth can be treated in the same fashion.[16] A general word of caution regarding primary teeth is warranted. **The apices of the primary teeth are in close anatomic proximately to the developing permanent tooth buds within the alveolus.** This close relationship can lead to numerous developmental disturbances in the permanent dentition whenever there is trauma to a primary tooth.[18] **Therefore, it is recommended that the Emergency Physician defer any manipulation of a primary tooth to the care of a Dentist, or at least consult them first.**

Extruded teeth represent a partial avulsion from the alveolar socket and a damaged attachment apparatus. They typically appear clinically longer than the surrounding teeth (**Figure 181-3B**). Patients may complain of occlusal prematurity. There may be associated gingival bleeding. A hematoma surrounding the apex may preclude complete repositioning. Extruded permanent teeth are treated with repositioning and temporary splinting.[2,3,5,7–9] Treatment decisions for extruded primary teeth are complex and best left to a Dentist. The majority of these teeth will likely require extraction.[16]

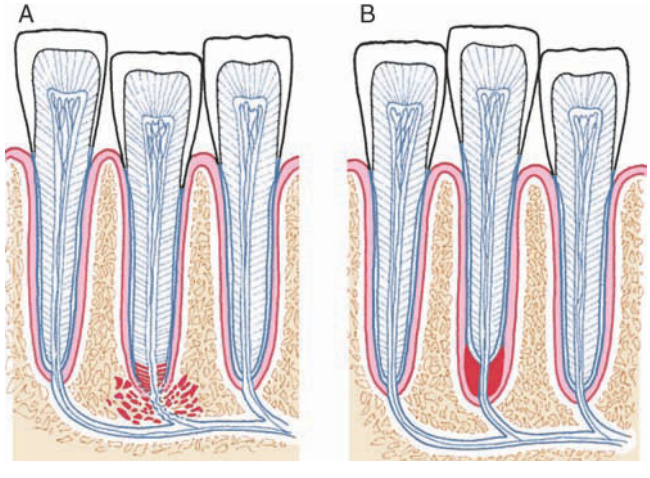


FIGURE 181-3. Luxation injuries with neurovascular damage to the apex. **A.** Intrusive luxation injury. **B.** Extrusive luxation injury.

Intrusion is a severe form of luxation injury with the tooth driven inward in an axial direction. These injuries are manifested by displacement of the tooth into the alveolar socket with a corresponding fracture of the alveolar bone surrounding the apex (**Figure 181-3A**). Adjacent structures, such as the floor of the nose or maxillary sinus, may be involved or damaged.[13,14] These injuries may be so profound that the tooth is not visible within the oral cavity and believed to be avulsed. **It is worth reiterating that a tooth that cannot be unequivocally located on physical examination requires radiographic localization.** Immature adult teeth suffering intrusion injuries generally have the best prognosis. They are often left alone and allowed to re-erupt. Mature adult teeth often require surgical or orthodontically assisted re-eruption and root canal therapy. The intrusion of primary teeth frequently leads to damage of the developing permanent tooth buds and requires close dental follow-up. Rule out more serious injuries, arrange an expedited appointment for definitive care, prescribe appropriate analgesics, and give strong consideration to the prescription of antibiotics.[2,3,5,7–9,19]

AVULSED TEETH

Avulsed teeth are teeth that have been completely torn from their alveolar sockets. **The teeth have suffered profound attachment and neurovascular damage that progresses in a time-dependent fashion.** There is a high likelihood of associated injuries with this type of trauma. Perform a thorough evaluation of the entire oral cavity after any dried blood, clots, and debris have been removed. Bleeding can generally be controlled with firm digital pressure or local infiltration of an epinephrine-containing local anesthetic solution. Patients may present with the tooth in hand or may not be aware of the location of the tooth. **The onus is on the Emergency Physician to determine the exact whereabouts of the tooth. Treat the patient for pain, control the bleeding, and provide tetanus prophylaxis.** Prescribe antibiotics for these patients if there are significant concomitant injuries or as the situation warrants. Arrange follow-up with a Dentist at their convenience. If available, a permanent tooth can be treated with replantation. **As a rule, avulsed primary teeth are not replanted to avoid damage to the developing permanent teeth and possible growth disturbances.**[5,7,8,16] Exercise great care in evaluating patients in the mixed dentition stage, roughly between the ages of 6 and 12 years.[2,3,5]

An attempt can be made at replantation in order to preserve patient comfort, cosmesis, and function when a permanent avulsed tooth is available. **The objective for the emergency treatment of these injuries is to maintain viability of the torn periodontal ligament fibers on the external root surface as pulpal necrosis is inevitable for the majority of these teeth.**[2] A successfully replanted tooth may be fully functional with little or no cosmetic impact following root canal therapy. **Periodontal ligament fibers are extremely sensitive to desiccation. The most critical factor in the successful replantation of avulsed teeth is the speed with which the tooth is replanted.**[2,3,17,20] Patients, parents, or Emergency Medical Service (EMS) personnel can be instructed to replant an avulsed tooth in the field in order to improve the prognosis.[2,3]

Take great care in the handling of an avulsed tooth. They should be handled minimally and only by the crown. The root

surface should not be manipulated in any way other than gentle cleansing with sterile saline, or tap water as a substitute. This will prevent further damage to the cementum and periodontal ligament. Treat the socket in a similar fashion (i.e., cleansed of any obstructing clots or debris with gentle irrigation and suction only) following anesthesia.[3,20]

When it is not possible to immediately replant an avulsed tooth, it can be transported or stored in such a way as to prevent desiccation of the fragile periodontal ligament fibers and to improve salvage rates.[2,5,7–9] The best possible transport and storage solutions are Hank's balanced salt solution (HBSS) and Viaspan, a special cell culture medium (SCCM) used to preserve transplant tissues. The SCCM seems to show some benefit over HBSS.[22] Several commercial products are readily available and specifically designed for tooth transportation and storage. They include EMT Tooth Saver (SmartPractice, Phoenix, AZ) and Dentosafe (Medice, Iserlohn, Germany) which utilize SCCM, or Save-a-Tooth (Phoenix-Lazerus, Pottstown, PA) which utilizes HBSS.[22] These products have great utility in the field and the Emergency Department. They should be considered standard and essential equipment for the Emergency Department. This is particularly true where definitive dental care is not readily available. Simply providing a patient with one of these products may allow successful replantation by a dental specialist hours or even days later.[2,23] Fresh pasteurized whole milk and sterile normal saline are alternatives, but carry diminishing returns for tooth salvageability. Saliva can be employed as a transport medium (by placing the tooth in the buccal vestibule of a conscious and cooperative adult) for very brief periods, again with diminishing hopes for salvage. Tap water or plastic wrap may prevent desiccation for a brief period if all else fails.[3,5,7–9,23]

The literature indicates that irreversible periodontal ligament cell damage occurs within minutes following total tooth avulsion.[3,5,20] Common clinical practice is typically to abandon attempts at salvageability if the tooth has been out of the socket for more than an hour. **However, the notion that replantation is not possible for extraoral times beyond 1 hour is a myth.** The dental trauma literature is replete with case reports with successful outcomes following very long extraoral times (up to a week) and under extremely suboptimal storage conditions such as being kept completely dry.[23,24] An esthetic and functional, albeit less than ideal, result may be possible for avulsed teeth with extraoral times over an hour through a process known as ankylosis if appropriately and aggressively treated by a skilled Dentist. **Therefore, it is never acceptable to discard an avulsed tooth.** Avulsed teeth with extraoral times greater than 1 hour require special treatment with topical fluoride and antibiotic soaks that are typically beyond the scope of care in the Emergency Department.[9,20] Consult a Dentist prior to considering these techniques. At the very least, always give the patient their tooth back in a suitable storage/transport device and advise them on their options for definitive care.

REDUCTION OF SEVERELY SUBLUXED, LATERALLY LUXATED, AND EXTRUDED TEETH

The emergent treatment of a severely subluxed tooth, a laterally luxated tooth, or an extruded tooth involves obtaining adequate anesthesia, reduction of the tooth, and a temporary splint for stabilization.

INDICATIONS

Any severely subluxed, laterally luxated, or extruded tooth is a candidate for reduction.

CONTRAINDICATIONS

There are no absolute contraindications to the reduction of a subluxed, laterally luxated, or extruded permanent tooth. Laterally luxated and primary teeth can be repositioned and splinted. However, their manipulation may damage the permanent tooth bud growing beneath the primary tooth root. Therefore, all subluxed, luxated, or extruded primary teeth should be considered for extraction in consultation with a Dentist or Oral Surgeon.[5,7,8,16,17,21] Consult a Dentist or Oral Surgeon if there is a significant alveolar bone fracture. Do not attempt to reduce teeth that are fractured or grossly carious.

EQUIPMENT

- Local anesthetic solution, with and without epinephrine
- Dental aspirating syringe or a 3 mL syringe with a 2 inch, 25 to 27 gauge needle
- Sterile saline
- Sterile 2 × 2 gauze squares
- Suction source and tubing
- Frazier suction catheter
- Cotton-tipped applicators
- Overhead lighting or headlight

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed informed consent for the procedure. Place the patient in a multipositional procedure chair with good overhead lighting. Administer dental anesthesia. Refer to Chapter 176 regarding the details of dental anesthesia and analgesia. Cleanse the oral cavity with warm saline or tap water and gentle suction. Thoroughly examine the entire oral cavity. Obtain radiographs as indicated. Provide tetanus prophylaxis if required.

TECHNIQUES

SEVERELY SUBLUXED TOOTH REDUCTION

A severely subluxed tooth is not displaced from its socket but is excessively mobile. Ensure that the tooth is in its proper anatomic location. Apply a temporary dental splint, as described below.

LATERALLY LUXATED TOOTH REDUCTION

A laterally luxated tooth has its roots displaced laterally and out of the socket (**Figure 181-4**). It is often associated with a fracture of the surrounding alveolar bone. Place the dominant thumb over the medial surface of the tooth and the index finger overlying the root end of the tooth (**Figure 181-4**). Apply downward and inward pressure with the index finger (**Figure 181-4A**) followed by application of outward pressure with the thumb (**Figure 181-4B**) to reduce the tooth. Apply a temporary dental splint, as described below.

EXTRUDED TOOTH REDUCTION

An extruded tooth is a partially avulsed tooth that protrudes above the adjacent teeth. Apply gentle pressure to the crown of the tooth to reduce the tooth. **Do not force the tooth into the socket** to avoid an iatrogenic fracture at its base. Consult a Dentist if the tooth will not reduce. A hematoma in the base of the socket often prevents reduction. Insert a piece of gauze over the tooth and instruct the patient to gently bite down.

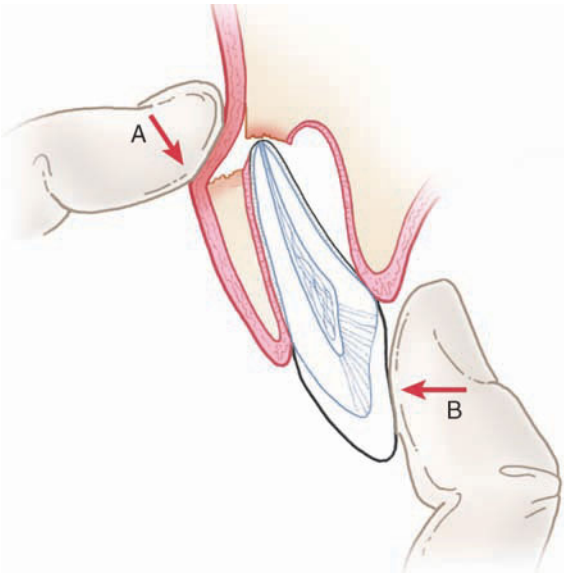


FIGURE 181-4. Manually repositioning a laterally luxated tooth. Apply downward and inward pressure with index finger (**A**) followed by outward pressure with the thumb (**B**).

ASSESSMENT

Obtain postreduction radiographs to verify the correct tooth position. Radiographs may be delayed until after splinting. Reassess the patient for pain, occlusal discrepancies, and stability of the reduction. Manage any soft tissue injuries.

AFTERCARE

Prescribe appropriate analgesics. Nonsteroidal anti-inflammatory drugs supplemented with occasional narcotic analgesic will provide adequate analgesia. Prescribe empiric antibiotics (penicillin or clindamycin). Twice daily rinses with chlorhexidine may also be useful. Instruct the patient to avoid extremely hot or cold substances, to eat a liquid or soft diet, and to avoid chewing in the area of the injury. Provide specific instructions regarding interim dental splint care as discussed below. Arrange follow-up with a Dentist or Oral Surgeon within 24 hours. Remind the patient that any dental injury can result in the loss of tooth vitality and, ultimately, the loss of the tooth despite the best of efforts to maintain it.[2,3,19]

COMPLICATIONS

Immediate complications of any dental trauma include pain and cosmetic deformity. Additionally, instability may be an issue following the application of a temporary splint. Delayed complications can be variable and include tooth mobility, root resorption, pulpal necrosis, infections, and abscess formation. Extension of untreated infections into alveolar bones can cause osteomyelitis and/or systemic infectious complications. A permanent tooth may develop abnormally in a younger child if injured. Bleeding is minimal and often self-limited. Refer to Chapter 179 for the details of post-extraction bleeding management. Ensuring prompt dental follow-up, adequate outpatient analgesics, and empiric antibiotics can limit most of these complications.

REPLANTATION OF AN AVULSED TOOTH

Permanent teeth that have been avulsed should be handled gently and only by the crown. Time is a critical factor in the successful treatment of these injuries and every effort should be made to expedite the care of these patients. Replantation consists of gently reinserting the tooth in the proper orientation and fully seating it with gentle pressure.

INDICATIONS

Any intact and avulsed permanent tooth is a candidate for replantation.

CONTRAINDICATIONS

There are no absolute contraindications to the replanting of permanent teeth by nondental personnel. Concerns for the ABC's (airway, breathing, and circulation), concomitant major morbidity, and aspiration risk in acutely or chronically debilitated patients should be considered prior to tooth replantation. Primary teeth are never replanted. Do not attempt to replant teeth that are fractured or grossly carious.

EQUIPMENT

- Local anesthetic solution, with and without epinephrine
- Dental aspirating syringe or a 3 mL syringe with a 2 inch, 25 to 27 gauge needle
- Sterile saline
- Hank's balanced salt solution
- Sterile 2 × 2 gauze squares
- Sterile cotton rolls
- Suction source and tubing
- Frazier suction catheter
- Cotton-tipped applicators
- Overhead lighting or headlight

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed informed consent for the procedure. Place the patient in a multipositional procedure chair with good overhead lighting. Administer dental anesthesia. Refer to Chapter 176 regarding the details of dental anesthesia and analgesia. Cleanse the oral cavity with warm saline or tap water. Use gentle suction, but never near the injured tooth. Thoroughly examine the entire oral cavity. Obtain radiographs as indicated. Provide tetanus prophylaxis if required. Gently irrigate the avulsed tooth and socket with warm sterile saline or Hank's solution. Remove and clots and debris using a Frazier suction catheter. **Take great care to avoid touching or contaminating the tooth root.** Soak the tooth in Hank's solution for 30 minutes prior to replantation if the extraoral dry time exceeds 30 minutes. Consult a Dentist skilled in dental trauma care prior to replanting if the extraoral time exceeds 1 hour.

TECHNIQUE

Grasp the avulsed tooth gently and only by the crown. Replace the avulsed tooth into the socket in an anatomically correct position. Seat the tooth fully with gentle but firm digital pressure. **Never force the tooth into the socket.** Evaluate the patient's occlusion. Instruct the patient to gently bite together several times while observing for any prematurity. Occasionally, a tooth cannot be completely seated or its position is uncertain. Instruct the patient to temporarily bite on a gauze roll until the dental specialist arrives or store the tooth in a storage/transport media until definitive dental

care can be rendered.[3,19] Address any soft tissue injuries once the tooth's position has been verified. Insert a piece of gauze over the tooth and instruct the patient to gently bite down. Apply a temporary dental splint, as described below.

ASSESSMENT

Obtain post-replantation radiographs to verify the correct tooth position. Radiographs may be delayed until after splinting. Reassess the patient for pain, occlusal discrepancies, and stability of the replanted tooth prior to discharge. Manage any soft tissue injuries.

AFTERCARE

Prescribe appropriate analgesics. Nonsteroidal anti-inflammatory drugs supplemented with occasional narcotic analgesic will provide adequate analgesia. Prescribe empiric antibiotics. Doxycycline is recommended as the drug of choice in patients over 12 years of age. Penicillin or clindamycin are useful substitutes. Twice daily rinses with chlorhexidine are useful, but not required. Instruct the patient to avoid extremely hot or cold substances, to eat a liquid or soft diet, and to avoid chewing in the area of the injury. Provide specific instructions regarding interim dental splint care as discussed below. Arrange follow-up with a Dentist or Oral Surgeon within 24 hours. Remind the patient that any dental injury can result in the loss of tooth vitality and, ultimately, the loss of the tooth despite the best of efforts to maintain it.[2,3,19]

COMPLICATIONS

Immediate complications of any dental trauma include pain and cosmetic deformity. Additionally, instability may be an issue following the application of a temporary splint. Delayed complications can be variable and include tooth mobility, root resorption, pulpal necrosis, infections, and abscess formation. Extension of untreated infections into alveolar bones can cause osteomyelitis and/or systemic infectious complications. A permanent tooth may develop abnormally in a younger child if injured. Bleeding is minimal and often self-limited. Refer to Chapter 179 for the details of post-extraction bleeding management. Ensuring prompt dental follow-up, adequate outpatient analgesics, and empiric antibiotics can limit most of these complications.

PREPARING A TEMPORARY DENTAL SPLINT

Concussed teeth, subluxed primary teeth, and subluxed permanent teeth usually do not require splinting. A temporary splint may prevent further damage and improve patient comfort if severe mobility, or subluxation, is present. Manually reposition laterally luxated and extruded permanent teeth using gentle and firm digital manipulation following adequate anesthesia. A Dentist or Oral Surgeon will typically extract laterally luxated or extruded primary teeth. Intruded teeth, both primary and adult, are associated with considerable comorbidity and complications. These injuries require consultation with a Dentist or Oral Surgeon after defining the extent of the injuries with appropriate radiographs.

INDICATIONS

Any severely traumatized and grossly mobile, luxated, repositioned, or replanted tooth requires temporary splinting. This will prevent further damage, promote patient comfort, preserve form, and preserve function.

CONTRAINDICATIONS

There are no absolute contraindications to the temporary splinting of mobile teeth. The aspiration risk in acutely or chronically debilitated patients should be considered prior to tooth splinting.

GENERAL SPLINTING EQUIPMENT

- Local anesthetic solution, with and without epinephrine
- Dental aspirating syringe or a 3 mL syringe with a 2 inch, 25 to 27 gauge needle
- Sterile saline
- Coe-Pak or Perio-Pak
- Dental utility wax or beeswax
- Sterile 2 × 2 gauze squares
- Sterile cotton rolls
- Applicator sticks; tongue depressors or the wooden end of cotton swabs will substitute
- Frazier suction catheter
- Suction source and tubing
- Overhead lighting or headlight

ADVANCED SPLINTING EQUIPMENT

- General splinting equipment as described above
- Wire cutters
- Tooth etching gel
- Composite resin material (e.g., Centrix Tempit Ultra-F, Centrix Inc., Shelton, CT)
- Single-component adhesive (e.g., Optibond Solo Plus kit, Kerr Corp., Orange, CA)
- Bondable reinforcement ribbon (e.g., Ribbond, Ribbond Inc., Seattle, WA)
- Orthodontic wire, 0.025 inch
- Tubing and regulator to attach to wall air supply
- Visible curing light

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed informed consent for the procedure. Place the patient in a multipositional procedure chair with good overhead lighting. Administer dental anesthesia. Refer to Chapter 176 regarding the details of dental anesthesia and analgesia. Cleanse and thoroughly examine the entire oral cavity. Obtain radiographs as indicated. Provide tetanus prophylaxis if required. Manually reposition any luxated and avulsed teeth. **Manage any soft tissue injuries prior to splint placement to avoid wound contamination by the splint material.**

TECHNIQUES

Cold-curing periodontal packing material (i.e., Coe-Pak or Perio-Pak) is an ideal splinting material for practitioners without dental experience. Measure out equal amounts (i.e., lengths) of the catalyst and the epoxy onto a paper pad (**Figure 181-5A**). Usually a 2- to 3-inch ribbon of each substance is adequate. Thoroughly mix the catalyst and epoxy compounds together with a tongue depressor to form a putty-like consistency (**Figure 181-5B**). Using tap water- or saline-wetted gloved hands, roll the material into a log (**Figure 181-5C**). Apply the material to frame both aspects, medial

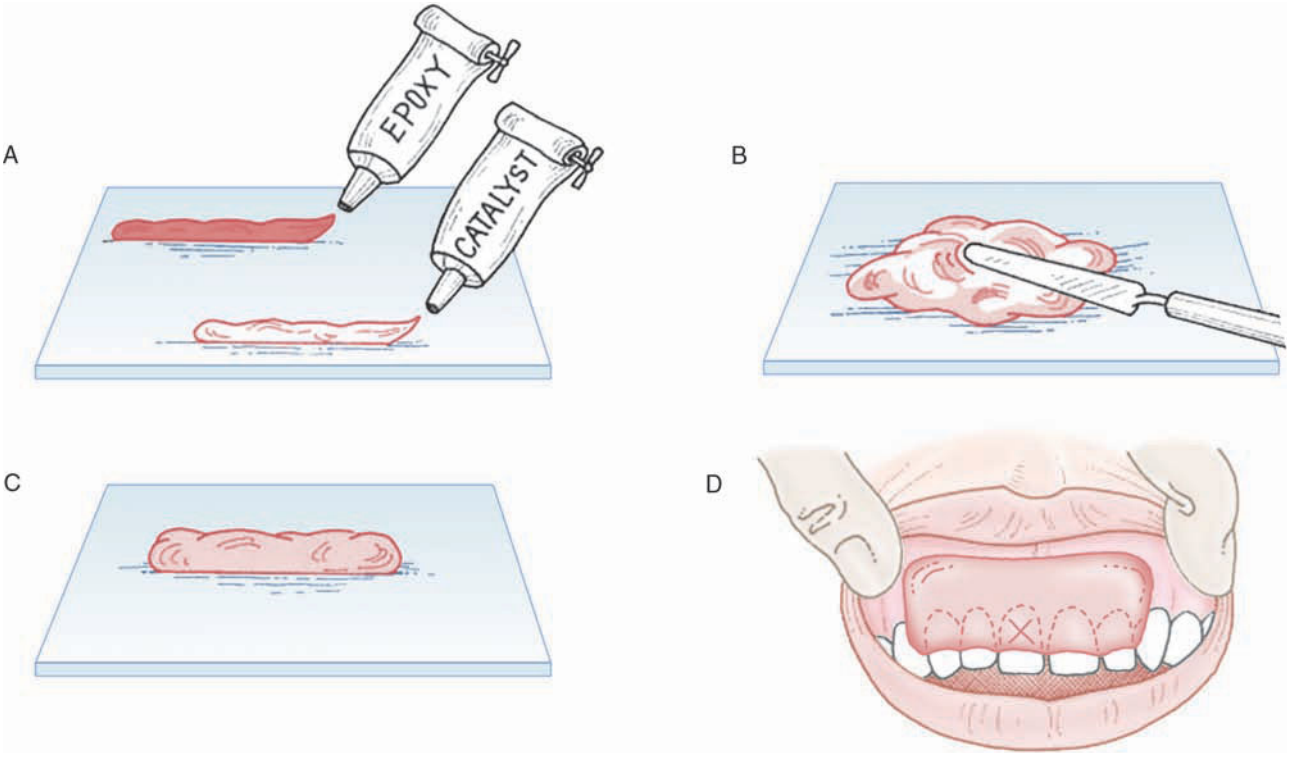


FIGURE 181-5. Preparation of the dental bonding resin and repair of the injured tooth. **A.** Equal amounts of the epoxy and catalyst are measured. **B.** The epoxy and catalyst are mixed together. **C.** The hardening dental paste is molded into a supportive bridge. **D.** The dental bridge is applied over the injured tooth and adjacent two uninjured teeth (both sides) for support while hardening.

and lateral, of the injured tooth and two to three adjacent stable teeth on either side of the injured tooth (**Figure 181-5D**). Use finger pressure to squeeze the material between the teeth medially and laterally to create a single splint unit. **To allow proper occlusion, do not place the packing material on the masticatory surfaces of the teeth. The material must be kept dry and uncontaminated to cure, which is achieved within minutes.**

ALTERNATIVE TECHNIQUES

Numerous alternative techniques have also been used to temporarily splint a tooth. A simpler technique employs softened dental utility wax or beeswax in a similar fashion as described above. The wax splint is not nearly as stable as the cold-curing periodontal packing. Both the medial and lateral surfaces of the teeth can be splinted in this fashion. Ligature splinting with suture material has been described, but rarely provides any significant stability.

Advanced techniques include bondable reinforcement ribbon, acid-etched composite resin, direct interdental wiring, resin-wire combinations, arch bars, and stabilization with a figure-of-eight stitch to the adjacent tooth. These are excellent materials in experienced hands. Unfortunately, they are difficult to use, fraught with complications, and cost prohibitive for routine Emergency Department use.[2,3,5,6,15,17,19,21] Two of these methods, which can be performed by the Emergency Physician if supplies are available, are described below. In an emergency with no immediate dental supplies or a Dentist, skin wound glue (2-octyl cyanoacrylate) and a metal nasal bridge from a face mask have been used to splint a tooth.[25]

A tooth may be splinted using bondable reinforcement ribbon. Open the Ribbond kit. Use the included scissors to cut a piece of the splinting fabric long enough to span the length of the injured tooth and one tooth on each side of the injured tooth. Apply a small drop of the acid etching solution onto all three teeth (the injured tooth, the one behind it, and the one in front of it). Allow the acid etching solution to remain on the teeth for 20 seconds. Thoroughly and gently rinse the acid etching solution using warm tap water or warm sterile saline in a syringe while using suction to capture the liquid. It is often easier to etch and rinse one tooth at a time instead of all three simultaneously. Thoroughly dry the teeth with compressed air. Remove the Optibond Solo Plus container from its packaging. Twist and remove the tip from the Optibond Solo Plus container. Apply a layer of the Optibond Solo Plus to the etched surface of all three teeth using the kits microbrush. Apply the curing light to the three teeth for 20 seconds each. Apply the Optibond Solo Plus onto the previously cut splinting fabric until it is saturated. Apply the tip onto the syringe containing the composite resin. Apply the composite resin to each of the three teeth. Apply and embed the splinting fabric into the composite resin on each tooth. Use a wooden stick (e.g., tongue depressor or cotton-tipped applicator) to ensure that the fabric is embedded in the resin as well as covered by the resin. Apply the curing light onto the three teeth for 40 seconds each. The procedure is the same if multiple adjacent teeth require splinting.

A tooth may be splinted using wire and composite resin. Use a wire cutter to cut a piece of orthodontic wire long enough to span the length of the injured tooth and one tooth on each side of the injured tooth. The remainder of the procedure is exactly as described above except the orthodontic wire is substituted for the splinting fabric.

ASSESSMENT

Allow the patient to wait in the Emergency Department until the splinting material has hardened. The splint material should impinge minimally on the soft tissues. The patient must be able to

open and close their mouth and lips freely, without any obstruction. Reassess the patient for pain, occlusal discrepancies, and stability of the replanted or subluxed tooth prior to discharge. Obtain post-splinting radiographs to verify the proper tooth position.

AFTERCARE

Prescribe appropriate analgesics. Nonsteroidal anti-inflammatory drugs supplemented with occasional narcotic analgesic will provide adequate analgesia. Prescribe empiric antibiotics. Instruct the patient to avoid extremely hot or cold substances, to eat a liquid or soft diet, and to avoid chewing in the area of the injury. Provide specific instructions regarding interim dental splint care. Arrange follow-up with a Dentist or Oral Surgeon within 24 hours. Remind the patient that any dental injury can result in the loss of tooth vitality and, ultimately, the loss of the tooth despite the best of efforts to maintain it.[2,3,19]

COMPLICATIONS

The complications of temporary dental splinting are minimal. The splint material may not stabilize the tooth. A tooth allowed to move within the socket may result in damage to the cementum or the periodontal ligament. An improperly splinted tooth may fall out and result in an aspiration risk. To prevent irritation and bleeding, do not apply splinting materials over the soft tissues. Do not leave the etching acid on longer than 20 seconds or it can penetrate too deep and damage the tooth.

SUMMARY

Traumatic dental injuries are a common presentation to the Emergency Department, especially in pediatric patients during the mixed dentition stage. These injuries may have significant cosmetic, functional, and psychological consequences for the rest of the patient's life. The appropriate Emergency Department management of dental trauma depends heavily upon the type of tooth involved (primary vs. permanent), the time elapsed since the incident, and the extent of the damage. A basic understanding of dental anatomy, terminology, pathophysiology, and treatment protocols will facilitate an accurate description of the extent of the injuries to the dental consultant and be of great aid in providing temporizing emergent dental care when no specialist is readily available.

182 Fractured Tooth Management

Daniel J. Ross

INTRODUCTION

Traumatic dental injuries are common and can have significant lasting consequences for the patient. Recent estimates indicate over three quarters of a million annual Emergency Department visits in the United States for dental-related complaints.[1] Nearly 12% of these are related to some form of trauma.[1] It has been estimated that approximately 50% of children will sustain traumatic dental injuries, and the majority of these are to the permanent dentition.[2–4] Violence of a suspicious nature, such as domestic or child abuse, must always be considered when evaluating dental injuries. **The goals of the emergent treatment of dental trauma are to maintain patient comfort and tooth vitality, while ensuring prompt dental follow-up for definitive care.**

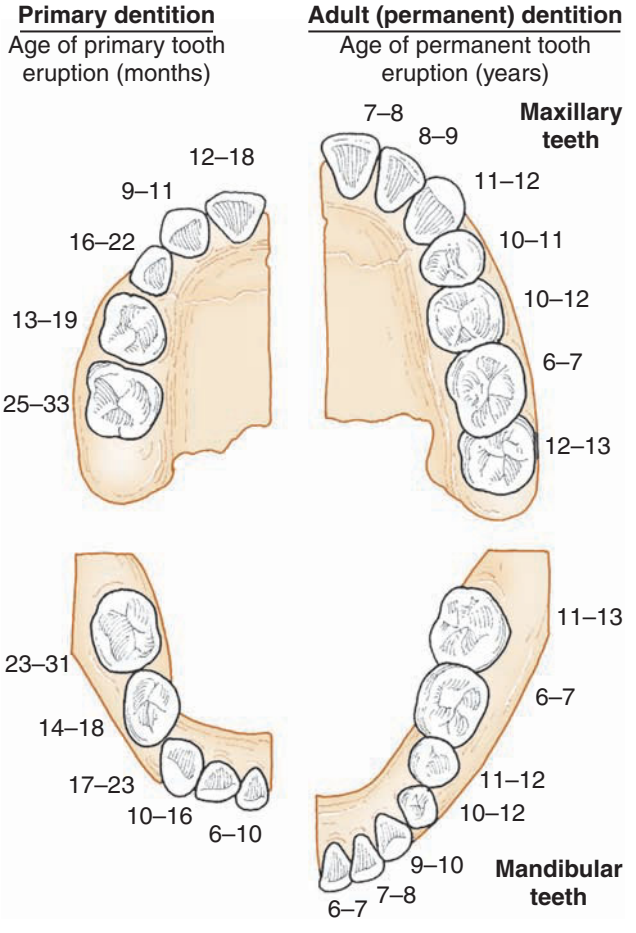


FIGURE 182-1. The normal eruptive patterns of the pediatric and adult dentition.

ANATOMY AND PATHOPHYSIOLOGY

TOOTH ANATOMY

There are significant differences in the adult and pediatric dentitions that impact their treatment in the Emergency Department (**Figure 182-1**). The pediatric dentition is known as the primary or deciduous dentition and consists of 20 teeth, which includes 8 incisors, 4 canines, and 8 molars. The adult dentition consists of 32 teeth and is composed of 8 incisors, 4 canines, 8 premolars, and 12 molars. The variable absence of a tooth or the addition of an extra tooth is common in either dentition. The teeth in both the pediatric and adult dentitions erupt in a predictable sequence, albeit with considerable individual variation (**Figure 182-1**). Treatment strategies differ for permanent versus deciduous (primary) teeth as well as by the age of the adult tooth. **Exercise great care when evaluating patients with a "mixed" dentition, roughly between the ages of 6 and 12 years.**

The anatomy of a tooth is rather simple (**Figure 182-2**). The tooth itself consists of a neurovascular pulp surrounded by supportive dentin, which is surrounded by a hard thick crown of enamel. The crown portion lies above the gum line or gingiva. The root portion lies embedded within the alveolar bone of the jaw, anchored by a thin layer of cementum and the periodontal ligament. The alveolar bone, periodontal ligament fibers, and fragile cementum cell layer taken together are considered a functional unit known as the attachment apparatus. A complete attachment apparatus requires a fully

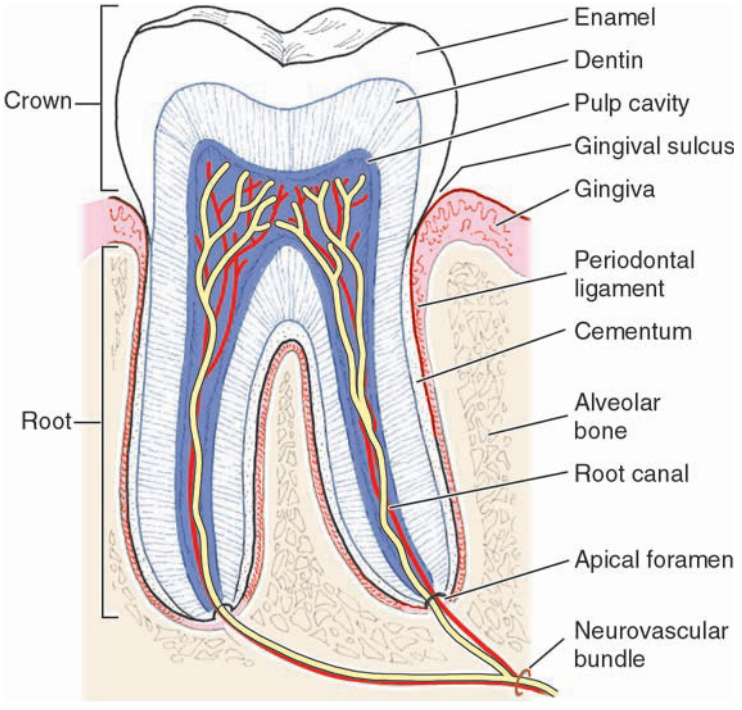


FIGURE 182-2. The dental anatomic unit (i.e., the tooth) and its supporting structures.

formed root apex. Immature adult teeth do not have a fully formed apex and necessitate special attention to maintain pulpal viability.[2,4,5]

TOOTH INJURY

Mechanisms of tooth injury include direct trauma (i.e., a blow) or occlusive trauma (i.e., biting on a hard object or a seizure). These mechanisms can result in a spectrum of injury patterns that vary from simple sensitivity to complete tooth avulsion. The fracture of any portion of the tooth, whether the crown or the root, falls in the middle of this spectrum and is frequently seen in the Emergency Department.[4]

Appropriate treatment of dental injuries requires a thorough history and meticulous examination of the oral cavity, including subsequent radiographs after ruling out more serious injuries. Historically, important points include the age of the patient, the time of the trauma, the mechanism of injury, teeth or tooth pieces at the scene, subjective disturbance of bite, and treatments provided since the time of the incident. The physical examination must include an assessment of the extraoral and intraoral soft tissues, bony displacement, missing teeth, crown fractures, pulp exposures, tooth sensitivity, and tooth mobility. This chapter focuses primarily on tooth fractures, while luxation and avulsion injuries are dealt with in Chapter 181.

The need for radiographs with dental trauma is worth emphasizing. A tooth that is missing, both by history and physical examination, may be found completely intruded below the gum line, impacted within the perioral soft tissues, floating within the maxillary sinus or stomach, or even aspirated. **Obtain facial films if a tooth, or a portion of a tooth, cannot be unequivocally located by history or physical examination.** Strongly consider obtaining chest and abdominal radiographs if the tooth, or portion in question, is not visualized on the facial films.[6–11] Any available tooth fragments, whether retrieved from the scene, the patient's perioral soft tissues, or the patient's pocket should be saved and stored for potential use during the definitive care process by the Dentist.[9,12–14] Bonding techniques in the Emergency Department are not prudent due to multiple potential complications including bond failure and tooth fragment aspiration.

TOOTH FRACTURES

Fractures involving the crown of the tooth are commonly described in the emergency literature using the Ellis classification system (**Figure 182-3**).[2,4–6,15,16] **An Ellis I fracture involves only the enamel portion of the tooth.** These injuries typically are not sensitive or

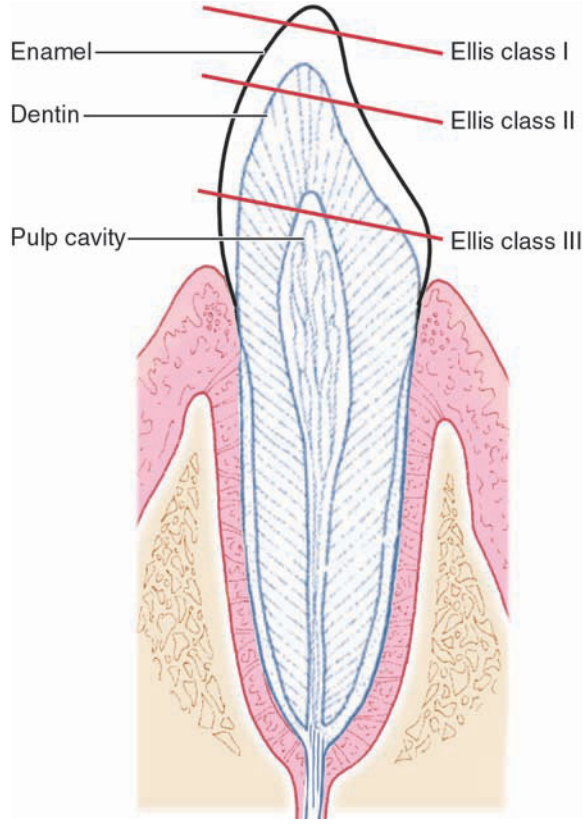


FIGURE 182-3. The Ellis classification scheme of dental fractures through the crown.

painful. They can result in a sharp edge of enamel that may irritate the tongue and other adjacent soft tissues. Emergency treatment may be as simple as smoothing the rough edge with an emery board or similar instrument.[2,4,14,17] These injuries frequently involve the prominent anterior teeth and may be cosmetically unappealing. Reassure patients with these concerns that aesthetic restorations are possible by their Dentist.[4–6,15,18] **Forewarn patients with even minor trauma and sensitivity that unseen or undiagnosed trauma at the apex of any traumatized tooth, even with an appropriately treated crown fracture, can compromise the blood flow to the pulp and obviate the need for root canal therapy.[4,18] Both primary and permanent teeth with these fractures can be treated in a similar fashion.[14,19]**

The Ellis II fracture involves the dentin. It can be recognized by the yellow to pink hue of the dentin in contrast to the white of enamel. This fracture allows for potential contamination of the dentin microtubular networks by oral bacteria that may eventually compromise the pulp if not treated. Dentin is alive and formed by the pulp. It is sensitive to temperature, osmotic gradients, and mechanical forces. Dentin is laid down concentrically from within the pulp chamber as the tooth ages. Therefore, children have less dentin than pulp (as compared to adults) and their pulp is less insulated against trauma and subsequent infection. Children under the age of 12 years with Ellis II fractures have a higher risk of complications and require more expeditious follow-up.[2,5,14,18] **Refer these patients to a General or Pediatric Dentist as soon as possible.**

Emergency treatment for Ellis II fractures consists of applying a protective dressing which is also sedative to the pulp. Examples include Dycal (L.D. Caulk Co., Milford, DE) and IRM (L.D. Caulk Co., Milford, DE). These materials need to cover the entirety of exposed dentin (and therefore the dentinal tubules) in order to protect the pulp from contamination. These materials are then often covered with a sealant such as Copalite (Cooley & Cooley, Houston, TX), clear acrylic nail polish, or a dental bonding resin.[2,3,5,6,14,15,18,20] Some authors have suggested that a non-light cured glass ionomer cement replace the long held standard of Dycal.[3] While these materials may offer some advantages, they can be expensive and tricky to use.[18]

Tissue adhesives such as Dermabond (Ethicon, Inc., Somerville, NJ) have been suggested as alternative dressings in the treatment of Ellis II dental fractures.[21–23] This should be discouraged as its effects on pulpal tissues via exposed dentinal tubules have not been studied and are unknown. Physicians may actually be causing harm by using this material on exposed dentin.

Both primary and permanent teeth with Ellis II fractured can be treated in a similar fashion. However, like immature permanent teeth, primary teeth with Ellis II fractured require special care and more expeditious follow-up.[14,19]

The Ellis III fracture involves exposure of both the dentin and the pulp. This is identified as a reddish tinge or subtle bleeding from the exposed dentin. Frank pulpal exposures are obvious. The pulp is highly vascular and exquisitely sensitive due to exposed nerve endings. The pulp is exceedingly vulnerable to bacterial infection if exposed. **These fractures constitute a true dental emergency and should be evaluated immediately by a Dentist for possible emergent root canal therapy or extraction.** Although less than ideal, minimal pulp exposures (less than 1 to 2 mm) may be treated as Ellis II fractures with dental follow-up within 24 hours.[2–6,14,15,18,19] Complete coverage of the fractured crown may be difficult in these cases. Dental dry foil or tin foil may provide adequate coverage. Any root canal manipulation is fraught with complications, even in the hands of Endodontists. Emergency Physicians are well advised to avoid these procedures.[2,15,18]

Fractures of the root are much less common than crown fractures and occur in less than 7% of dental injuries.[2,4] Root fractures are uncommon in primary teeth as they have short roots.[2] Root fractures may be described as either horizontal or vertical. Horizontal root fractures are described according to their location along the tooth root (**Figure 182-4**). Vertical root fractures occasionally extend into the crown. All root fractures are prone to infection and impaired healing, and may ultimately lead to pulpal necrosis and tooth loss.

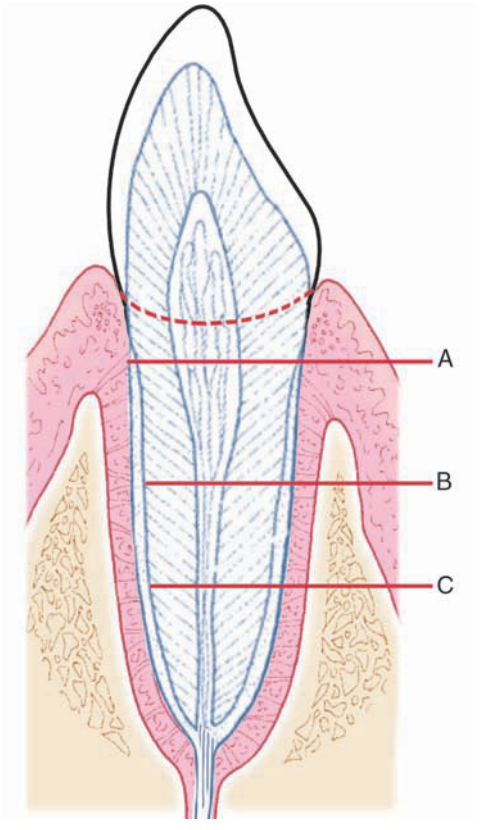


FIGURE 182-4. Classification of root fractures according to their location. **A.** Incisal or coronal third fracture. **B.** Mid-root fracture. **C.** Apical third fracture.

The clinical diagnosis of root fractures is challenging at best, even with the aid of radiographs readily available in the Emergency Department setting (i.e., Panorex). Root fractures classically present with pain, mobility, and sometimes displacement of a tooth fragment. However, these fractures are often insidious and found only on dental radiographs after follow-up reveals continued sensitivity. **Emergency Physicians must maintain a high level of clinical suspicion for these injuries and probably err on the side of cautious overtreatment.[2,4]**

Vertical root fractures and root fractures in the coronal portion of the root have a poor prognosis. Horizontal root fractures elsewhere along the tooth root have a good prognosis if treated before a coagulum can develop between the fragments, generally within 24 to 72 hours.[2,15] Immediate reduction and immobilization with one of the various splinting techniques is the treatment of choice. Refer to Chapter 181 for the details regarding dental splinting techniques. Root fractures in the primary teeth require extraction.[19]

INDICATIONS

Fractured teeth may require no treatment or a significant amount of treatment based upon the type of injury as described by the Ellis classification system. Fractured roots must be treated based upon the level of clinical suspicion.

CONTRAINDICATIONS

There are no absolute contraindications to the temporary repair of a fractured tooth or tooth root. Concerns for the ABC's (airway, breathing, and circulation), concomitant major morbidity, and aspiration risk in acutely or chronically debilitated patients should be considered prior to tooth repair.

EQUIPMENT

- Local anesthetic solution, with and without epinephrine
- Dental aspirating syringe, or a 3 mL syringe, with a 2 inch, 25 to 27 gauge needle
- Dental explorer
- Discoid-cleoid carver
- Dental drill or emery board
- Sterile saline
- Sterile 2 × 2 gauze squares
- Sterile cotton rolls
- Applicator or molding sticks; tongue depressor or the wooden end of cotton swabs will substitute
- Calcium hydroxide paste (e.g., Dycal), mixable or premixed (preferred)
- Copalite cavity varnish or clear acrylic nail polish
- Zinc oxide—eugenol paste (e.g., ZOE or IRM)
- Dental dry foil or tin foil
- Frazier tip suction catheter
- Suction source and tubing
- Good overhead lighting or headlight
- Dental floss

PATIENT PREPARATION

Explain the risks, benefits, and aftercare to the patient and/or their representative. Obtain an informed consent for the procedure. Position the patient upright in a multipositional procedure chair in a well-lighted environment. Provide tetanus prophylaxis as required. Provide anesthesia to the patient. Refer to Chapter 176 for the complete details regarding dental anesthesia and analgesia.

Irrigate the oral cavity and dental repair region with warm saline to remove any gross contaminants or clotted blood. Warm gentle irrigation is usually less sensitive to exposed dentin.[15] **A dry and uncontaminated field is mandatory.** This can be achieved via dabbing with sterile cotton pellets or gently blowing with compressed air. Maintain a dry working environment by isolating the traumatized tooth with sterile cotton rolls on either side. Inject a small amount of local anesthetic solution containing epinephrine directly into the pulp if continued bleeding from a large pulpal exposure is problematic.

TECHNIQUES

ELLIS I FRACTURES

Ellis I fractures are clinically minor injuries. The management includes smoothing of any sharp edges with a dental drill or a nail file to prevent injury or irritation to the soft tissues of the oral cavity. **Use care to avoid over-aggressive smoothing and exposure of the dentin (i.e., iatrogenic Ellis II injury).**

ELLIS II FRACTURES

Ellis II fractures are clinically more important than Ellis I fractures. They require coverage of the exposed dentin to prevent infection and reduce sensitivity. Paint small or large dentinal exposures with calcium hydroxide paste covering all of the exposed dentin.[6,15,17] Apply the premixed calcium hydroxide paste in a thin layer with any small, blunt instrument or the wooden handle of a cotton-tipped applicator. If not premixed, apply equal amounts of the calcium hydroxide base and catalyst on a piece of paper. Mix these two components thoroughly with a blunt instrument or wooden stick and then apply it to the tooth. Allow the calcium hydroxide paste to dry. Apply three to four coats of cavity varnish or clear acrylic nail polish over the dry calcium hydroxide paste. Allow adequate drying time between the coats. This will relieve any sensitivity. Alternatively, place a tin foil dressing over the tooth to act as a bandage following placement of the calcium hydroxide paste.[6,15,16] With cautious care, a calcium hydroxide dressing will typically last 2 to 3 days.[18]

ELLIS III FRACTURES

Ellis II fractures are true dental emergencies and should be treated by a Dentist or Oral Surgeon. Treat pulpal exposures, if no specialist is immediately available, by applying a saline-moistened or lidocaine-moistened cotton pledget over the exposed pulp and holding it there until the bleeding stops. This may take 2 to 5 minutes. Apply a thick mixture of calcium hydroxide paste over the exposed pulp and dentin. Apply the calcium hydroxide paste over an adjacent tooth to form a temporary hold. Contour the calcium hydroxide paste so that it does not irritate the surrounding tissue. The majority of these injuries will require root canal therapy. Refer the patient to a Dentist within 24 hours if they are not seen in the Emergency Department.

ASSESSMENT

Reassess the patient for pain and any occlusal discrepancies prior to discharge.

AFTERCARE

Most of these patients will have some degree of sensitivity until definitive treatment by a Dentist. Prescribe appropriate outpatient analgesics. Nonsteroidal anti-inflammatory drugs supplemented with a narcotic analgesic will provide adequate pain control for Ellis II and III fractures. Antibiotics are generally not necessary unless the initial presentation had been significantly delayed, suppuration is present, or a significant delay is expected in obtaining dental follow-up. Instruct the patient to avoid extremely hot or cold substances, to begin a liquid or soft diet until seen by a Dentist, to avoid chewing in the area of the injured tooth, and to avoid topical analgesics (such as oil of cloves) due to the propensity for sterile abscess formation.[2,4,15] Always warn patients about continued sensitivity.

COMPLICATIONS

Complications of dental trauma include pain, cosmetic deformity, loss of tooth viability, and unsuspected or unrecognized injury to adjacent teeth with later complications. A permanent tooth may develop abnormally in a younger child if injured. Infection can form locally and advance to an abscess, osteomyelitis, and/or systemic infectious complications. Ensuring prompt follow-up with a Dentist can abate the majority of these complications. The Emergency Physician should be ever vigilant for cases suspicious for child abuse or neglect.

SUMMARY

Dental fractures are relatively common traumatic injuries. Appropriate clinical assessment and treatment requires an understanding of basic dental anatomy, terminology, and pathophysiology. Management includes addressing patient discomfort, stabilization, and coverage of the exposed vulnerable tooth components. Arrange prompt follow-up with a Dentist for definitive care of any dental injury.

183 Temporomandibular Joint Dislocation Reduction

Marilyn M. Hallock

INTRODUCTION

Mandible or temporomandibular joint (TMJ) dislocations usually occur in the setting of prior musculoskeletal problems of the jaw.[1–3] This includes joint laxity, prior injury or dislocation, inherent hypermobile syndromes (e.g., Marfan, Ehlers-Danlos), or neuromuscular problems (e.g., dystonic reactions) that pull the mandible out of its joint. The mandibular dislocation typically results from TMJ hyperextension or trauma. The Emergency Physician must be able to reduce a TMJ dislocation. The procedure is easy, simple, and straightforward.

ANATOMY AND PATHOPHYSIOLOGY

The TMJ is an unusual joint (**Figure 183-1**). It is composed of two joints separated by an articular disk. The TMJ functions as a hinge and gliding joint. A discussion of the mechanics of the TMJ is beyond the scope of this chapter. Anterior dislocations are most commonly seen in the Emergency Department. The etiology of the dislocation includes laughing, chewing, opening the mouth wide (e.g., eating, for procedures, yawning, vomiting), seizures, and trauma. All of these actions can result in the mandibular condyle sliding forward and anterior to the articular eminence of the temporal bone. Anatomic abnormalities of the TMJ have a greater predisposition for mandibular dislocation. These include a shallow articular eminence, weak or torn temporomandibular ligaments, an overstretched joint capsule, previous TMJ dislocations, or hypermobile syndromes (e.g., Marfan's or Ehlers-Danlos syndrome).[4] The muscular attachments of the mandible result in a pulling of the condyle superiorly and in front of the articular eminence (**Figure 183-2**). This causes the mandible to become fixed in dislocation and rarely spontaneously reduce.[5]

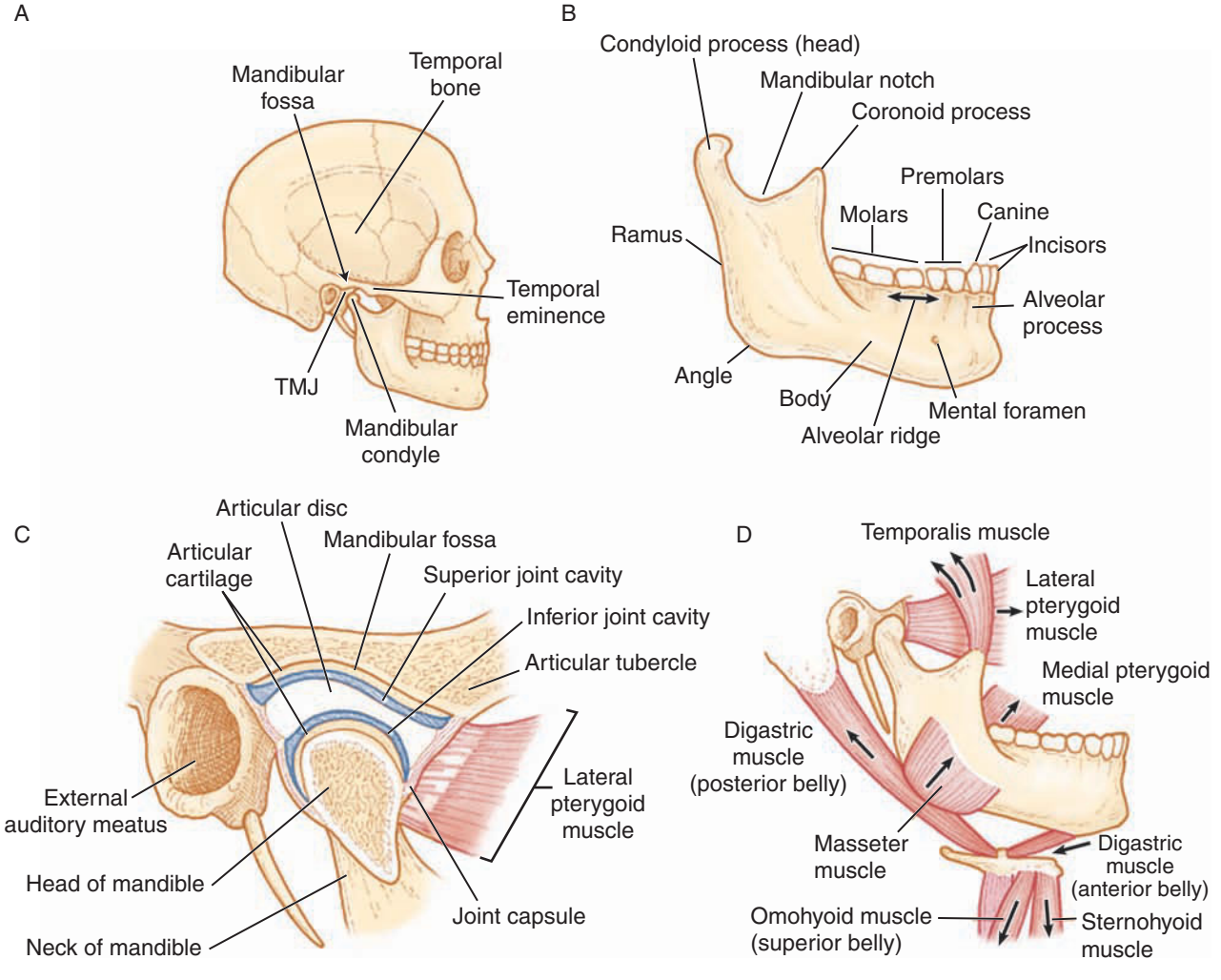


FIGURE 183-1. Anatomy. **A.** Lateral view of the head and temporomandibular joint. **B.** Anatomy of the mandible. **C.** Sagittal section through the temporomandibular joint. **D.** The attachment of the muscles of mastication to the mandible. The arrows represent the direction of pull of the muscles.

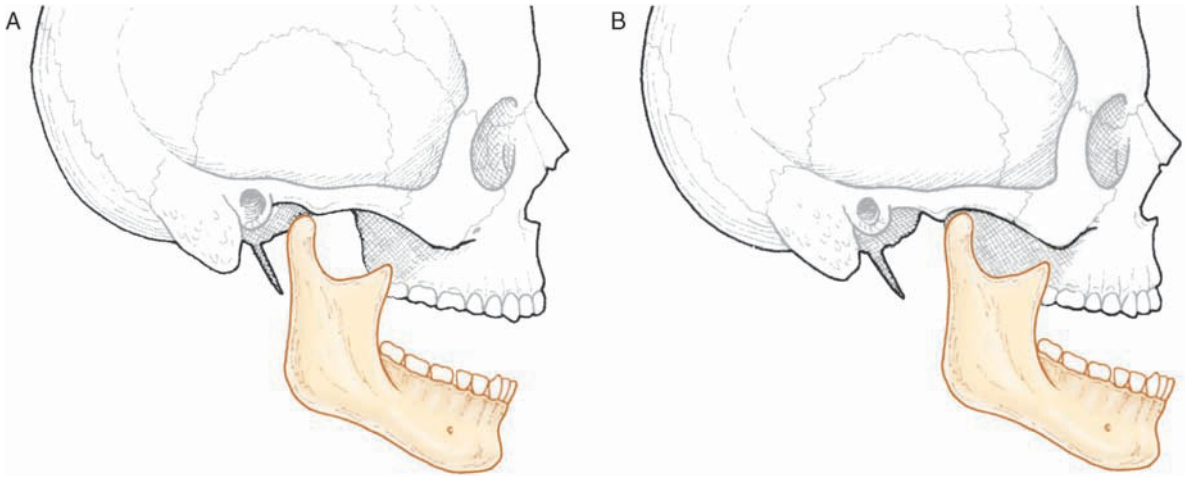


FIGURE 183-2. Anatomic relationships of the mandible. **A.** The fully opened mandible. **B.** An anterior TMJ dislocation.

TMJ dislocations are commonly anterior, but may be in any direction. Anterior TMJ dislocations may occur spontaneously in normal individuals and can occasionally reduce spontaneously. Dislocations of the TMJ are usually bilateral, but can occur unilaterally. Posterior, superior, and lateral dislocations are much more rare. They are seen in the context of direct trauma to the mandible, with or without an associated mandible fracture, cervical spine fracture, or a skull fracture.[6,7]

The diagnosis can often be made clinically in a cooperative patient with a nontraumatic history. The patient will present in pain with an open mouth, protruding mandible, and malocclusion. A unilateral dislocation will cause the mandible to protrude toward the nondislocated side. A depression, both palpable and visible, will be noted in the preauricular area. The mandible appears symmetrical in bilateral anterior dislocations and deviated to the opposite side of the dislocation in the case of a unilateral anterior dislocation.

Mandibular radiographs are indicated when trauma is involved to rule out an associated fracture. The dislocation is often best seen on the Panorex view of the mandible. TMJ views, if available, are also useful. Computed tomography (CT) scanning is warranted if an associated basilar skull fracture, intracranial injuries, or facial fractures are suspected.

INDICATIONS

Attempt to reduce a closed anterior TMJ dislocation without a concomitant mandible fracture in an alert, cooperative, and consenting patient.

CONTRAINDICATIONS

Mandibular dislocations that are open, superior in direction, lateral in direction, or posterior in direction require an Oral Surgeon or Otolaryngology consultation prior to reduction attempts. Dislocations, regardless of the direction, associated with mandible fractures require consultation prior to reduction attempts. The inability to reduce an anterior mandible dislocation by the closed method requires consultation and reduction under general anesthesia. Patients presenting with cranial nerve injuries associated with the dislocation require emergent consultation prior to the reduction.

EQUIPMENT

- 25 gauge needle
- 3 mL syringe
- Gauze 4 × 4 squares or rolls
- Gloves
- Povidone iodine or chlorhexidine solution
- Local anesthetic solution without epinephrine
- Equipment and supplies for procedural sedation

PATIENT PREPARATION

Explain the procedure, its risks, and benefits to the patient and/or their representative. Obtain a signed informed consent for the procedure. Place the patient sitting in a multipositional procedure chair with a solid headrest to support their head. Alternatives include placing the patient supine on a gurney or in a chair with an assistant standing behind the patient to stabilize their head (**Figure 183-3**).

The mandible can often be reduced without anesthesia. This is not recommended. **Adequate analgesia and muscle relaxation will allow easier manipulation of the mandible back into its anatomic position.** Strongly consider the use of parenteral

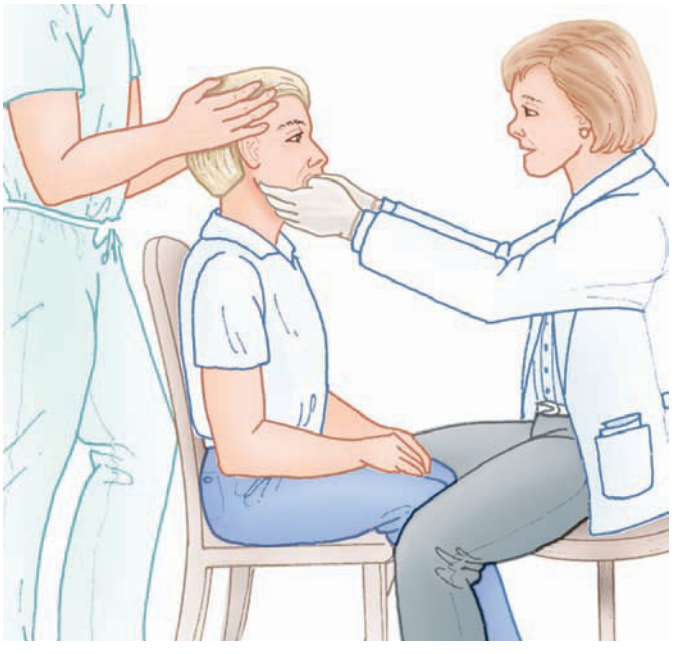


FIGURE 183-3. Alternative positioning of the patient.

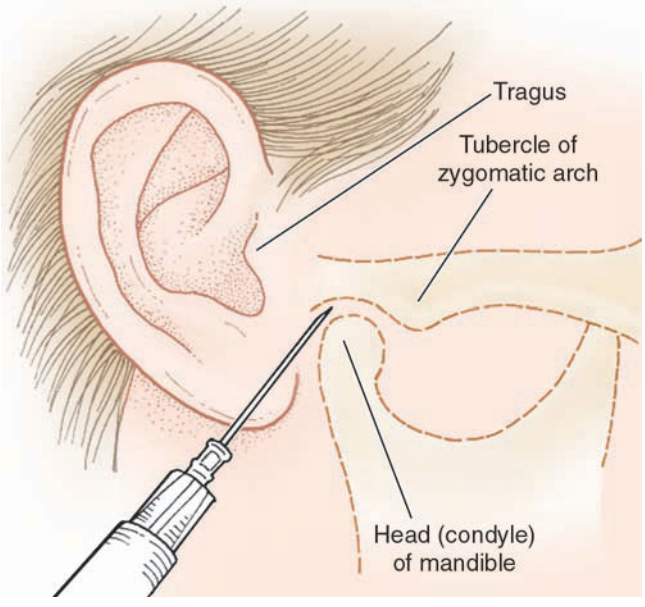


FIGURE 183-4. Anesthesia of the temporomandibular joint. Insert the needle 2.5 cm anterior to the tragus of the auricle and just above the mandibular condyle.

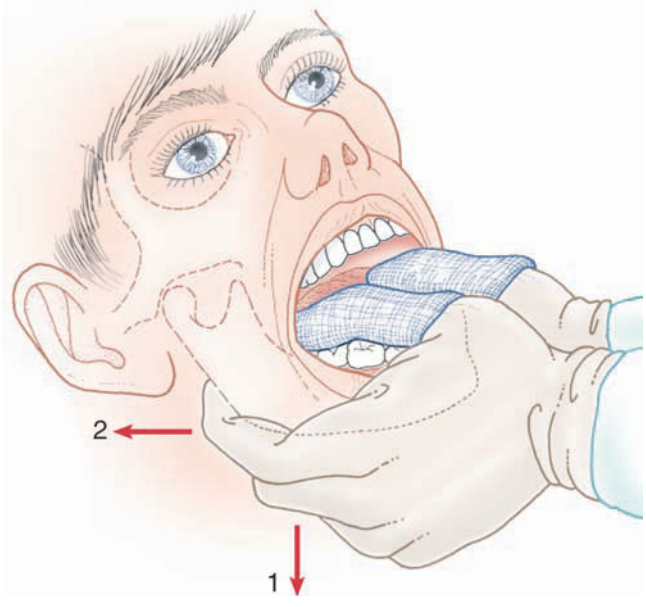


FIGURE 183-5. Proper thumb and hand placement for the reduction of an anteriorly dislocated mandible. Apply downward pressure with the thumbs (1) followed by posteriorly directed pressure (2) to reduce the dislocation.

analgesics, sedatives, and/or muscle relaxants. Procedural analgesia and sedation may be required to overcome the patient's pain and masticatory muscle spasm. This is especially true to relax the muscles of mastication and allow reduction if the mandible has been dislocated for more than 6 to 8 hours. Refer to Chapter 129 for the complete details regarding procedural analgesia and sedation.

An alternative, or adjunct, to the administration of parenteral medications is to inject local anesthetic solution into the TMJ space (**Figure 183-4**). This injection is simple, quick, and relieves significant discomfort. Locate the depression 2.5 cm anterior to the tragus of the pinna and just above the head (condyle) of the mandible. This is the location of the TMJ space. Clean the skin of any dirt and debris. Apply povidone iodine or chlorhexidine solution to the skin over the TMJ space and allow it to dry. Insert a 25 gauge needle perpendicular to the skin and directed medially. Advance the needle 0.5 cm and into the TMJ space. Inject 1 mL of local anesthetic solution without epinephrine. Inject the contralateral TMJ space if the dislocation is bilateral. Consider injecting the contralateral TMJ space in a unilateral TMJ dislocation. The patient may experience pain in their contralateral TMJ from muscle spasm due to the increased pressure on it from the dislocation.

TECHNIQUE

The actual reduction requires no specialized equipment beyond nonsterile gloves and gauze 4 × 4 squares. Position the patient as mentioned previously. Apply gloves and then wrap several layers of gauze around each thumb. **The gauze squares on the thumbs are to prevent possible lacerations to the Emergency Physicians' thumbs when the mandible reduces.**

This technique is the most commonly used method to reduce an anterior TMJ dislocation. Stand or sit in front of the patient (**Figure 183-3**). Place both thumbs into the patient's mouth and onto the most posterior molars of the mandible bilaterally (**Figure 183-5**). Alternatively, the thumbs can be placed on the mandibular ridge immediately posterior to the molars. Wrap the index, middle, ring, and little fingers below the mandible, with the index fingers behind the angles of the mandible (**Figure 183-5**). Slowly apply downward and backward pressure to allow the muscles of mastication to stretch and overcome the muscle spasm (**Figure 183-5**). The downward pressure releases the mandibular condyle from the articular eminence of the temporal bone. Instruct the patient to further open their jaw to accentuate the deformity. This may disengage the impacted mandibular condyle from the anterior articular eminence of the TMJ. The masseter muscle will cause a rapid and sudden closing of the patient's jaw when the condyle of the mandible snaps back and over the articular eminence.[8]

ALTERNATIVE TECHNIQUES

Numerous alternative techniques have been developed to reduce a TMJ dislocation. One technique is to place the thumbs on the buccal aspect of the molars. This avoids the potential injury to the thumbs when the mandible relocates. This method limits the force placed upon the mandible and may not result in a reduction. Another technique requires the physician to stand behind the patient and place downward and backward pressure on the lower molars (**Figure 183-6**). Inducing a gag reflex with a tongue depressor to relax the spasming muscles and free the condyle so it snaps back into anatomical position has been used to successfully reduce an anterior TMJ dislocation.[9] Placing both thumbs on the occlusal surface of the molars on the dislocated side may allow additional pressure to reduce the dislocation that is not reduced using the traditional method.[10] A final method to reduce an anterior TMJ dislocation is the wrist pivot method (**Figure 183-7**). Wrap the index and middle fingers of both hands with gauze. Place both thumbs under the patients' chin and the wrapped fingers of both hands on the patients' premolars and molars (**Figure 183-7**). Apply upward pressure with the thumbs while simultaneously applying downward pressure on the mandible with the fingers to unlock the mandible and reduce the dislocation.

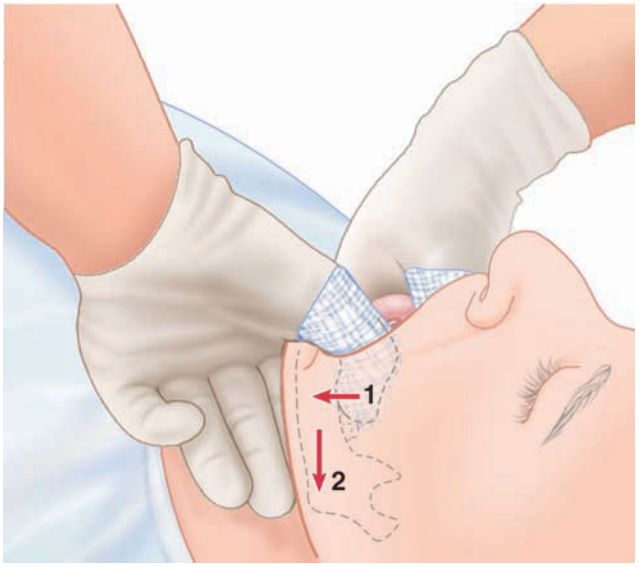


FIGURE 183-6. An alternative method to reduce an anterior TMJ dislocation. The patient is supine. Downward and backward pressure is applied on the molars to reduce the dislocation.

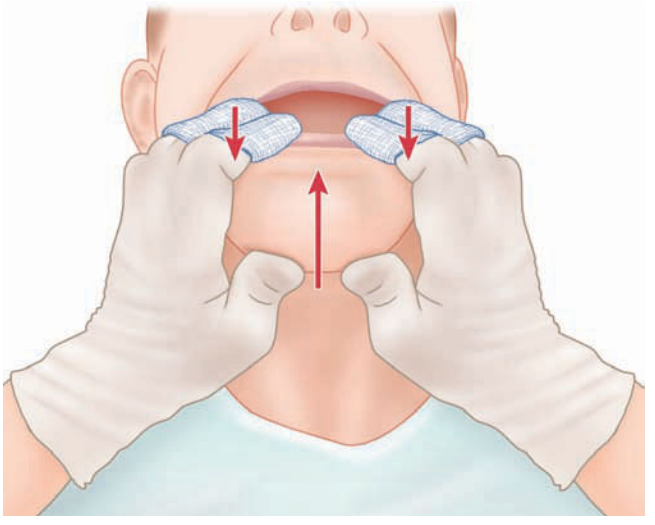


FIGURE 183-7. The wrist pivot method to reduce an anterior TMJ dislocation.

ASSESSMENT

The patient should be able to open and close their mandible without any difficulty after a successful reduction. Postreduction radiographs are not necessary unless a fracture was present or suspected on prereduction radiographs.

AFTERCARE

Refer the patient to an Oral Surgeon or Otolaryngologist within 24 to 48 hours.[11] Chronic or recurrent dislocations may require surgical fixation, intermaxillary wiring, surgical alteration of the articular eminence (e.g., eminectomy or eminoplasty), sclerosing of the TMJ, or the injection of botulinum toxin into the lateral pterygoid muscles.[12] Instruct the patient to avoid excessive jaw opening (over 2 cm), to avoid "gummy" foods and hard foods, and to begin a soft diet to avoid excessive strain on the TMJ. Instruct the patient to support their mandible with their hand when yawning so that it does not open widely and dislocate. Nonsteroidal antiinflammatory drugs will provide adequate analgesia, if needed at all. The application of warm compresses to the TMJ may provide additional pain relief.

A Barton's bandage can be applied around the head to keep the mandibular condyle in its fossa and minimize mandible opening. This bandage is often applied for 2 weeks in patients with chronic dislocations or acute recurrences. Only apply a Barton's bandage in consultation with an Oral Surgeon or Otolaryngologist. Patients often do not like this bandage, are noncompliant, and remove it before follow-up.

COMPLICATIONS

Complications of the initial injury include fractures, intrusion of the mandibular condyle into the external auditory canal (posterior dislocation) or basal skull (superior dislocation), cerebral contusions, facial nerve injuries, and middle or inner ear injuries with hearing and balance impairments. Recurrent dislocations are possible in the future after the mandible has been dislocated once.

The reduction technique is rarely associated with complications. Significant pain after a successful reduction may signify a fracture or articular cartilage avulsion. Fractures are rarely iatrogenic. They are often present on initial radiographs but not identified until retrospectively examined. A fracture may be displaced during the reduction. The Emergency Physician's thumbs can be crushed and/or lacerated by the patient's teeth.

Closed reduction may be unsuccessful. The patient will require reduction under general anesthesia. This is particularly true of chronic dislocations, dislocations for longer than 12 hours, and recurrent dislocations. An avulsed articular cartilage or articular disc may be interposed and prevent closed reduction.

SUMMARY

Uncomplicated anterior mandible dislocations can be managed with basic anesthesia and sedation techniques. A gentle and progressive reduction will allow the mandibular condyle to relocate into the TMJ space without significant complications. Dislocations that are complicated by fractures, overlying skin damage, nonanterior in location, or have associated neurological injuries require an emergent consultation and reduction by an Oral Surgeon or an Otolaryngologist.

184 Ingrown Toenail Management

Jeff Schaider

INTRODUCTION

An ingrown toenail (onychocryptosis) is a common affliction that can occur in any toe. It most commonly afflicts the great toe, occurring when the lateral edge of the nail plate penetrates the soft tissue of the lateral nail fold. There are three stages of ingrown toenails. Stage I includes erythema, slight edema, and pain when pressure is applied to the lateral nail fold. Stage II includes the stage I findings plus signs of infection and a purulent drainage. Stage III is a magnification of the two previous stages with the addition of granulation tissue formation and lateral nail fold hypertrophy. Most ingrown toenails can be definitively managed in the Emergency Department by the Emergency Physician.

ANATOMY AND PATHOPHYSIOLOGY

The toenail usually does not grow into the soft tissue. Instead, the soft tissue overgrows and obliterates the nail sulcus in response to external pressure and irritation.[1–5] The toenail itself is usually normal, although some older patients may have incurved nails. The causes of an ingrown toenail are multiple and include trimming the toenails too short, using sharp tools to clean the toenail gutters, wearing improperly fitted (too tight) shoes, rotated digits, and bony deformities. Improper toenail trimming can result in a small nail spike on the lateral aspect of the toenail (**Figure 184-1**). As the toenail continues to grow, the spike will irritate the soft tissue causing the end result of chronic inflammation and an infection.

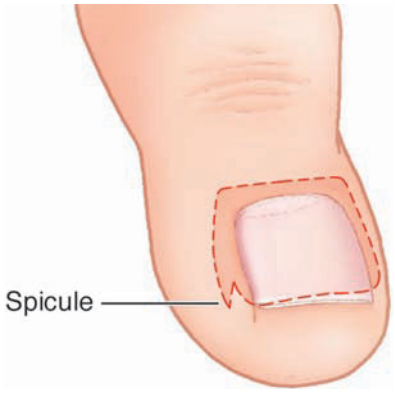


FIGURE 184-1. An ingrown toenail. Note the nail spicule and the overgrowth of the adjacent soft tissues.

INDICATIONS

Warm soaks, oral antistaphylococcal antibiotics, and shoes with an adequate toe box may be curative in mild cases (stages I and II). Elevate and maintain the nail edge above the soft tissues or trim the edge of the nail (**Figure 184-2**). More severe cases (stage III) require partial toenail removal. Have a lower threshold for toenail removal in diabetic patients to prevent a more severe infection from forming. Other indications for removal of an ingrown toenail include chronic or recurring ingrown toenails, failure of conservative therapy, fungal infections of the toenail, and severe pain.

CONTRAINDICATIONS

The only relative contraindication to toenail removal is a decreased vascular supply to the toe. Trim the toenail edge if possible and minimize any injury to the adjacent soft tissues. These patients require an evaluation by a Podiatrist and a Vascular Surgeon to minimize future complications.

EQUIPMENT

General Supplies

- Povidone iodine or chlorhexidine solution
- Sterile drapes
- Sterile gloves
- Curved hemostat
- Freer or another periosteal elevator
- Cotton
- Scissors or nail splitter
- Tourniquet or sterile Penrose drain
- Curette
- Topical antibacterial ointment
- 4 × 4 gauze squares
- Tape, 1 inch wide

Chemical Matrix Ablation

- Above listed general supplies
- Cotton-tipped applicators
- 89% phenol solution
- 70% isopropyl alcohol solution
- Silver nitrate matchsticks

Surgical Matrix Excision

- Above listed general supplies
- #15 scalpel blade on a handle
- Needle driver
- 5-0 nylon suture

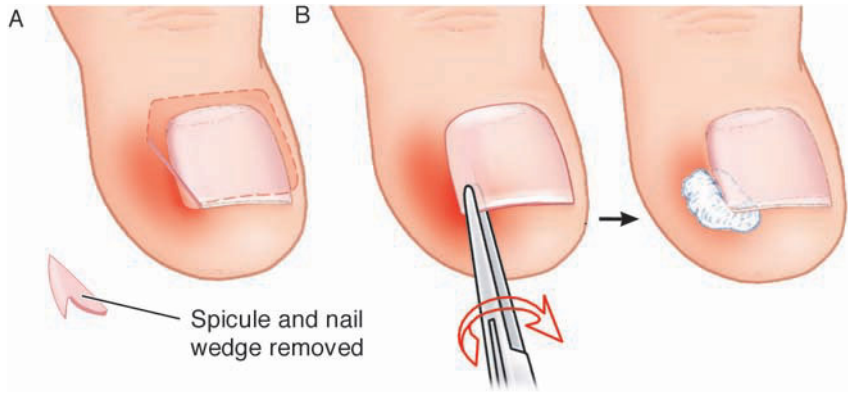


FIGURE 184-2. Management of stage I and II ingrown toenails. **A.** Trimming the lateral nail edge. **B.** Elevation of the lateral nail edge.

Nail Matrix Cauterization

- Above listed general supplies
- Electrocautery unit, disposable

PATIENT PREPARATION

Explain the risks, benefits, complications, and aftercare of the procedure to the patient and/or their representative. Obtain an informed consent for the procedure. Place the patient supine on a gurney or procedure table. Flex the patient's hip and knee so that the plantar surface of their foot is flat against the gurney. An overhead light source is essential to provide appropriate illumination. Perform a digit block using aseptic technique. Refer to Chapter 126 regarding the details of digital anesthesia. While rare, an occasional nervous or uncooperative patient may require an intravenous anxiolytic or even procedural sedation prior to the digital anesthesia. The young child will require physical restraint with a sheet or commercial device (e.g., Papoose board) and procedural sedation. Apply povidone iodine or chlorhexidine solution over the involved toe and allow it to dry. Apply a sterile drape to delineate a sterile field.

TECHNIQUES

Manage early ingrown toenails (stages I and II) with conservative therapy. Remove the medial or lateral one-quarter of the toenail along with the germinal matrix at the base of the toenail for stage III ingrown toenails. The entire nail may be removed if both sides are ingrown. It may be necessary to prevent any new nail growth in the area once the nail has been removed. Three options include chemical ablation of the matrix, surgical excision of the matrix, and electrocautery of the nail matrix. The treatment of the pediatric patient is no different than the adult patient.

TOENAIL ELEVATION AND TRIMMING

Ingrown toenails in the first two stages can be trimmed or elevated to relieve the patient's symptoms (**Figure 184-2**). Trim the distal edge of the nail plate to remove the ingrown portion (**Figure 184-2A**). Remove the distal one-third to one-half of the nail plate. Smooth the nail plate edge so that it will grow out freely. Remove any debris along the lateral nail fold (paronychia) or nailbed.

An alternative is to elevate the edge of the nail plate (**Figure 184-2B**). Insert the jaws of a hemostat so that one is above and the other is below the ingrown nail edge. Clamp the jaws of the hemostat onto the nail plate. Slowly rotate the hemostat to elevate the edge of the nail plate above the adjacent soft tissues (**Figure 184-2B**). Insert a wad of cotton under the nail edge to maintain it above the adjacent soft tissues. Release the hemostat. Teach the patient and/or their representative this technique so that they can replace the cotton wad daily until the nail plate grows out and past the soft tissues. The main disadvantages of this technique are that the patient or their representative must elevate the nail edge and replace the cotton daily as well as maintain the nail plate elevation for 3 to 6 weeks. This can be quite a challenge, if it is even possible, in the young child.

TOENAIL REMOVAL

Apply a tourniquet along the base of the afflicted toe (**Figure 184-3A**). The tourniquet may be a commercially available product for the digits or a Penrose drain. Refer to Chapter 104 for several examples of digital tourniquets. Separate the nail from the underlying nail bed. Grasp and stabilize the toe with the nondominant hand. If available, use a Freer periosteal elevator to lift the soft tissue off the lateral and proximal toenail. The elevator can also be used to separate the nail plate from the underlying nail bed, but this is optional. Insert one jaw of a curved hemostat under the distal toenail margin and along the medial or lateral side of the nail plate, depending upon which side is ingrown (**Figure 184-3B**). Advance the hemostat until the jaw is at the proximal corner of the involved side of the ingrown nail (**Figure 184-3C**). Grasp the nail by clamping the jaws of the curved hemostat on the toenail.

Dislodge the ingrown nail from the skin, the nail bed, and the nail matrix by rotating the hemostat away from the ingrown portion (**Figure 184-3D**). Continue to rotate the hemostat until the entire ingrown portion of the nail is separated from the skin, the nail bed, and the nail matrix. A large and complete portion of the underlying toenail will emerge from under the skin fold (**Figure 184-3E**). The nail plate might have broken and a significant piece may still be under the inflamed skin border if only a small amount of the nail is visible after rotating the hemostat. Expose this area and use the curved hemostat to remove any remaining nail plate.

Cut away the ingrown portion of the toenail, from distal to proximal, with a heavy scissors or nail splitter (**Figure 184-3F**). **Make sure that the points of the scissors or nail splitter are facing upward to prevent injury to the nail bed.** The granulation tissue overlying the nail bed must be removed to prevent another ingrown toenail (**Figure 184-3G**). Trim the granulation tissue using a #15 scalpel blade or a curette (**Figure 184-3H**). Remove the tourniquet and control any bleeding.

Some Emergency Physicians prefer to perform the above-described procedural steps in a slightly different order. Apply a tourniquet along the base of the afflicted toe. Grasp and stabilize the toe with the nondominant hand. If available, use a Freer periosteal elevator to lift the soft tissue off the lateral and proximal

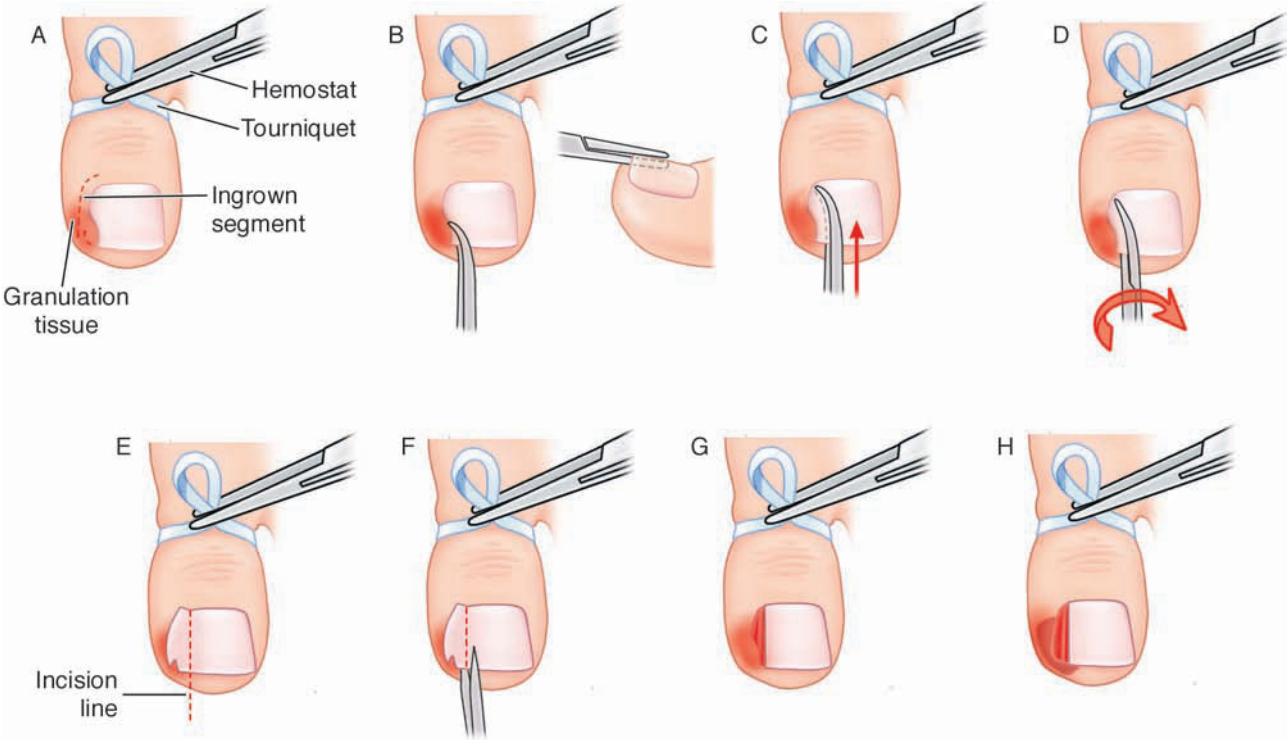


FIGURE 184-3. Ingrown toenail removal. **A.** Placement of a tourniquet. **B.** Place one jaw of the hemostat above the nail plate and one jaw beneath the nail plate. **C.** Advance the hemostat toward the base of the nail plate. **D.** Rotate the hemostat to elevate the edge of the toenail. Be sure to elevate and expose the proximal nail segment at the base of the nail in the region of the nail matrix. **E.** Determine where to cut the nail plate. **F.** Cut the nail plate with a heavy scissors or a nail splitter. **G.** The lateral one-fourth of the nail plate has been removed. **H.** The granulation tissue has been trimmed away.

toenail. The elevator can also be used to separate the nail plate from the underlying nail bed, but this is optional. Cut away the ingrown portion of the toenail, from distal to proximal, with a heavy scissors or nail splitter. **Make sure that the points of the scissors or nail splitter are facing upward to prevent injury to the nail bed.** Insert one jaw of a curved hemostat under the distal toenail margin and along the medial or lateral side of the nail plate, depending upon which side is ingrown. Advance the hemostat until the jaw is at the proximal corner of the involved side of the ingrown nail. Grasp the nail by clamping the jaws of the curved hemostat on the toenail. Dislodge the ingrown nail from the skin, the nail bed, and the nail matrix by rotating the hemostat away from the ingrown portion. Continue to rotate the hemostat until the entire ingrown portion of the nail is separated from the skin, the nail bed, and the nail matrix. A large and complete portion of the underlying toenail will emerge from under the skin fold. The nail plate might have broken and a significant piece may still be under the inflamed skin border if only a small amount of the nail is visible after rotating the hemostat. Expose this area and use the curved hemostat to remove any remaining nail plate. Remove the granulation tissue overlying the nail bed to prevent another ingrown toenail using a #15 scalpel blade or a curette. Remove the tourniquet and control any bleeding.

CHEMICAL NAIL MATRIX ABLATION

Chemical ablation of the nail matrix with phenol has several advantages.[6,7] The procedure is easy, quick, and simple to perform. No special equipment is required. The use of an incision or electrocautery, and their associated complications, is avoided.

Chemical ablation of the matrix with phenol is the author's preferred method. Remove any obvious remaining nail matrix and nail bed with a blunt instrument such as a curette. **Completely dry the field of any blood and fluid.** Dip a cotton-tipped applicator in a phenol solution. **Avoid excessive saturation of the swab.** Introduce the swab between the roof and the root matrix (i.e., under the eponychium) of the removed nail section (**Figure 184-4**). Rotate the cotton-tipped applicator slowly for 30 seconds (20 seconds for children) and then remove it. Repeat the phenol application two additional times using a fresh phenol-soaked cotton-tipped applicator.

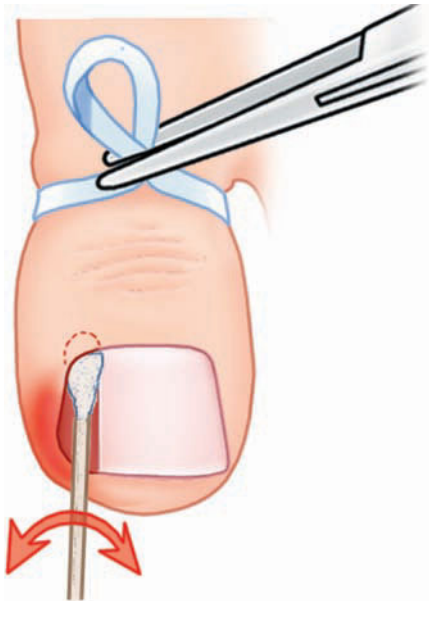


FIGURE 184-4. Chemical nail matrix ablation.

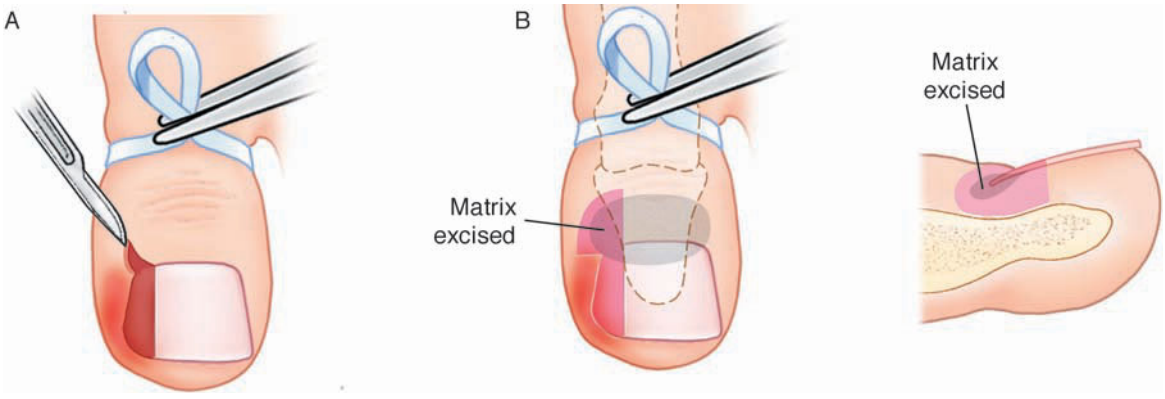


FIGURE 184-5. Surgical nail matrix ablation. **A.** An incision in the eponychium to expose the matrix. **B.** Removal of the matrix. The pink shading represents the areas of tissue to be removed.

Do not allow the phenol to contact normal skin. Immediately wipe off any phenol that contacts the skin. The phenol will turn the tissue pale or gray. Dip a cotton-tipped applicator in isopropyl alcohol. Swab the area in similar fashion as the phenol swab. The isopropyl alcohol neutralizes the necrotizing effect of the phenol.[6–8]

An alternative to phenol is silver nitrate. The preferred technique is a phenol matrixectomy. Silver nitrate may be used if phenol is not available. The main disadvantage of silver nitrate is that it turns the tissues black. Insert the silver nitrate matchstick under the eponychium (**Figure 184-4**). Roll the matchstick around for 5 to 10 seconds to ablate the matrix.

SURGICAL NAIL MATRIX ABLATION

Surgical excision of the toenail matrix requires more time and experience than chemical ablation.[4] This technique is usually reserved for the Podiatrist or the Orthopedic Surgeon. An experienced Emergency Physician can easily perform this technique in the Emergency Department. Expose the nail matrix by retracting the adjacent overlying skin. Make an oblique proximal incision from the proximal corner of the nail if necessary to fully expose the nail matrix in the ingrown area (**Figure 184-5A**). Make an incision with a #15 scalpel blade to separate the nail matrix to be removed from the remaining nail and matrix (**Figure 184-5B**). Grasp the corner of the matrix with a hemostat. Use the scalpel blade to separate the matrix from the underlying tissues. Remove the nail matrix. Do not forget to remove the dorsal and deep matrix that envelops the base of the toenail under the skin fold. Remove any remaining nail matrix and nail bed with a curette. Close the skin incision with 5-0 nylon suture.

ELECTROCAUTERY NAIL MATRIX ABLATION

Electrocauterization of the nail matrix is rapidly performed but requires access to an electrocautery instrument. Apply electrocautery between the roof and the root matrix of the removed nail section to destroy the matrix in this area. Avoid excessive burning of the surrounding tissues. This technique can cause significant damage to normal tissue and should be reserved for the Podiatrist or the Orthopedic Surgeon.

AFTERCARE

Apply a topical antibiotic ointment and a small compressive gauze dressing over the toe. The patient requires follow-up in 24 to 48 hours for a dressing change and evaluation of the wound. Saturate the dressing with saline or sterile water to make the removal process less painful. Instruct the patient to elevate the foot for the first 2 to 3 days to prevent bleeding and edema. Large shoes, sandals, or cast shoes are best used in the immediate postprocedure days. The use of oral antibiotics is restricted for patients who are immunocompromised, have an associated cellulitis, or whose vascular supply to the toe is decreased. Prescribe nonsteroidal anti-inflammatory drugs supplemented with narcotic analgesics as needed for pain control. Instruct the patient to return to the Emergency Department immediately if they experience increased pain, develop a fever, a purulent discharge, or notice increased redness of the toe or foot. Demonstrate the proper method to trim toenails (**Figure 184-6**).

Chemical ablation of the matrix with phenol induces a chemical burn. The patient may experience a serous drainage for a few days up to 2 weeks.[1] The use of nonsteroidal anti-inflammatory drugs can limit the duration and the amount of drainage.[1] Instruct the patient to soak the foot in warm water three times a day for 10 to 15 minutes each time. Apply a topical antibiotic ointment after each soak. Prolonged drainage may be due to a superficial infection and requires evaluation.

COMPLICATIONS

The most common complication is the persistence of toenail horns or spikes due to incomplete ablation of the nail and matrix. These can be managed with nail trimming if mild or en bloc excision of the area if severe. Ensure that the portion of the nail is completely removed and that no fragments remain under the nail folds. Use care to not lacerate the nail bed when elevating or cutting the nail plate. Lacerations of the nail bed can bleed significantly, cause chronic pain once healed, and result in a deformed

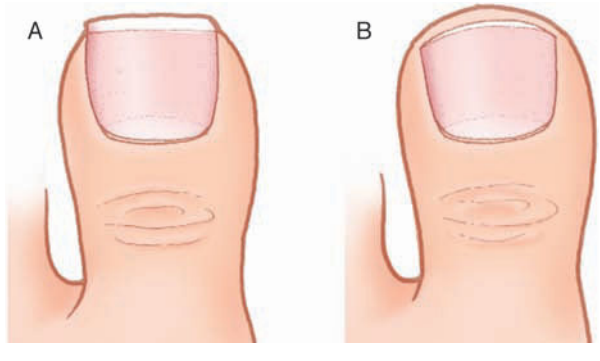


FIGURE 184-6. The technique of toenail trimming. **A.** Correct. **B.** Incorrect.

nail. Repair any nail bed lacerations. Refer to Chapter 104 for a complete discussion regarding nail bed repair.

Phenol will deteriorate if it is exposed to air or light. Store the phenol solution in a cool, dark place. Replace the solution frequently. The field must be dry before applying phenol. Phenol mixed with blood results in an alteration of the pH of the phenol, decreasing its effectiveness, and turning the tissues black. The ingrown toenail will recur if the phenol is old or exposed to light before it is used, if the phenol is not properly applied, or if fragments of the toenail or matrix remain. The patient may experience a chemical burn if too much phenol is applied or it is not neutralized with isopropyl alcohol.

SUMMARY

An ingrown toenail can be managed easily, quickly, and definitively in the Emergency Department. Perform a partial toenail removal on patients with clinical stage III toenails characterized by pain, overgrowth of inflamed and infected tissue, and drainage. Remove the lateral or medial one-quarter of the nail. Apply phenol solution to the nail matrix to prevent further growth of the nail and a recurrence.

185 Toe Fracture Management

George Chiampas and Steve Zahn

INTRODUCTION

Toe fractures result from a direct blow (from an object falling on an unprotected toe) or a "stubbing" injury.[1] The incidence of toe fractures has been estimated at 140 cases per 100,000 people per year.[2] The significance of toe fractures depends upon which digit is affected. Most important is the great toe, as it is the main propulsive segment of the forefoot. Many patients do not present to the Emergency Department as they consider the injury trivial. Those who do present often do so because of severe pain and/or a large subungual hematoma.

Toe fractures are common injuries that rarely require surgical treatment. They may be completely and definitively managed in the Emergency Department. Most toe fractures require only a properly placed splint. An intraarticular fracture with severe displacement of the great toe may require open reduction and internal fixation to prevent deformity and arthritis in the joint. Complications of a toe fracture include damage to the articular cartilage, hypermobility of fracture segments, malposition, and malunion.

ANATOMY AND PATHOPHYSIOLOGY

The foot can be anatomically divided into the forefoot, the midfoot, and the hindfoot (**Figure 185-1**). The forefoot is composed of the metatarsals and their respective phalanges. Sesamoid bones often lie along the plantar surface of the metatarsal heads. The sesamoid bones of the great toe lie in a groove on the plantar surface of the metatarsal head and within the tendon of its respective flexor hallucis brevis muscle belly.

Each toe has two pairs of digital nerves that course along the superior and inferior aspects of the digit. The digital artery and vein accompany the nerve. The great toe often receives superficial cutaneous nerves along its dorsal surface.

Anteroposterior and oblique radiographic views will demonstrate most fractures. Lateral views may be necessary to identify phalangeal fractures of the great toe. Obtain the lateral projection with toes 2 through 5 passively dorsiflexed to avoid overlap. An alternative method to achieve adequate radiographic views of the great toe in the lateral projection is to insert dental X-ray film between the first and second toes and direct the X-ray beam laterally.[3]

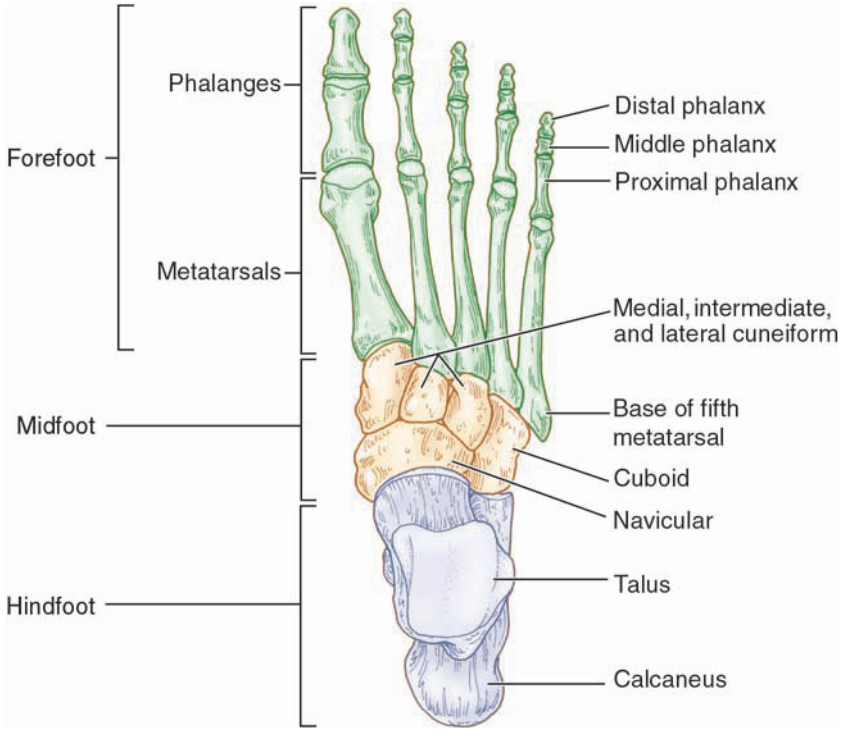


FIGURE 185-1. The bony anatomy of the foot.

INDICATIONS

The indications for simple splinting of toe fractures are to relieve pain and allow for healing. The management of closed fractures depends upon the digit involved. Manage nondisplaced phalangeal fractures of the great toe with buddy taping to the adjacent normal toe as a splint. Mildly displaced phalangeal fractures of the great toe can be reduced using local anesthesia, gentle traction, and buddy taping. Manage nondisplaced phalangeal fractures of toes 2 through 5 with buddy taping. Mildly displaced phalangeal fractures of toes 2 through 5 can be reduced using local anesthesia, gentle traction, and buddy taping. Exact anatomic reduction of toes 2 through 5 is not a concern as long as the general alignment of the toe is satisfactory.[4]

CONTRAINDICATIONS

Consult an Orthopedic Surgeon or Podiatrist for open fractures, extensive crush injuries to the forefoot, injuries with the potential to develop a compartment syndrome, intraarticular fractures, or severely displaced toe fractures (especially of the great toe). The incidence of arthritis and malunion is quite high with these injuries. Fractures of multiple toes on one foot cannot be treated with buddy taping.

EQUIPMENT

- Povidone iodine or chlorhexidine solution
- Local anesthetic solution without epinephrine
- 25 or 27 gauge needle
- 5 mL syringe
- 2 × 2 gauze squares or a soft corn pad
- Finger trap, optional
- Bunion pad
- Metatarsal bar or wooden tongue depressors
- Permeable tape, ½ inch wide
- Fluoroscopy unit, optional

The use of a fluoroscopy unit, if available, will make the reduction technique much easier and quicker. It allows for the immediate evaluation of the reduction, multiple reduction attempts without the waiting time to obtain plain radiographs after each reduction attempt, and the reduction to be completed and splinted before the anesthesia wears off.

PATIENT PREPARATION

Explain the risks, benefits, and potential complications of the procedure to the patient and/or their representative. Obtain a signed informed consent for the procedure. Obtain plain radiographs or a fluoroscopic image to assess the severity of the injury. Place the patient sitting upright so that the affected foot is suspended above the floor in order to allow adequate space for manipulation and splinting of the toe. An alternative is to place the patient supine with their hip and knee flexed, so that the sole of the foot is flat against the gurney. If a subungual hematoma is present, it should be drained to relieve the pressure on the nail bed and improve patient comfort. Refer to Chapter 102 for the complete details regarding the management of a subungual hematoma.

The use of anesthesia is Emergency Physician and patient dependent. Buddy taping of nondisplaced fractures of toes 1 through 5 or minimally displaced fractures of toes 2 through 5 requires no anesthesia. Consider performing a digital block if the patient is significantly tender and a displaced fracture must be reduced. Clean the web spaces of the affected toe of any dirt or debris. Apply povidone iodine or chlorhexidine solution to the web space and surrounding skin. Allow the solution to dry. Arm a 5 mL syringe containing local anesthetic solution (e.g., lidocaine or bupivacaine) without epinephrine with a 25 or 27 gauge needle.

Insert the needle into the dorsal surface of the web space. Aim the needle 45° downward and toward the posterior aspect of the phalanx (**Figure 185-2A**). Advance the needle while injecting 1 to 2 mL of local anesthetic solution. **Do not puncture the plantar surface of the toe.** The local anesthetic solution will easily inject into the areolar tissue of the web space. Withdraw the needle. Shift the needle so that it is aimed along the dorsal surface of the toe (**Figure 185-2B**). Advance the needle while injecting 1 to 2 mL

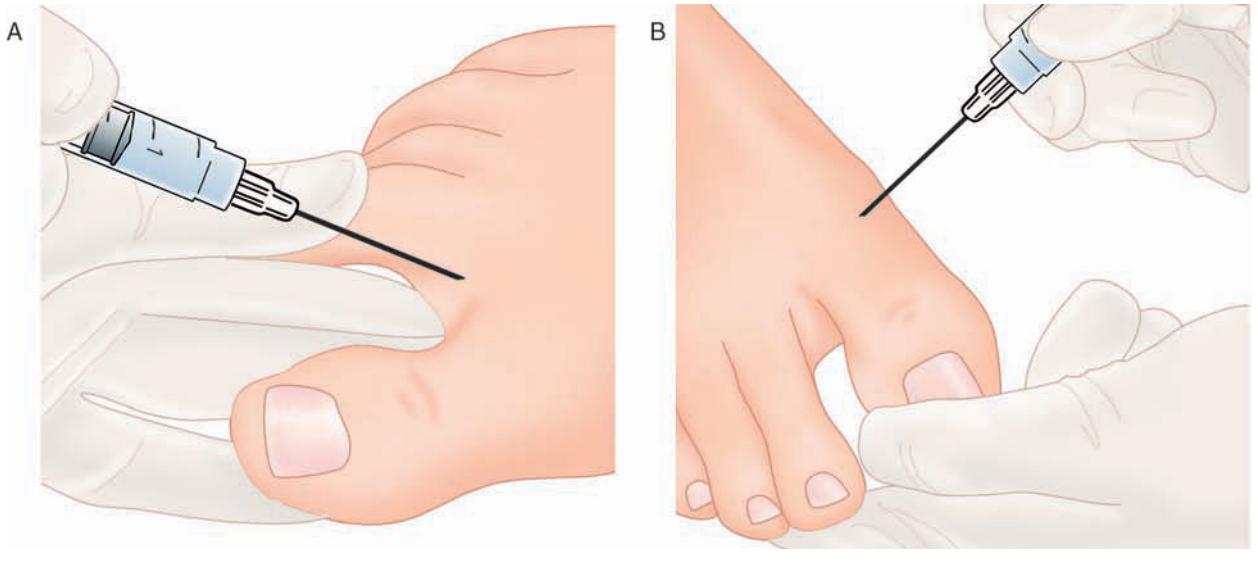


FIGURE 185-2. Digital block of the toe. **A.** Needle position and direction for infiltration of the lateral surface. **B.** Needle position and direction for infiltration of the dorsal surface.

of local anesthetic solution over the dorsal surface. Completely withdraw the needle. Inject local anesthetic solution into the contralateral side of the affected toe in the same way as in the first web space. Allow 5 to 10 minutes for the block to take effect. Reassess the patient to determine whether the block was successful. An additional injection along the plantar surface of the toe may be required to provide total anesthesia, especially of the great toe. Refer to Chapter 126 for additional details regarding digital anesthesia.

An alternative is to perform a hematoma block by injecting local anesthetic solution directly into the fracture site. Clean and prepare the skin. Insert the needle over the fracture site. Advance the needle until it enters the fracture. Aspirate a small amount of blood to confirm that the tip of the needle is properly positioned within the fracture. Inject 2 to 3 mL of local anesthetic solution into the hematoma. Allow 5 to 10 minutes for the local anesthetic to take effect before proceeding. Refer to Chapter 125 for a more complete discussion of a hematoma block.

TECHNIQUES

FRACTURE REDUCTION

Closed reduction can be achieved with the use of a finger trap or straightforward axial traction. Place the anesthetized affected toe in the finger trap (**Figure 185-3**). Elevate and suspend the foot by the affected toe in the finger trap (**Figure 185-3**). Allow the weight of the leg to slowly distract the fracture site. Reduce the fracture (**Figure 185-4**). Grasp the forefoot near the base of the affected toe or fractured phalanx with the nondominant index finger and thumb. Grasp the distal aspect of the fractured phalanx with the dominant index finger and thumb. Apply distally directed inline traction with the dominant hand and simultaneous countertraction with the nondominant hand to distract the fracture site. Remove the toe from the finger trap. Obtain a radiograph or fluoroscopic image to confirm the reduction. Buddy tape the toe to the adjacent toe as described below.

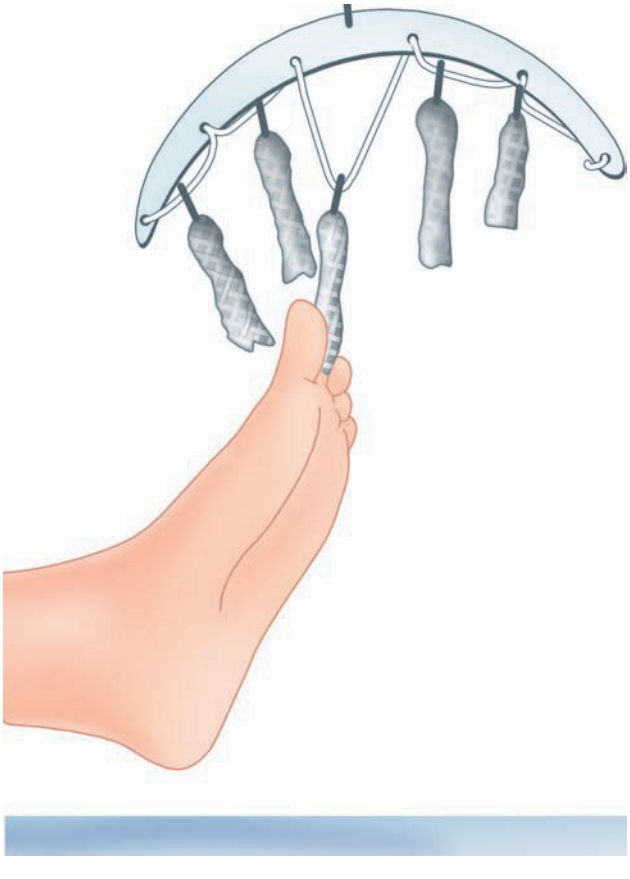


FIGURE 185-3. Use of the finger trap to aid fracture reduction.



FIGURE 185-4. Manual fracture reduction.

The alternative is to reduce the fracture manually without the use of a finger trap (**Figure 185-4**). Grasp the forefoot near the base of the affected toe or fractured phalanx with the nondominant index finger and thumb. Grasp the distal aspect of the fractured phalanx with the dominant index finger and thumb. Apply distally directed inline traction with the dominant hand and simultaneous countertraction with the nondominant hand to distract the fracture site. Reduce the fracture. Obtain a radiograph or fluoroscopic image to confirm the reduction. Buddy tape the toe to the adjacent toe as described below.

BUDDY TAPING

Buddy tape the toe after the reduction (**Figure 185-5**). Place a piece of folded 2 × 2 gauze or a corn pad between the fractured toe and its neighboring toe (**Figure 185-5A**). The gauze or corn pad will prevent maceration and pressure necrosis of the skin. Tape the toes together (**Figure 185-5B**).

ASSESSMENT

Reassess the toe's perfusion by checking the capillary refill time after any attempt at reduction. Obtain a postreduction radiograph or fluoroscopic image to verify proper alignment. Mild to moderate displacement in phalangeal fractures of toes 2 through 5 is quite acceptable as long as the toes are not rubbing together. Repeat the reduction process as necessary to reduce the fracture. Consult an Orthopedic Surgeon or Podiatrist if the fracture cannot be adequately reduced.

AFTERCARE

All toe fractures are persistently painful. They require analgesia and splinting for 2 to 3 weeks. Prescribing nonsteroidal anti-inflammatory drugs (NSAIDs) supplemented with narcotic analgesics has been the standard of care. New research may shift future management from the use of NSAIDs as these medications can delay fracture healing.[5] The patient can apply ice packs for 10 to 15 minutes every 3 hours to help decrease pain and swelling.

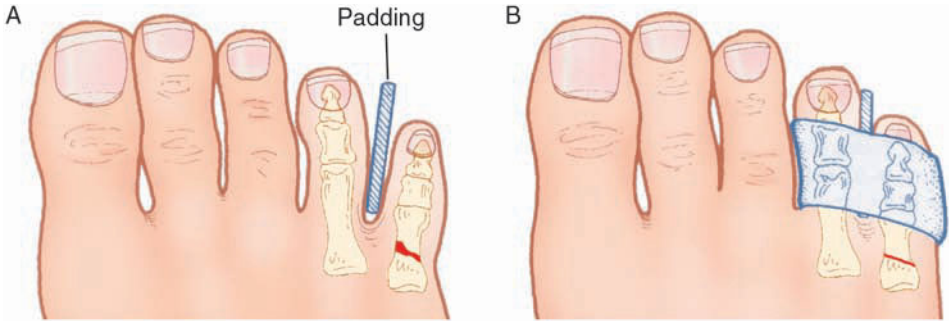


FIGURE 185-5. Buddy taping the fractured toe. **A.** Place gauze or a corn pad between the fractured toe and an adjacent toe. **B.** Tape the toes together.

Provide the patient with a hard-soled shoe, wooden-soled shoe, or Reese orthopedic shoe. It is felt that dorsiflexion of the forefoot in walking causes the most pain in toe fractures.[3] The use of these shoes, as opposed to the patient's own shoes, minimizes pain with walking.

An alternative to the orthopedic shoe is to place a metatarsal bar for patient comfort.[6] Use a commercially available unit or make a metatarsal bar by taping wooden tongue depressors together (**Figure 185-6**).[3] Obtain four tongue depressors and cut one in half (**Figure 185-6A**). Place two tongue depressors side by side (**Figure 185-6B**). Place the third tongue depressor to cover the seam of the adjacent tongue depressors (**Figure 185-6B**). Tape the tongue depressors together to form the longitudinal support (**Figure 185-6C**). Apply the cut tongue depressor to form the transverse support (**Figure 185-6D**). Tape the transverse support to the longitudinal support (**Figure 185-6E**). Apply the metatarsal bar to the sole of the patient's shoe (**Figure 185-7**). Additional support and pain control can be achieved by immobilizing the foot in a short leg walking cast with a toe plate for no more than 1 to 2 weeks if the patient complains of persistent pain.[4]

Instruct the patient to continue weight bearing as tolerated and, when not walking, to elevate the foot above the level of their heart to minimize swelling. Teach the patient how to re-apply the buddy taping splint, as it must be changed every 2 to 3 days for up to 6 weeks. All patients with great toe fractures should follow-up with an Orthopedic Surgeon or Podiatrist within 48 hours for a reevaluation.

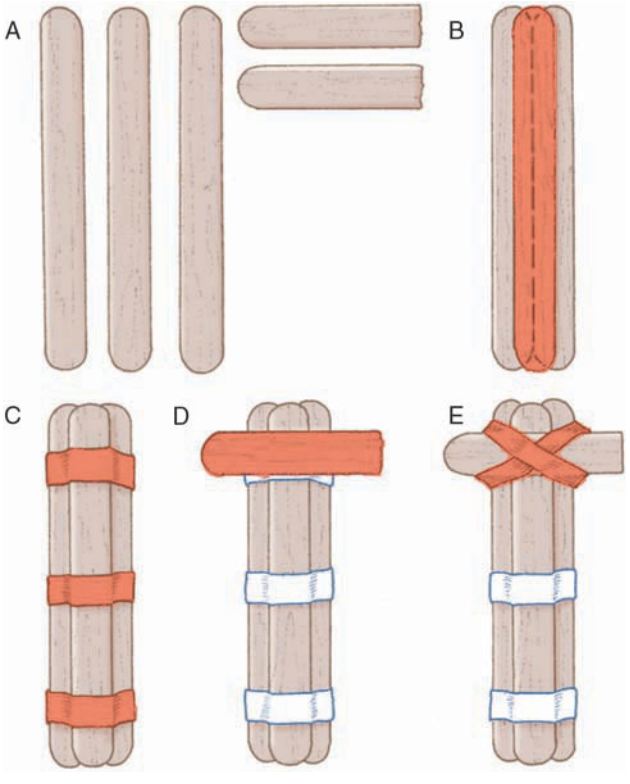


FIGURE 185-6. Fabricating a metatarsal bar from tongue depressors. **A.** Lay out four tongue depressors, one of which is cut in half. **B.** Place two tongue depressors side by side. Place the third tongue depressor to cover the seam between the first two. **C.** Tape the tongue depressors together to form the longitudinal support. **D.** Apply the cut tongue depressor to form the transverse support. **E.** Tape the transverse support to the longitudinal support.

COMPLICATIONS

Long-term sequelae from toe fractures are rare. Persistent angulation at the fracture site with a malunion may result in a "sore area" on the plantar surface of the toe. Refer the patient to an Orthopedic Surgeon or Podiatrist if such areas remain symptomatic and functionally disabling. A simple surgery can correct the problem. Any fractures involving the joint space will result in some degree of arthritis. Warn the patient of this possible complication before they are discharged.

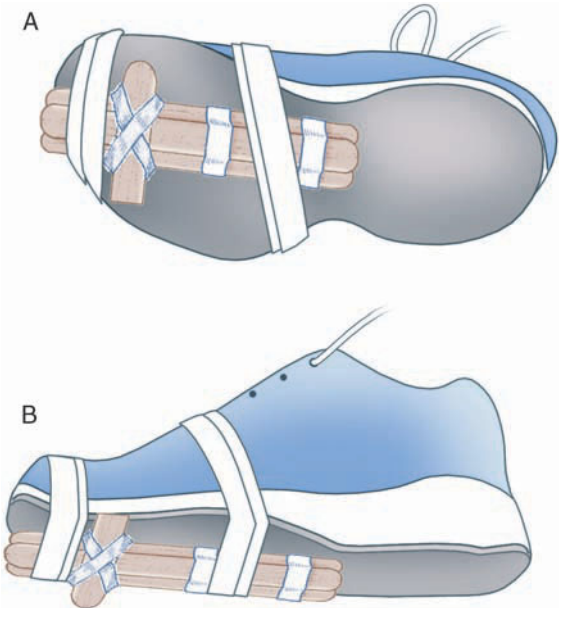


FIGURE 185-7. Application of the metatarsal bar to the patient's shoe. **A.** Inferior view. **B.** Lateral view.

Few complications are associated with the management of toe fractures. Incomplete reduction can result in an angulated toe. Persistent angulation can result in the toe pushing against adjacent toes, skin irritation, and possible skin ulceration. Always place a pad between the toes before buddy taping to prevent irritation, pressure necrosis, ulceration, and maceration of the skin.

SUMMARY

Toe fractures are commonly seen in the Emergency Department. They may cause the patient significant pain and discomfort. Simple conservative management with the use of buddy taping and appropriate footwear helps the fracture heal in 3 to 6 weeks. Open or closed surgical reduction of phalangeal fractures may be required to achieve proper reduction. Intraarticular or severely displaced toe fractures, especially those of the great toe, should be referred to an Orthopedic Surgeon or Podiatrist. Most toe fractures can be satisfactorily and definitively managed by the Emergency Physician with a minimum of complications.

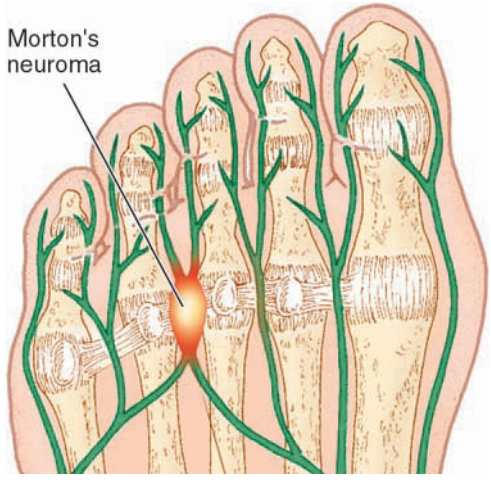


FIGURE 186-1. Morton's neuroma most commonly occurs in the third intermetatarsal space beneath the transverse metacarpal ligament.

186 Neuroma Management

Eric R. Snoey and Stephen Miller

INTRODUCTION

Morton's neuroma, also referred to as an interdigital neuroma, is one of the most common painful disorders of the forefoot. It was first described in 1845 by Dulacher. It is named after Thomas Morton, who presented a case series of patients afflicted with this disorder in 1876. Patients with an established Morton's neuroma are usually cared for by a Podiatrist or an Orthopedist. They may present to the Emergency Department with a previously undiagnosed neuroma or with a painful exacerbation of a previously diagnosed neuroma.

The term neuroma is actually a misnomer. Histologic investigation does not reveal the typical proliferation of axons found in true neuromas. Instead, there is a fibrosis and thickening of the perineural tissue with corresponding degeneration of the underlying nerve in a Morton's neuroma.[1] This most commonly affects the third plantar common digital nerve located in the third interspace, between the third and fourth metatarsal heads. It may also occur less commonly in the second interspace, between the second and third metatarsals. A neuroma is rarely seen in the first or fourth interspaces, between the first and second or the fourth and fifth metatarsals, respectively.

Morton's neuroma most commonly affects women between their fourth and sixth decades.[2] It is especially common in those who wear high-heeled shoes, poor fitting shoes, worn shoes, shoes with poor or no padding, or shoes that are narrow at the forefoot. Persons with pronated or pes cavus feet are similarly at risk.[3] Neuromas do not usually become symptomatic until their transverse diameter reaches more than 5 mm.[4]

ANATOMY AND PATHOPHYSIOLOGY

Neuromas form just proximal to the bifurcation of the plantar common digital nerves (**Figure 186-1**) and below the deep transverse intermetatarsal ligament (**Figure 186-2**). The deep transverse intermetatarsal ligament connects the metatarsal heads on the plantar aspect of the foot (**Figure 186-2**). The neuroma is made up of branches from both the medial and lateral plantar nerves (**Figure 186-1**). Most commonly affected is the third interdigital nerve. It is the largest of the interdigital nerves and may explain the increased frequency of neuroma formation in this location.

Morton and others postulated that the increased mobility of the fourth and fifth metatarsal heads relative to the more fixed medial portion of the foot results in disproportionate trauma to the third interdigital nerve. These mechanical factors, combined with the impingement and stretching from a tight transverse intermetatarsal ligament, result in repetitive microtrauma. Histologic evaluation reveals perineural fibroma formation consistent with compression-induced trauma.[2] Injury begins with edema of the endoneurium, followed by fibrosis beneath the perineurium, axonal degeneration, and finally neuronal necrosis.

Some authors believe that a more significant contributor to neuroma formation is enlargement of the interphalangeal component of the intermetatarsophalangeal bursa, leading to microvascular trauma.[5] Movements of the bursa result in minor compressive effects on the adjacent digital arteries, leading to ischemia of local neural tissue.

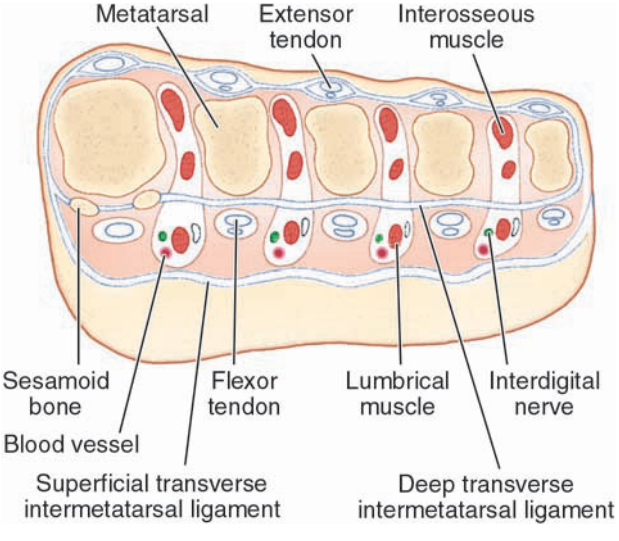


FIGURE 186-2. Anatomy of the forefoot. Cross section through the distal metatarsals.

The diagnosis of a Morton's neuroma is usually made clinically, based upon classic historical features and physical examination findings.[1] The pain of a neuroma usually begins intermittently, becoming more frequent with time and eventually constant. The patient may complain of pain, burning, electric shocks, or tingling over the involved intermetatarsal space. Attacks typically occur suddenly after a period of walking, running, or standing.[5] Some patients may complain of pain disturbing their sleep.[5] Hyperesthesia or hypoesthesia in the involved toes and web space is common. Patients often complain of the unilateral feeling of "walking on a lump." Symptoms are aggravated by walking, particularly in narrow shoes, and relieved by rest and shoe removal.

Physical examination localizes the pain to the involved interspace with minimal involvement of the adjacent metatarsal heads. Moderate pressure applied proximally in the affected web space reproduces the pain. A small mass, representing the neuroma, can be palpated in approximately one-third of the cases. A positive Mulder's sign is diagnostic.[6] This is a click felt in the interspace with medial and lateral compression of the metatarsal heads during simultaneous palpation of the interspace (**Figure 186-3**).

Radiographic imaging may be helpful in confirming the diagnosis and exploring alternative etiologies. Plain radiographs will not demonstrate a neuroma. They may reveal splaying of the involved toes when the neuroma is especially large or alternative diagnoses such as stress fractures or arthritis. Ultrasound represents the most efficient and effective imaging modality.[2,7] An experienced operator may identify hypoechoic neuromas as small as 2.9 mm.[8] Magnetic resonance imaging (MRI) is quite effective at identifying the presence of a neuroma, but cost and access issues make it a less practical choice, especially in the Emergency Department.[1] Computed tomography (CT) may be useful if an MRI is contraindicated or not available. The sensitivity of CT scanning is less than that of MRI or ultrasound.[2]



FIGURE 186-3. Examination for Mulder's click. The thumb and forefinger of the examiner's dominant hand are used to compress the interdigital space. The nondominant hand then performs medial and lateral compression of the metatarsal heads (*arrows*). A palpable click is diagnostic, while pain alone is suggestive of a neuroma.

INDICATIONS

Injection of the presumed neuroma will provide significant relief to the patient and confirm a Morton's neuroma as the etiology of the patient's complaints. Injection is indicated after less invasive methods have failed.[9,10] These include foot elevation and rest, nonsteroidal anti-inflammatory drugs, arch supports, orthoses, and changing footwear to prevent forefoot compression (i.e., low heels and wide toe boxes). Corticosteroid injections can provide partial or complete relief in up to 80% of patients.[9,11]

CONTRAINDICATIONS

The primary contraindication to injection of a Morton's neuroma is failure to make a correct initial diagnosis. The differential diagnosis for forefoot pain includes a wide variety of pathologies, many of which may closely mimic the presentation of a neuroma. Alternative diagnoses include tarsal tunnel syndrome, peripheral neuropathy, capsulitis, bursitis, rheumatoid arthritis, foreign bodies, avascular necrosis, stress fractures, and peripheral vascular insufficiency. A careful history and physical examination with discretionary use of imaging modalities will lead to a correct diagnosis.

Some specialists believe injection therapy to be contraindicated in serious athletes.[3] They propose that steroid injection may result in fat pad atrophy, degeneration of the volar plate, and degeneration of the collateral ligaments. A discussion of alternative therapies to injection therapy is provided later in this chapter.

EQUIPMENT

- Sterile gloves
- Sterile drapes
- Povidone iodine or chlorhexidine solution
- 3 mL syringe
- 22 or 25 gauge needle
- 0.5% bupivacaine without epinephrine
- Injectable methylprednisolone or triamcinolone
- Sterile bandage

PATIENT PREPARATION

Explain the risks, benefits, complications, and aftercare of the procedure to the patient and/or their representative. Place the patient supine on a gurney with their hip and knee flexed so that the sole of the affected foot is flat on the gurney. Clean the skin overlying the neuroma of any dirt and debris. Apply povidone iodine or chlorhexidine solution and allow it to dry. Apply sterile drapes to isolate a sterile field.

Prepare the injection solution. Mix 1 mL of 0.5% bupivacaine without epinephrine in a 3 mL syringe with 10 mg of methylprednisolone or triamcinolone. Another local anesthetic agent, without epinephrine, may be used instead of bupivacaine. Long-acting local anesthetic agents are preferred as they provide the patient with longer pain relief after the injection.

TECHNIQUE

Instruct the patient to moderately dorsiflex their toes to separate the metatarsal heads. **Use a dorsal approach to the neuroma, as this is less painful than penetrating the sole with a needle.** If the neuroma is palpable, insert the needle perpendicular into the skin overlying the neuroma. Advance the needle perpendicular to the skin and into the neuroma or into its fascial plane (**Figure 186-4**). Inject the affected interspace with 1 to 2 mL of the combination long-acting local anesthetic agent and steroid.



FIGURE 186-4. Injection of the neuroma.

In the absence of a palpable neuroma, insert the needle approximately 1 to 2 cm proximal to the web space. Direct the needle into the facial space between the deep and superficial transverse metatarsal ligaments. Note that this space is deep to the metatarsal heads on the plantar aspect of the foot (**Figure 186-2**).

ALTERNATIVE TECHNIQUES

Various types of conservative treatment can be initiated once a Morton's neuroma is diagnosed. A wide range of success rates have been reported (20% to 80%) using a combination of injections with other conservative therapy including orthoses, metatarsal pads, shoes with wider toe boxes, and physical therapy.[12,13] Orthoses are used to help control abnormal pronation, although some studies have shown this to be ineffective.[13] Metatarsal pads serve to spread the metatarsal heads at the involved interspace and decrease compressive trauma (**Figure 186-5**). The types of physical therapy employed include massage, ultrasound, electrical stimulation, and whirlpool immersion. A trial of acetaminophen or nonsteroidal anti-inflammatory drugs may be helpful in the short term.



FIGURE 186-5. Placement of a metatarsal pad.

Two recent studies have described the injection of dilute alcohol into the site of the neuroma using ultrasound guidance. The effect is to sclerose and harden the perineural tissues. The injection is typically repeated every 1 to 2 weeks and on average 4 to 7 times, with treated patients experiencing a significant reduction in symptoms and neuroma size.[14,15]

Podiatrists and Orthopedists may offer more aggressive and definitive therapy when conservative measures fail. Surgical excision using a dorsal approach has success rates as high as 84% to 93%.[16–18] The podiatry literature offers increasing support for endoscopic decompression of the deep transverse intermetatarsal ligament, thus leaving the nerve intact. The advantage is a shorter recovery time, which may make this especially desirable for athletes. No long-term results have been reported, but short-term results appear quite promising.[3] Excision using a carbon dioxide laser is yet another treatment option that may allow for an even shorter recovery.[7]

ASSESSMENT

Allow 10 to 20 minutes for the local anesthetic agent to take full effect. The patient will experience a rapid resolution of symptoms if the injection is successful. The relief of pain confirms that the corticosteroid has been injected into the correct location, allowing it to work on the neuroma.

AFTERCARE

Pain may be controlled with the use of acetaminophen or nonsteroidal anti-inflammatory drugs. Instruct the patient to wear flat shoes, shoes with flat and wide toe boxes, and to avoid shoes whose heel is elevated above the metatarsals (usually a heal no higher than 0.5 to 1.0 inches). The patient should avoid activities that place repeated pressure on the forefoot (e.g., bicycling, jogging, and sports). Apply a metatarsal pad to decrease compressive forces on the neuroma. Place the dome of the pad between the third and fourth metatarsals and just posterior to the metatarsal heads (**Figure 186-5**). Cold packs can be applied for 10 to 15 minutes every 3 hours to decrease inflammation and pain, especially after activities that aggravate the patient's symptoms. Refer the patient to a Podiatrist or Orthopedic Surgeon for follow-up, additional injection therapy, orthoses, physical therapy, and possible surgical management.

COMPLICATIONS

Complications associated with neuroma injection are exceedingly rare. They include the introduction of infection, damage to neurovascular structures, local fat pad and skin atrophy secondary to the effects of the steroid, skin depigmentation or hyperpigmentation, telangiectasias, and thinning of the skin.[14,15] Fat pad atrophy on the dorsal foot is primarily a cosmetic issue. Fat pad atrophy on the plantar aspect of the foot can result in painful ambulation and gait disturbances.[19] Skin changes and fat pad atrophy can be prevented by ensuring the injection is deep and properly placed so that the corticosteroids do not leak into the subcutaneous tissues.[20] It is common for the pain to recur in days to weeks, even when the injection is successful. Single injections may not totally relieve the patient's symptoms. The patient often requires a series of injections every 1 to 2 weeks to be successful.

SUMMARY

Morton's neuroma is one of the most common causes of forefoot pain. Injection therapy is useful in alleviating the symptoms of a neuroma and in confirming the diagnosis. Arrange Podiatric or Orthopedic follow-up for all patients given this diagnosis, as more invasive procedures may be needed for long-term resolution of symptoms.

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SECTION 16

Miscellaneous Procedures

187 Relief of Choking and Acute Upper Airway Foreign Body Removal

Tamara Espinoza, Shekhar Menon, and John Bailitz

INTRODUCTION

Accidental foreign body obstruction of the airway is the leading cause of accidental death in children less than 6 years of age.[1] Airway foreign body obstruction accounts for over 4000 adult and pediatric deaths per year in the United States.[1] Tragically, 90% of these deaths occur in children less than 4 years of age, with 65% occurring in infants.[2] The most common cause of an airway foreign body obstruction in infants are feeding liquids while the most common etiologies in older children are candy, grapes, peanuts, and vegetables. Mortality due to airway foreign body obstruction is bimodal and increases again in the elderly, with 13.6 deaths per 100,000 people greater than 75 years of age.[3,4] Food impaction is the primary etiology with the elderly, with those intoxicated and institutionalized being at an increased risk.[3,4]

ANATOMY AND PATHOPHYSIOLOGY

The clinical presentation and patient management is dependent on three related factors: the anatomical site of obstruction, the degree of obstruction, and the size of the foreign body. Autopsy reports have found the foreign body obstruction to be located supraglottic in 32% and infraglottic in 68%.[5] Patients with a supraglottic obstruction classically present with inspiratory stridor while those with an infraglottic obstruction present with expiratory wheezes. Infraglottic foreign bodies lodge in the trachea or the mainstem bronchus and require instrument removal. A foreign body that simply contacts the vocal cords while moving through the glottis may result in laryngospasm that can completely obstruct the airway, even after the expulsion of the foreign body.[6]

Partial airway obstructions often allow limited amounts of air passage and their removal by the patient's cough reflex. Complete airway obstructions can result in a silent cough followed by loss of consciousness, thus requiring higher pressures for removal. A larger foreign body is more likely to lodge above or at the vocal cords causing a complete airway obstruction. Sharp, small, and thin foreign bodies are more likely to obstruct between or below the vocal cords and result in difficulty breathing and odynophagia.[7]

Pediatric and adult patients provide different clues to an airway foreign body obstruction. Adults and older children typically indicate the "universal choking sign" by clutching or pointing to their neck and nodding affirmatively when asked if choking. An infant or toddler will present after a witnessed or suspected acute foreign body ingestion. Their symptoms range anywhere on a spectrum from subtle stridor and wheezing to cyanosis and unconsciousness.[8]

Dr. Henry Heimlich first proposed the Heimlich maneuver in 1974. Controversy soon followed as he publicly denounced the recommendations made by the American Red Cross and the American Heart Association. He claimed that back blows previously listed as a first-line treatment were "death blows" and that various national organizations were involved in "Watergate cover-ups" intended to prevent acceptance and widespread use of his maneuver.

No prospective clinical trials have been reported on the various techniques used to relieve an airway foreign body obstruction. Physiologic data demonstrate that each technique produces varying effects on intrathoracic pressure and airflow to overcome the static resistance of the obstructing foreign body.[9] Back blows generate a substantial increase in intrathoracic pressure over a very short period of time, potentially dislodging an airway foreign body without its expulsion from the airway. Conversely, abdominal thrusts generate more prolonged increases in airway pressure and flow rates, theoretically allowing for expulsion of the dislodged foreign body. Rescuers must be prepared to quickly utilize a combination of these techniques for the dislodgement and expulsion of an airway foreign body obstruction.[4]

DIGITAL REMOVAL (FINGER SWEEP)

Perform digital removal of an intraoral foreign body only when it is directly visualized in the patient's mouth or oropharynx. Blind finger sweeps are contraindicated to prevent inadvertently pushing the foreign body into a more distal location, thereby converting an incomplete supraglottic obstruction into a difficult to remove and complete infraglottic obstruction.[7]

Open the patient's mouth and airway using the thumb and fingers of the nondominant hand to grab the tongue and mandible then lift it anteriorly. Use a hooking action with the index finger of the dominant hand to dislodge and remove the foreign body.

The most important potential complication is the conversion of a partial airway obstruction into a complete airway obstruction. Local trauma can result in intraoral abrasions, bleeding, and dental trauma. The rescuer can sustain digital abrasions and lacerations from the patient's teeth. **Do not place your fingers into the mouth of a conscious patient as this can result in a significant bite injury.**

BACK BLOWS AND CHEST THRUSTS IN INFANTS

An uncoordinated swallow mechanism and the lack of molar dentition predispose the infant to an airway foreign body obstruction within their narrow and pliable glottis and trachea.[10] **Perform back blows and chest thrusts on the infant with a witnessed or suspected airway foreign body obstruction who suddenly develops respiratory distress, appears cyanotic, or becomes unconscious. This technique should be used on infants less than 1 year of age. Use the Heimlich maneuver if the patient is over 1 year of age. Continue to closely observe the infant but do not intervene if they are maintaining their airway as indicated**

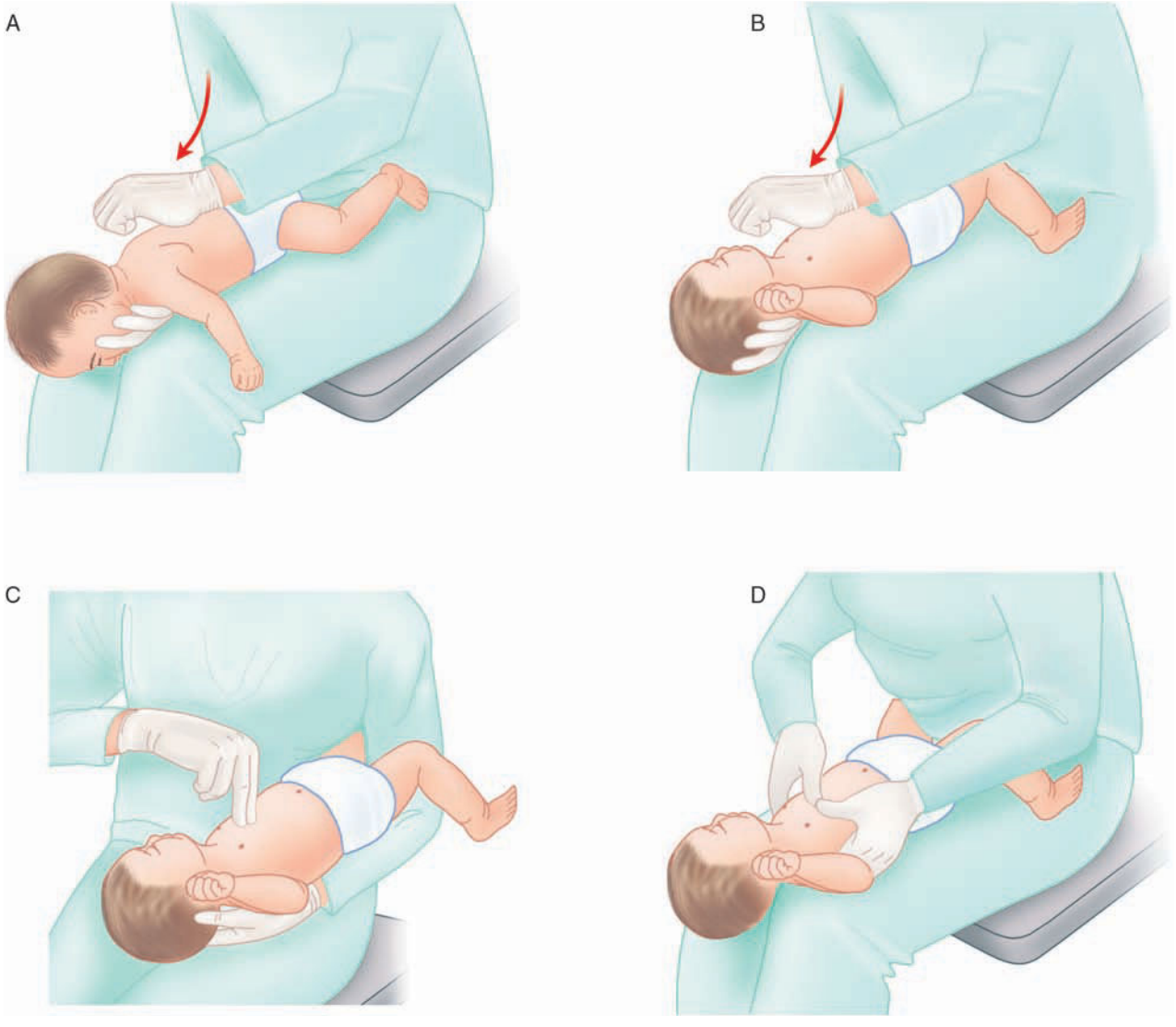


FIGURE 187-1. Relief of an airway foreign body obstruction in the infant. **A.** Back blows using the heel of a hand. **B.** Chest thrusts using the heel of a hand. **C.** Chest thrusts using two fingers. **D.** Chest thrusts using both thumbs.

by clear breathing and an effective cough. Their cough reflex may allow them to dislodge and expel the foreign body.

Place the choking infant with their head angled down in a prone position over the arm or thigh of the rescuer (**Figure 187-1A**). This head-down position allows gravity to assist in the expulsion of the dislodged foreign body. Perform five firm back blows with the heel of a hand between the infant's shoulder blades (**Figure 187-1A**). Turn the infant around into the supine position with their head angled down. Perform five chest thrusts with the heel of a hand applied to sternum (**Figure 187-1B**). Repeat this sequence of back blows and chest thrusts until the foreign body is expelled or the infant becomes unresponsive.

Chest thrusts may also be performed using two other methods. The first is to apply the index and middle fingers just below the intermamillary line and compress the chest (**Figure 187-1C**). This is usually performed when there is one rescuer. The second method is to use both thumbs on the infant's sternum (**Figure 187-1D**). This method is performed when one or two rescuers are present. Place both thumbs together over the lower half of the infant sternum just below the intermamillary line. Encircle the infant's chest with both hands, spreading the fingers around the posterior thorax. Compress the sternum while squeezing the thorax to apply counterpressure.

The procedure is successful when the foreign body is expelled. Closely observe the infant after expulsion of the foreign body for any signs of persistent respiratory distress due to an incompletely expelled foreign body or injury from the removal techniques.

For the unresponsive infant, first check their mouth and remove any obvious foreign body. **Blind finger sweeps are always contraindicated.** Case reports describe wedging of foreign bodies into more distal locations and converting a partial airway obstruction into a complete airway obstruction.[7] In the apneic infant, immediately begin more advanced pediatric procedures as described below as well as Basic Life Support and Advanced Life Support maneuvers.

Back blows often result in back and chest wall contusions. The use of acetaminophen or nonsteroidal anti-inflammatory drugs should relieve any discomfort. Vigorous back blows can result in rib fractures. Occasionally, nausea and vomiting can result. Chest thrusts may result in rib and sternal fractures, myocardial contusions, punctured lungs, pneumothoraces, and intraabdominal injury.[4] While these potential complications are serious, not relieving an airway foreign body obstruction can result in death.

Maintain a low threshold for performing back blows and chest thrusts to relieve an airway foreign body obstruction in infants. An

airway foreign body obstruction in an infant is more likely, more difficult to assess, and more often fatal than in an older child, adolescent, and adult. **The key steps to remember include positioning the infant head down over the rescuer's arm or leg with their head lower than their trunk, performing five back blows alternating with five chest thrusts, and repeating this sequence continuously until the foreign body is expelled.**

ABDOMINAL THRUSTS (HEIMLICH MANEUVER) IN THE CONSCIOUS PATIENT

Perform the Heimlich maneuver in the conscious patient over 1 year of age with a witnessed or presumed aspiration who cannot speak, cough, or breathe effectively. Older children and adult patients will often present and be grasping or pointing to their neck with the "universal choking sign" (**Figure 187-2**). Young children will often have a history or presentation consistent with an airway foreign body obstruction. As long as the patient is conscious and has signs of a complete airway obstruction, perform this technique from behind. Do not perform the Heimlich maneuver in patients less than 1 year of age due to the significant risk of liver injury.[11] **Observe the patient closely while their cough reflex attempts to expel the partial obstruction if they are able to cough, speak, and breathe effectively. Perform abdominal thrusts only for a complete airway obstruction.**

Stand directly behind the patient (**Figure 187-2**). Wrap both arms around the patient's waist. Make a fist with one hand. Place this hand with the thumb side of the fist against the midline of the patient's upper abdomen, between the rib cage and umbilicus. Place the other hand over the fisted hand and grasp the fisted hand (**Figure 187-2**). **Press inward with a deliberate and quick upward thrust. Confine the force of the thrust to the hands without squeezing the rib cage.** Repeat the quick upward thrusts until the foreign body is expelled or the patient becomes unresponsive.

Closely observe the patient after the foreign body is expelled for signs of respiratory distress from persistent obstruction or from injury from the Heimlich maneuver. **If the patient becomes unresponsive, lay them supine and perform abdominal thrusts as described below.** Incorrect hand placement can result in sternal and rib fractures. Significant but rare complications include a punctured lung, pneumomediastinum, and intraabdominal trauma (e.g., liver laceration, splenic laceration, and bowel injury). While these potential complications are serious, not relieving an airway foreign body obstruction can result in death.

ABDOMINAL THRUSTS IN THE UNCONSCIOUS PATIENT

Perform abdominal thrusts in the patient with a witnessed or suspected airway foreign body obstruction, failure of the previously described maneuvers, or in the unresponsive patient. Do not perform this maneuver in patients less than 1 year of age due to the significant risk of liver injury.

Place the patient supine on a firm surface, usually on the floor. A bed is not firm enough to allow the appropriate generation of intraabdominal pressure. Open their mouth. **Perform a finger sweep only if a foreign body is clearly visible.** Place the heel of one hand in the midline of the abdomen and just above the umbilicus. Place the other hand over the first (**Figure 187-3**). Apply five rapid and forceful thrusts downward and upward, forcing the diaphragm upward and compressing the lungs. Reassess the patient's airway. Inspect their mouth for a foreign body. Remove the intraoral foreign body if it is visible. If the foreign body is not visible, repeat the abdominal thrusts or attempt another technique.

One case study reported that increased airway pressure was generated using a knees-to-chest approach in the supine position. While there are no further studies to support this technique, it may be a simple adjunct when other methods have failed.[12]



FIGURE 187-2. The Heimlich maneuver in a conscious patient.

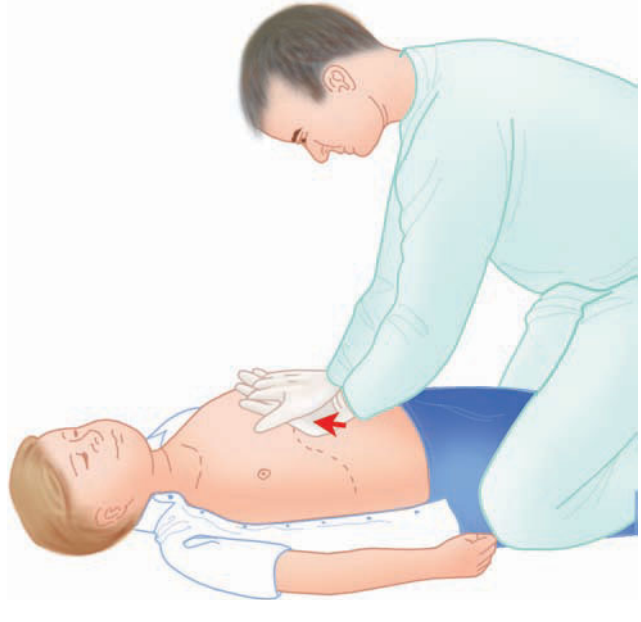


FIGURE 187-3. Abdominal thrusts in the unconscious patient.

Frequently reassess the patient for spontaneous breathing. Each time the mouth and airway is opened, look for a foreign body prior to ventilation attempts. Closely observe the patient after the foreign body is expelled for signs of respiratory distress from persistent obstruction or from injury from the abdominal thrusts. Incorrect hand placement can result in sternal and rib fractures. After the foreign body is removed, place the patient in the semirecumbent position or sitting upright if no contraindications exist.

Reported complications include abdominal pain, vomiting, pharyngeal abrasions, esophageal lacerations, intraabdominal trauma (e.g., liver laceration, splenic laceration, and bowel injury), fractured ribs, punctured lung, pneumothoraces, a pneumomediastinum, and even retinal detachment. While these potential complications are serious, not relieving an airway foreign body obstruction can result in death.

DIRECT LARYNGOSCOPY

Developmental differences in the pediatric airway make visualization and removal of foreign bodies more difficult than in the adult patient. The pediatric tongue occupies a larger percentage of the oral cavity and the oropharynx. Their epiglottis is larger, U-shaped, and more cephalad. The pediatric epiglottis does not attain the adult position until age four. The narrowest portion of the pediatric airway, and a likely site of obstruction, is below the vocal cords at the level of the cricoid cartilage, making removal more difficult.

The timing of endoscopy and airway foreign body retrieval must be based upon each individual patient. Do not waste time if impending airway obstruction exists. Immediately notify and mobilize an Anesthesiologist, Otolaryngologist, and the Operating Room, as this is an emergent situation. It is appropriate to wait for NPO status to be present and the stomach empty prior to proceeding to the Operating Room if the diagnosis of an airway foreign body is highly suspected and the patient is stable. This is considered a timely approach and may take up to 6 hours for children or 8 hours for adults. Waiting this time in the stable patient decreases the risk of aspiration and further compromising the situation. It is also appropriate to wait, in a stable patient, in order to assemble the appropriate and best nursing and anesthesia team to care for the patient. Using personnel who are unfamiliar with endoscopy can create a compromised and stressful situation.

It is always best not to manipulate the airway or attempt intubation in a stable patient with an airway foreign body and who is moving air and breathing. The airway may be best controlled in the Operating Room at the time of the actual foreign body removal. Once the airway is manipulated a foreign body can become dislodged, turning a partial airway obstruction into a complete airway obstruction. If this occurs in the Operating Room, the bronchoscopy equipment is available for urgent use by the endoscopist if needed.

It is possible to remove foreign bodies located within the hypopharynx in the Emergency Department. Typical foreign bodies that may be removed include pieces of food and fishbones. **The patient must be stable and in no risk of airway compromise.** Obtain anteroposterior and lateral soft tissue radiographs of the neck to localize, if possible, the foreign body. The use of CT scans to attempt to identify potential fish or chicken bones that may be lodged in the pharynx, hypopharynx, or esophagus is an option in the stable patient. Perform indirect laryngoscopy to identify the foreign body and its location. Refer to Chapter 173 regarding the complete details of laryngoscopy. Obtain intravenous access.

Perform a forceps removal of an airway foreign body in the patient with a complete airway obstruction or severe respiratory distress due to partial obstruction when less invasive measures have failed.[13] **Do not try to blindly grasp for a presumed airway foreign body.** Observation and removal in the Operating Room, and not an Emergency Department intervention, is indicated in the patient who is coughing, speaking, or otherwise breathing effectively. Begin with less invasive techniques before performing direct laryngoscopy and manual removal. Be ready to utilize multiple laryngoscope blades, clamps, and forceps to safely visualize and remove accidental foreign body obstruction.

EQUIPMENT

- Topical anesthetic spray (e.g., Cetacaine)
- Laryngoscope
- Laryngoscope blades, Miller and Macintosh, various sizes
- Tracheal suction catheter
- Magill forceps
- Pulse Oximeter
- Cardiac Monitor
- Noninvasive blood pressure cuff
- Oxygen
- Video laryngoscope, optional
- Surgical airway equipment

Direct laryngoscopy and bronchoscopy in a child or adult with an airway foreign body is a dangerous situation. The procedure may result in a partial airway obstruction becoming a complete airway obstruction. **Always have a cricothyroidotomy tray and/or percutaneous transtracheal jet ventilation device immediately available.** All equipment must be selected, assembled, and ready for use. Place the patient in full monitoring (i.e., pulse oximeter, cardiac monitor, and noninvasive blood pressure cuff). Apply a topical anesthetic spray to the oropharynx and the base of the tongue to blunt the gag reflex. Place the patient supine or semirecumbent. Administer a small dose of an intravenous sedative if required and not contraindicated.

Slowly and gently insert the laryngoscope blade. An alternative to a traditional laryngoscope, if available, is a video laryngoscope. The video laryngoscope may provide a better field of view with less manipulation. **Do not immediately insert the laryngoscope blade all the way.** Stop frequently to lift the laryngoscope and look for the foreign body. This slow insertion and frequent looks will prevent the laryngoscope blade from pushing the foreign body further into the airway. Elevate the patient's tongue and jaw. Grasp the foreign body with a Magill forceps. If the foreign body is too large or impacted, it may need to be crushed with the forceps to securely grasp it as a whole piece.[14] Withdraw the McGill forceps followed by the laryngoscope.

One case report describes passing a Foley catheter distal to the foreign body under direct visualization with a laryngoscope.[14] The balloon was then inflated with 5 mL of air and subsequently pulled back until the foreign body could be grasped and removed with a Magill forceps. There were no reported complications. However, it should be noted the foreign body in this case was impacted within the esophagus at the level of the cricoid cartilage. Do not use this technique with subglottic airway foreign bodies since retraction of a dilated catheter balloon through the glottic structures may cause injury, edema, bleeding, and further worsen the obstruction.

Observe the patient for persistent or delayed respiratory distress resulting from incomplete removal or procedural complications. The severity of the obstruction determines whether a patient may be safely discharged home or admitted for observation.

One review reported no complications with subglottic foreign body removal when utilizing Magill forceps under direct

laryngoscopy.[13] Potential complications include oropharyngeal trauma resulting in glottic edema and bleeding.

OROTRACHEAL INTUBATION

Attempt orotracheal intubation in the Emergency Department if the airway obstruction progresses rapidly and the patient cannot ventilate. Intubation can be used to force the foreign body into one mainstem bronchus and allow ventilation of the other lung. One-lung ventilation will keep the patient alive until the foreign body can be removed in the Operating Room.

Position the laryngoscope to visualize the larynx. If a foreign body is visualized, grasp the foreign body with a McGill forceps and remove it. If no foreign body is visualized, intubate the patient. Insert and advance the endotracheal tube as far as it will advance if the foreign body is not visualized or unable to be grasped. If the endotracheal tube will not pass, try passing a smaller size endotracheal tube. Withdraw and position the endotracheal tube with the tip above the carina to optimize ventilation. As an alternative, properly insert and position the endotracheal tube above the carina then advance a bougie through the endotracheal tube in an attempt to move the foreign body distally. **Always be prepared to perform a cricothyroidotomy or transtracheal jet ventilation.** Transtracheal jet ventilation allows for short-term oxygenation, is temporary, and may allow time for safe transport to the Operating Room so that endoscopy and foreign body retrieval can be performed in a more controlled environment with appropriate equipment at hand. Refer to Chapters 11, 25, and 24 regarding the details of orotracheal intubation, cricothyroidotomy, and transtracheal jet ventilation, respectively.

AFTERCARE

After the extraction, removal, or retrieval of an airway foreign body, most patients should be breathing spontaneously. An endotracheal tube may rarely, in the presence of significant laryngeal or tracheobronchial edema, need to remain in place temporarily. This would require admission to an intensive care unit. Humidified oxygen is helpful to keep the airway moist and prevent mucous crusts from forming. A postprocedural radiograph will help to determine any subcutaneous air, air in the soft tissues, a pneumothorax, or any changes to the lung fields following the extraction.

All patients who have undergone foreign body extraction, removal, or retrieval require at least a few hours of airway observation in a monitored setting. Racemic epinephrine treatments and intravenous Decadron can be administered as needed. Discharge from the hospital is acceptable when the patient is breathing comfortably and no longer in danger of airway compromise. Some patients may be discharged home the same day, while others may require multiple days of airway support and observation.

COMPLICATIONS

Complications from the foreign bodies themselves include hypoxia leading to cerebral anoxia if not identified. Cardiac arrhythmias can occur from hypoxia or direct pressure on the left main-stem bronchus. Other complications include laryngeal or tracheobronchial edema from the foreign body or the instrumentation of the airway. Mucosal irritation can instigate a bronchitis, pneumonia, or tracheitis. A pneumomediastinum and/or a pneumothorax is possible. The complications specific for each technique have been described previously in the respective sections.

A foreign body in the hypopharynx can be pushed distally and result in a total airway obstruction. The foreign body needs to be quickly removed, pushed back down into one of the mainstem bronchi to allow ventilation of at least one lung, or a surgical airway performed. Failure to react appropriately in this situation can result in asphyxiation and death.

SUMMARY

An airway foreign body obstruction is a significant cause of preventable morbidity and mortality in the pediatric, debilitated, and elderly patients. Prompt recognition and management is vital to preventing cardiopulmonary arrest. Do not intervene in the awake patient who is talking, coughing, or otherwise breathing effectively. Observe these patients to determine if their own cough reflex can expel the foreign body. Perform the age and condition appropriate maneuvers with a complete airway obstruction or severe respiratory distress with a partial airway obstruction. Multiple attempts with a combination of procedures are often required for the successful removal of an airway foreign body. Back blows and chest thrusts are first line for infants while abdominal thrusts may be performed on all others. Blind finger sweeps are always contraindicated. Perform manual removal with finger sweeps or direct laryngoscopy under direct visualization.

188 Induction of Therapeutic Hypothermia

Mark Hansen, Mike Nelson, and John Bailitz

INTRODUCTION

Sudden cardiac death claims approximately 450,000 victims in the United States every year.[1] The mortality rate for out-of-hospital cardiac arrest remains a staggering 65% to 95%, with only 10% to 20% of survivors discharged from the hospital with a good neurologic outcome.[2] **Therapeutic hypothermia for the treatment of comatose survivors of cardiac arrest is the only therapy proven to improve survival and neurological outcome.[3]**

Although many consider therapeutic hypothermia to be a relatively new concept, experiments with deep therapeutic hypothermia actually began in the 1940s with initially mixed results. In the 1950s, studies examining moderate hypothermia in the range of 26°C to 32°C (78.8°F to 89.6°F) in comatose survivors of cardiac arrest reported a trend toward improved outcomes but were complicated by difficult to control side effects. Additional animal studies of mild hypothermia in the range of 32°C to 35°C (89.6°F to 95°F) in the 1980s and small clinical trials in the 1990s demonstrated that even mild hypothermia provided the protective benefits with far fewer side effects.[2]

Two landmark randomized trials published in 2002 specifically examined the use of mild hypothermia in comatose survivors of witnessed cardiac arrests with initial rhythms of pulseless ventricular tachycardia or ventricular fibrillation.[4,5] **More recent meta-analysis report that only seven patients need to be treated to save one life and only five patients need to be treated to prevent one poor neurological outcome.[6,7]** Utilizing these studies' strict screening criteria resulted in only 10% of screened patients being eligible. Follow-up studies suggest a wider benefit in patients with other rhythms at presentation, cardiogenic shock, and those requiring percutaneous cardiac intervention (i.e., angioplasty and stenting).[2,3,8–16]

Preliminary studies of therapeutic hypothermia for other indications including traumatic brain injury, strokes, subarachnoid hemorrhages, myocardial infarctions, and ARDS have to date reported

only limited data or conflicting results. The exception being studies of neonates with perinatal asphyxia that reported similar results to adult cardiac arrest with a number needed to treat of six for one favorable outcome.[3] Extensive ongoing research is currently being conducted to determine the effectiveness of therapeutic hypothermia for other indications, as well as the optimal timing, duration, target temperature, and best techniques.

Despite recommendations for therapeutic hypothermia in the 2005 International Liaison Committee on Resuscitation Recommendations and American Heart Association Resuscitation Guidelines, a recent survey showed that 74% of physicians in the United States had not used therapeutic hypothermia.[15] They cited reasons such as not enough data, not part of ACLS protocol, too technically difficult, or that it had not been considered.[15] However, the induction of therapeutic hypothermia for comatose survivors of cardiac arrest is relatively straightforward in any Emergency Department. Similar to Early Goal Directed Therapy (EGDT) for septic shock, the creation of collaborative protocols between Emergency Physicians, Intensivists, Cardiologist, and Neurointensivists is essential to producing the best outcomes at each institution.

ANATOMY AND PATHOPHYSIOLOGY

The postcardiac arrest syndrome has recently been defined as a complex pathophysiological process involving brain injury, myocardial dysfunction, systemic ischemia and reperfusion response, and the underlying persistent precipitating pathology.[3] Brain injury is the reported cause of death in two-thirds of patients after an out-of-hospital arrests and one quarter of patients after in-hospital cardiac arrests.[16] Multiple cellular mechanisms contribute to neuronal apoptosis and necrosis including the formation of free radicals, disruption of calcium homeostasis, excitotoxicity, altered gene expression, mitochondrial dysfunction, and inflammation. At the tissue level, these cellular mechanisms lead to failure of cerebral autoregulation and ultimately hypotension, hypoxemia, brain edema, pyrexia, hyperglycemia, and seizures.[3]

Surprisingly, the postcardiac arrest state does not result in myocardial infarction but only myocardial stunning for 24 to 48 hours, producing a reduced ejection fraction and a reduction in end organ oxygen delivery.[3] The accumulated oxygen debt activates an inflammatory endothelial response further worsening oxygen delivery. The vicious cycle of oxygen debt and resultant inflammation does not end with reperfusion. Instead, the burst of reactive oxygen intermediates further exacerbates the inflammatory response and organ injury. The resultant state of systemic ischemia with reperfusion response leads to intravascular volume depletion, changes in vasoregulation, decreased oxygen utilization and delivery, and an increased risk of infection.

The underlying persisting pathology that caused the cardiac arrest also must be addressed. Acute coronary syndrome is strongly implicated in up to 50% of out-of-hospital cardiac arrests.[10] Elevations of troponin T are present in up to 40% of patients at the time of cardiac arrest, suggesting an ongoing cardiac ischemia or injury hours prior to the cardiac arrest. Additional etiologies of the cardiac arrest to consider include pulmonary embolism, primary pulmonary disease, sepsis, drug toxicity, or severe hemorrhage.

Hypothermia improves outcomes through several proposed mechanisms.[17] Metabolic demand is reduced 5% for each degree Celsius reduction in core body temperature. At the cellular level hypothermia decreases adenosine triphosphate demand, preventing intracellular acidosis and stabilizing cell membranes. At the tissue level hypothermia leads to decreased vascular permeability at the blood–brain barrier thus decreasing edema. Hypothermia interrupts the inflammatory cascade by inhibiting neutrophils, reducing the production of proinflammatory cytokines, and helping to prevent the free radical production associated with reperfusion injury.

INDICATIONS

Hypothermia is most effective in patients meeting the strict inclusion criteria of the initial landmark studies. Begin the induction of hypothermia in the Emergency Department for comatose survivors of cardiac arrest with a presumed cardiac etiology, an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia, and between 18 and 75 years of age.[3,7] More recent studies have demonstrated improved outcomes in patients with other initial rhythms (e.g., pulseless electrical activity and asystole), comatose survivors of in-hospital cardiac arrest, patients requiring percutaneous cardiac intervention, and those suffering from cardiogenic shock.[10,11,13,14,18] Consider the induction of therapeutic hypothermia when the cardiac arrest is witnessed, there is <30 minutes from the time of the collapse to the start of resuscitative efforts, it is <60 minutes from collapse to the return of spontaneous circulation (ROSC), the patient has a core body temperature >35°C (95°F), blood pressure can be maintained >80 mmHg with or without IV fluid boluses and pressors. Refer to **Figure 188-1** regarding a sample induction of therapeutic hypothermia checklist and clinical pathway.

CONTRAINDICATIONS

Hypothermia is contraindicated in patients with a known status of do not resuscitate (DNR) or do not intubate (DNI), have a terminal illness, have severe comorbidities, have multiorgan failure prearrest, or are comatose due to a noncardiac etiology. Patients with a preexisting coagulopathy or pregnancy have been excluded from most studies. One case of successful therapeutic hypothermia in pregnancy has been reported.[19] Other contraindications include patients when prehospital or in-hospital resuscitation is initiated greater than 15 to 30 minutes after collapse, with >60 minutes from the time of arrest to the ROSC, who are persistently hypoxic (SpO_2 < 85%) for greater than 15 minutes after the ROSC, if the arrest is related to blunt or penetrating trauma, when greater than 6 hours have elapsed since the ROSC, and if the patient spontaneously awakens with a normal mental status.

EQUIPMENT

General Supplies

- Arterial line equipment and supplies (Chapter 57)
- Nasogastric tube equipment and supplies (Chapter 58)
- Cardiac Monitor
- Ventilator
- Orotracheal intubation equipment and supplies (Chapter 11)
- Venous access equipment and supplies (Chapters 48 and 49)
- Analgesics (e.g., Fentanyl, Morphine, or Meperidine)
- Sedatives (e.g., Propofol, Ativan, or Versed)
- Neuromuscular blockers (e.g., Pancuronium, Vecuronium, or Rocuronium)
- Defibrillator–cardioverter unit and supplies (Chapter 30)

Cooling Supplies

- 4°C sterile normal saline or lactated Ringers
- Ice packs or ice water-soaked blankets
- Core temperature probe and monitor (e.g., esophageal, rectal, or urinary)

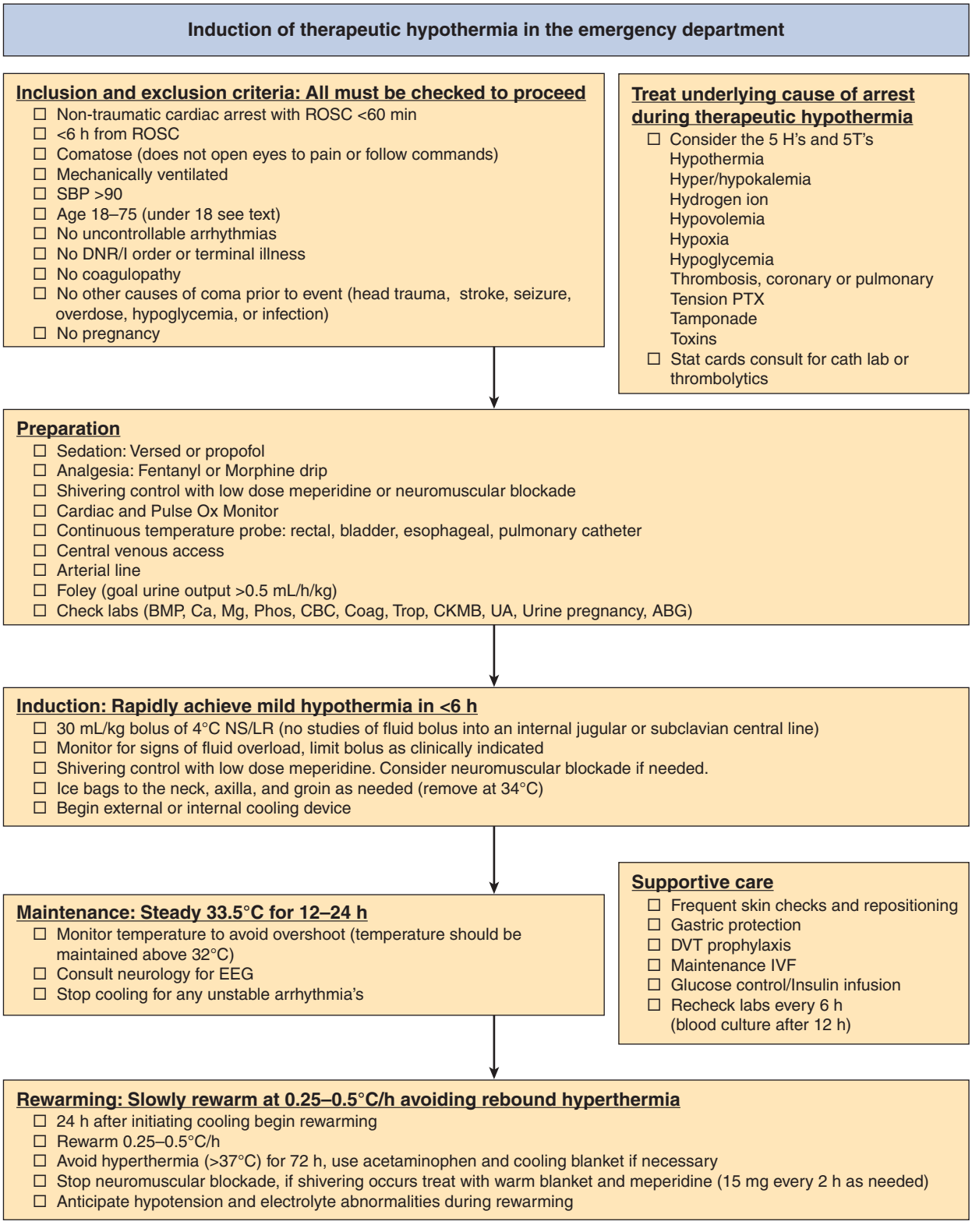


FIGURE 188-1. A sample induction of therapeutic hypothermia checklist and clinical pathway.

External Commercial Cooling Devices (Figure 188-2)

- Excel Cerebral Cooling System (Life Core Technologies LLC, Cleveland, OH)
- Medi-Therm III (Gaymar Industries Inc., Orchard Park, NY)
- Arctic Sun Temperature Management System (Medivance Inc., Louisville, CO)
- Cincinnati Sub-zero Blankets (Cincinnati Sub-zero Products Inc., Cincinnati, OH)
- InnerCool STx Surface Pad Systems (Phillips Healthcare, San Diego, CA)
- Thermosuit (Life Recovery Systems, Waldwick, NJ)











FIGURE 188-2. Examples of externally applied cooling devices. **A.** The Excel Cerebral Cooling System (Photo courtesy of Life Core Technologies LLC, Cleveland, OH). **B.** The Arctic Sun Temperature Management System (Photo courtesy of Medivance Inc., Louisville, CO). **C.** The Cincinnati Kool-Kit (Photo courtesy of Cincinnati Sub-zero Products Inc., Cincinnati, OH). **D.** The Thermosuit (Photo courtesy of Life Recovery Systems, Waldwick, NJ). **E.** The Medi-Therm (Photo courtesy of Stryker Medical, Orchard Park, NY).

Internal Endovascular Cooling Devices (Figure 188-3)

- Accutrol catheter (Phillips Healthcare, San Diego, CA)
- Cool Line, Icy, and Quattro catheters (Alsius, Irvine, CA)

Nasal cooling systems are currently being developed and tested (BeneChill, San Diego, CA and Johns Hopkins University, Baltimore, MD). These systems take advantage of the large surface area of the nasal cavity with an abundant capillary supply just below the mucosa as a heat exchanger. Early studies are promising. These systems may be used prehospital as well as in-hospital for the cooling of the postcardiac arrest patient. Further development and testing is required before these devices will be available for use.

PATIENT PREPARATION

Carefully consider inclusion and exclusion criteria for each individual patient utilizing pre-established institution-specific protocols. The risks, benefits, potential complications, and aftercare of the procedure should be explained to the patient's representative and an informed consent obtained whenever possible. The postarrest

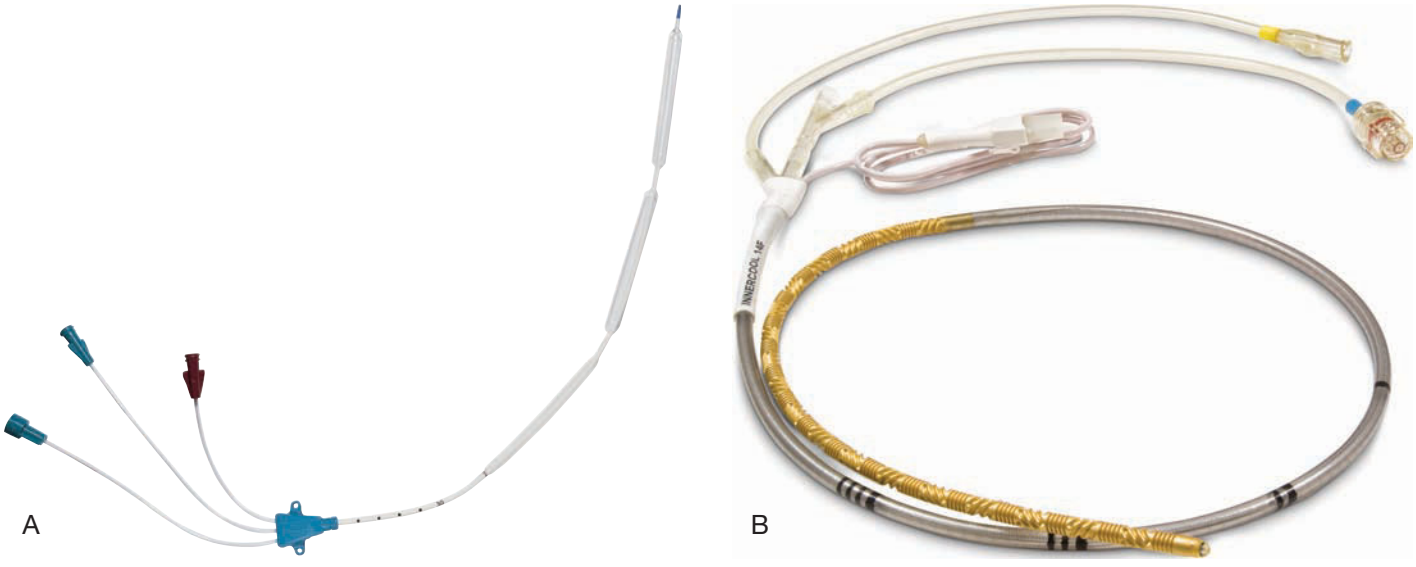


FIGURE 188-3. Examples of internally applied cooling devices. **A.** The Icy catheter (Photo courtesy of Alsius, Irvine, CA). **B.** The Accutrol catheter (Photo courtesy of Phillips Healthcare, San Diego, CA).

patient will be or should be intubated, have continuous pulse oximetry and cardiac monitors, and have frequent automated cuff or continuous arterial line blood pressure monitoring.

Perform a detailed examination to document a postarrest comatose state and the patient's baseline neurologic status including Glasgow Coma Scale, pupillary light reflex, corneal reflex, facial movements, eye movements, gag, cough, and motor response to painful stimuli. The retention of any neurologic function during or after cardiopulmonary resuscitation suggests a good prognosis. However, the absence of neurologic function immediately after the ROSC is not a reliable predictor of a poor outcome. The reliability of the neurologic exam to predict a poor outcome is time dependent. The absence of pupillary light reflexes, corneal reflexes, or motor responses to painful stimuli at day 3 provides the most reliable predictor of poor outcome.[3]

Prepare the patient for therapeutic hypothermia. Turn the ventilator's warm humidified air function off so as not to warm the patient. Perform an ECG. Obtain basic laboratory analyses to include electrolytes, renal function, calcium, magnesium, phosphorus, complete blood count, coagulation profile, cardiac markers, urinalysis, pregnancy, and arterial blood gas. Other laboratory analyses may include cortisol levels and thyroid function tests at the discretion of the admitting team. Titrate intravenous sedation and analgesia for comfort with mechanical ventilation. Shivering increases oxygen consumption, requiring control with low dose meperidine (15 mg IV Q 2 hours) and possibly neuromuscular blockade. Place a urethral catheter (Chapter 142) and monitor the urine output with a goal of >0.5 mL/hour/kg. Continuously monitor the core temperature with an esophageal, rectal, or urinary temperature probe. Place a nasogastric tube. Apply defibrillator/pacing pads (Chapter 30) in case they are required during the therapeutic hypothermia process. Otherwise, standard acute coronary syndrome and postresuscitation protocols apply.

TECHNIQUE

Therapeutic hypothermia is performed in three phases: induction, maintenance, and rewarming. There are multiple methods to perform all three phases. **However, the goals of each phase always remain the same. Rapidly achieve a hypothermic state of 32°C to 34°C (89.6°F to 93.2°F), maintain hypothermia for at least 12 to 24 hours, and then slowly rewarm at no faster than 0.25°C to 0.50°C (0.45°F to 0.9°F) per hour.**

INDUCTION

Beginning the induction phase of therapeutic hypothermia in the Emergency Department is straightforward and inexpensive. The typical temperature decrease seen in survivors of cardiac arrest begins the process even before it starts. The infusion of 4°C normal saline or lactated Ringers stored in a temperature-controlled refrigerator provides a reliable and safe method for rapid induction. Bolus 30 mL/kg or 1.5 to 2 L of fluid to create a 1.5°C to 2.3°C (2.7°F to 4.1°F) decrease in temperature.[20–22] **Monitor the patient for signs of fluid overload and adjust the rate and total volume accordingly.** Smaller repeat boluses of 500 mL may be given when required.[17] The application of ice packs to the head, neck, torso, and groin provides another safe and reliable method for rapidly decreasing temperature.[23] Patients requiring immediate angiography or admission to other locations may be transferred with both of these methods in place and without delay.[10,13]

Several commercially available external and internal cooling devices listed in the equipment section allow the Emergency Physician to set and maintain a target temperature through the use of continuous feedback from the patient's core temperature monitor. External systems utilize cooled circulated air, pads, or blankets. Internal systems require the placement of a femoral or subclavian central venous catheter with an endovascular cooling device. When available, these devices should be initiated while the fluid boluses and/or ice packs are applied.

To date there have been no studies comparing external versus internal cooling devices in cardiac arrest patients.[23] However, a manufacturer sponsored study of therapeutic hypothermia in neurosurgical patients demonstrated that the endovascular device reached target temperature faster (35 vs. 204 minutes), maintained a tighter control of target temperature, and had no significant increase in complications versus surface cooling.[24]

Beginning the induction in the Emergency Department with cooled IV fluids and ice packs, followed by the immediate transfer of the patient to the Intensive Care Unit for the application of more

expensive and delicate commercial cooling devices for maintenance of therapeutic hypothermia provides a clinically and cost-effective approach in any institution. These commercial cooling devices should be applied and the process of therapeutic hypothermia continued in the Emergency Department if there is any delay in transferring the patient to the Intensive Care Unit.

MAINTENANCE

Cooling should be stopped at 33.5°C (92.3°F) to prevent overshoot.[17] Use an external or internal cooling system with feedback control to maintain a core temperature of 32°C to 34°C (89.6°F to 93.2°F). Other methods include the use of cold wet blankets and ice packs placed around the head, neck, torso, and extremities. Although less expensive, these methods are more labor intensive, result in greater temperature fluctuations, and do not allow for controlled rewarming.[25] Maintaining hypothermia with fluid boluses alone is not possible.[26]

Supportive therapy with continuous cardiac monitoring should occur in the Intensive Care Unit setting. Continue administering analgesics, sedatives, and neuromuscular blockade as required. Maintain a goal mean arterial pressure of 65 to 100 mmHg with a central venous pressure of 8 to 12 mmHg. Monitor urine output and laboratory values to best manage the resulting cold diuresis. Maintain tight glucose control (108 to 144 mg/dL) to improve survival and neurologic outcomes.[3]

REWARMING

Rewarming typically begins 24 hours after the initiation of cooling. Gradual rewarming at a rate of 0.25°C to 0.5°C (0.45°F to 0.9°F) an hour over a 6 to 8 hour period helps prevent rapid changes in metabolic rate, electrolyte levels, and hemodynamics. Techniques include passive rewarming, resetting the temperature on commercial devices, and the application of heated-air blankets when needed.

Discontinue analgesics, sedatives, and neuromuscular blockade during the rewarming phase. In the landmark studies, Bernard stopped the neuromuscular blockade before 24 hours, while Holzer maintained blockade for 32 hours. Other published protocols call for medications to be held when the core temperature reaches 35.5°C to 36.5°C (95.9°F to 97.7°F). Treat shivering during the rewarming with a warm blanket and low dose meperidine.[27] Care must be taken to avoid hyperthermia/pyrexia (>37.5°C or 99.5°F) by treating with antipyretics and active cooling for 72 hours postarrest. Hypotension and hyperkalemia commonly occur during rewarming.[3] This requires close monitoring of the patient, the ECG tracings, and periodic laboratory analysis.[3]

Detailed protocols for therapeutic hypothermia from several institutions are available through the University of Pennsylvania's Center for Resuscitation Science at http://www.med.upenn.edu/resuscitation/hypothermia/protocols.shtml.

TECHNIQUE FOR PEDIATRIC PATIENTS

Although patients under the age of 18 were excluded from the landmark studies, the 2005 International Liaison Committee on Resuscitation recommends that the induction of hypothermia should be considered for 12 to 24 hours in children who remain comatose after resuscitation from a cardiac arrest. There are currently no published studies of the use of therapeutic hypothermia for pediatric survivors of a cardiac arrest. However, neonates with perinatal asphyxia have been treated successfully with external cooling elements for 72 hours with impressive results.[28] Consult a Pediatric Intensivist and Pediatric Cardiologist prior to inducing hypothermia in a patient under the age of 18 years. After considering the risks and benefits of therapeutic hypothermia, begin induction and maintenance with the techniques described previously.

AFTERCARE

Consult an Intensivist and Cardiologist. Admit the patient to the appropriate Intensive Care Unit. Therapeutic hypothermia requires Intensive Care Unit admission for ventilator management as well as the continuous monitoring of core temperature, cardiac rhythm, blood pressure, and central venous pressure. Sedatives and paralytics are required for patient comfort and shivering control. Obtain laboratory analyses every 4 hours or as clinically indicated. Further bedside cardiac testing or cardiac catheterization laboratory intervention may be performed by a Cardiologist to help determine and treat the precipitating coronary artery disease. Consult a Neurologist for an electroencephalogram (EEG) and other neurological testing to detect seizures and determine patient prognosis.[29]

Standard Intensive Care Unit and postcardiac arrest/acute coronary syndrome care should be applied to all patients after completion of therapeutic hypothermia. Consider the use of deep venous thrombosis prophylaxis with sequential compression devices, subcutaneous heparin, or subcutaneous low molecular weight heparin. Apply lacrilube to the patient's eyes every 4 to 6 hours to prevent a corneal abrasion or corneal ulceration from dry corneas. Consider the use of stress ulcer prophylaxis. Once the 24 hour therapeutic hypothermia period is completed, begin to rewarm the patient and wean any neuromuscular blockade and sedation. Extubation is determined and evaluated on a case-by-case basis.

COMPLICATIONS

Despite the proven safety and benefit of therapeutic hypothermia, Emergency Physicians must be aware of several complications. Shivering during the induction phase increases core temperature and oxygen consumption. Low dose meperidine, buspirone, and magnesium have been reported to lower the shivering threshold in awake hypothermic patients.[27,30] Magnesium sulfate has the added benefits of improving cooling rates through vasodilatation while acting as an antiarrhythmic.[31]

Pulmonary edema may occur with cooled IV fluid boluses. Arrhythmias may occur, especially with the use of endovascular cooling techniques. Hypothermic patients may be more susceptible to infection, especially pneumonia and sepsis. The landmark studies showed only an insignificant trend toward increased sepsis. Postcardiac arrest patients are at high risk of developing pneumonia in the first 48 hours, with aspiration being a key risk factor.[3]

A coagulopathy may occur due to changes in platelet function, clotting factor enzyme function, and fibrinolytic activity. However, thrombolytics, heparin, and aspirin may be safely administered during induction when clinically indicated.[14] A cold diuresis may lead to electrolyte abnormalities including hypophosphatemia, hypomagnesemia, hypocalcemia, and hypokalemia, or hyperkalemia. Hyperglycemia must be avoided to improve neurologic outcomes after cardiac arrest and in all critically ill patients. Increases in amylase and a transient rise in renal markers have been reported but are of unclear significance. Decreased core temperature often prolongs the duration of action of neuromuscular blockers such as Vecuronium as well as sedatives including Versed or Propofol.[32]

The cooling devices themselves may be as source of complications. The endovascular catheter of internal cooling devices increases risk of infections and venous thrombosis similar to any central venous catheter.[24] External cooling devices may cause skin breakdown and tissue necrosis.[23]

SUMMARY

The staggering number of sudden cardiac deaths and the often poor neurologic outcomes of survivors place an enormous burden on the healthcare system. Two well done landmark studies in 2002 clearly demonstrated improved survival and neurologic outcomes in comatose survivors of an out-of-hospital cardiac arrest with an initial rhythm of pulseless ventricular tachycardia or ventricular fibrillation treated with mild therapeutic hypothermia of 32°C to 34°C (89.6°F to 93.2°F) for 12 to 24 hours. These results were incorporated into both the 2005 recommendations by the International Liaison Committee on Resuscitation and subsequently by the 2005 American Heart Association Resuscitation Guidelines. These organizations recommend therapeutic hypothermia for comatose survivors of an out-of-hospital cardiac arrest with an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia. They also recommend the consideration of therapeutic hypothermia in other rhythms and in-hospital cardiac arrests. After establishment of institution-specific multidisciplinary protocols, the induction of therapeutic hypothermia is a straightforward, inexpensive, safe, and effective procedure in any Emergency Department.

189 Hypothermic Patient Management

Gary An and Nabil Issa

INTRODUCTION

Hypothermia is defined as a core body temperature below 35°C. The normal physiologic thermoregulatory responses start to fail once the core body temperature reaches this level, leading to the body's inability to generate enough heat to maintain bodily functions. Hypothermia can be subdivided into primary and secondary hypothermia.[1] Primary accidental hypothermia occurs when a previously normal individual is subjected to an environmental stress. Secondary accidental hypothermia occurs when a predisposing factor leads to disruption of temperature homeostasis and increases the individual's susceptibility to lesser environmental stresses (e.g., drug intoxication, trauma, and endocrine disorders). Drug intoxication and trauma are acquired conditions that are highly associated with the development of hypothermia.[1]

There are multiple reasons why trauma patients are at an increased risk to develop hypothermia. These include extended prehospital time, resuscitation with cold (i.e., ambient air temperature) intravenous fluids, exposure to environmental factors, and physiological characteristics of the trauma itself. Both bleeding and hypoperfusion alter thermoregulation. Hypothermia is an independent contributing factor for increased morbidity and mortality in trauma patients, regardless of the patient's Injury Severity Score (ISS). Hypothermia is associated with an increase in the incidence of coagulopathy, multiple organ failure, length of hospital stay, and mortality.[2]

Significant emphasis has been placed on the prevention of hypothermia as well as the early recognition and correction of hypothermia in the prehospital setting. **It is important to recognize that hypothermia can also progress after the patient arrives in the Emergency Department.** Studies in the trauma population have reported a significant percentage of patients to have a decrease in their core body temperature during their stay in the Emergency Department.[3–5] This recognition has led to the development of multidisciplinary approaches to maintaining normothermia as the patient moves through the hospital.[6] **The importance of continuity and communication in dealing with hypothermia cannot be overstated.**

ANATOMY AND PATHOPHYSIOLOGY

Hypothermia can be characterized as mild, moderate, and severe. Mild hypothermia is defined as a core temperature of 32.2 to 35°C or 90 to 95°F. Moderate hypothermia is defined as a core temperature of 28 to 32°C or 82.4 to 90°F. Severe hypothermia is defined as a core temperature of less than 28°C or 82.4°F. The scale can be amended in the trauma patient to 34 to 36°C or 93.2 to 96.8°F for mild hypothermia, 32 to 34°C or 89.6 to 93.2°F for moderate hypothermia, and <32°C or <89.6°F for severe hypothermia.

Mild hypothermia causes the body to increase heat production by shivering and increasing its metabolic rate. The heart rate increases and the patient may become tachypneic. Peripheral vasoconstriction may result in acrocyanosis. Neurologic symptoms may include confusion, dysarthria, and impaired judgment.

Moderate hypothermia is associated with a further decrease in the mental status. This includes lethargy, hallucinations, and loss of the pupillary reflex. The heart rate changes from tachycardia to bradycardia. The cardiac rhythm commonly converts from normal sinus to atrial fibrillation.[7] The respiratory pattern becomes depressed, with a decreasing respiratory rate and tidal volume. The patient stops complaining of "feeling cold" and shivers less.

The patient is usually comatose by the time severe hypothermia is present, often with evidence of cardiorespiratory collapse. Ventricular irritability becomes evident. Ventricular fibrillation becomes refractory to conversion below 28°C. Asystole occurs at 20°C. The characteristic electrocardiographic (ECG) finding of an Osborne J wave occurs at approximately 32°C (**Figure 189-1**). This is a positive deflection between the QRS and the ST segment. It is often best seen in ECG leads aVL, aVF, and the left chest leads.[8,9] Respiratory drive is increased during the early stages of hypothermia, but progressive respiratory depression occurs below 33°C, resulting in a decrease in minute ventilation. The ciliary action and the cough reflex are also depressed, predisposing to atelectasis and aspiration.

Metabolic problems associated with hypothermia include hyperglycemia (mild hypothermia), hypoglycemia (moderate and severe hypothermia), and impaired oxygen consumption (severe hypothermia). Oxygen consumption per unit time (VO_2) increases dramatically with any fall in body temperature.[10] A core temperature decrease of 0.3°C is associated with a 7% increase in VO_2. Temperature reductions between 0.3 and 1.2°C have been reported to result in a 92% increase in VO_2, with proportional increases in minute ventilation.[10] The resultant increase in oxygen utilization may result in anaerobic metabolism, acidosis, and significant cardiopulmonary stress.[11]

Serum electrolyte changes are often unpredictable in the hypothermic patient. Serum potassium is often slightly increased because of renal tubular dysfunction, acidosis, and the breakdown of liver glycogen. When interpreting blood test results, it is recommended that uncorrected values be used to guide therapy due to

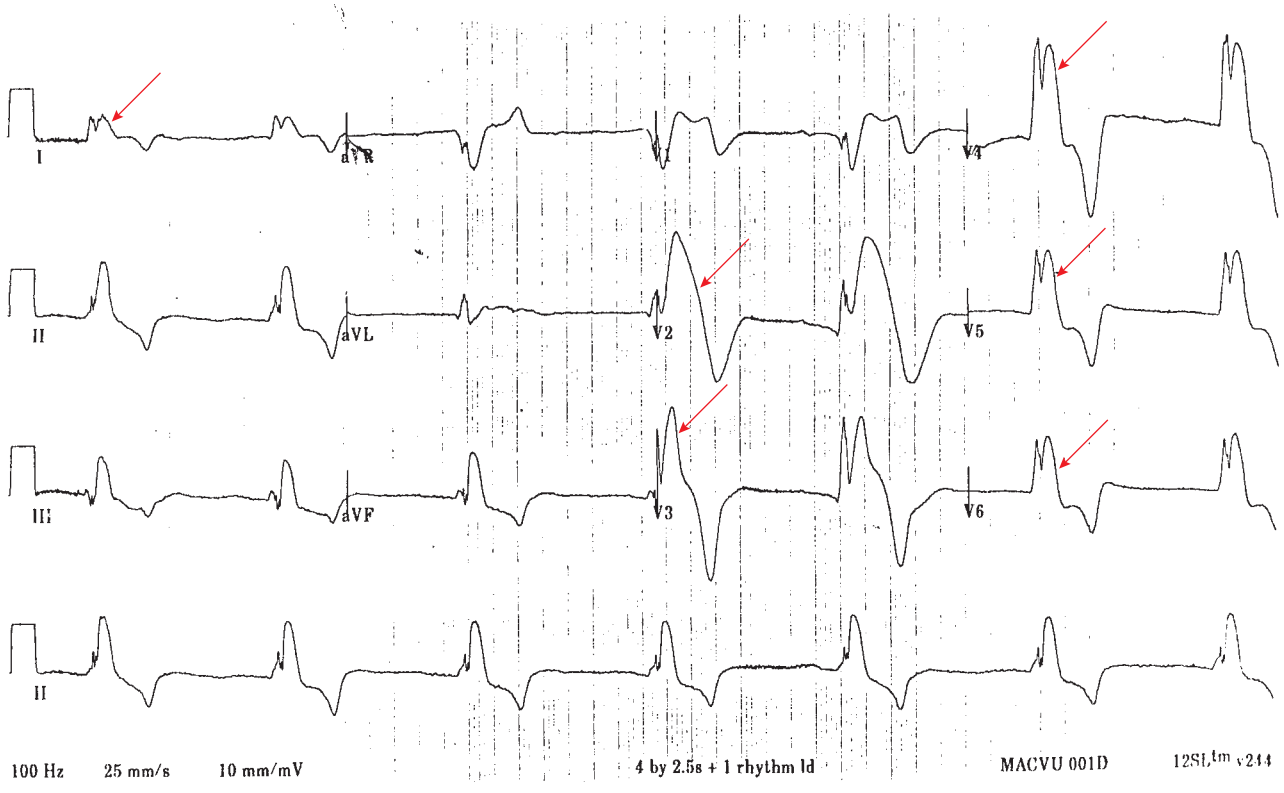


FIGURE 189-1. The Osborne or J wave associated with hypothermia is indicated by the arrows. This patient had a core temperature of 34°C.

the complexities of the acid–base balance associated with hypothermia. These derangements are reversible with rewarming.

Coagulopathy is one of the most clinically significant metabolic derangements seen with hypothermia. Evidence suggests that significantly increased clotting times occur at core temperatures less than 35°C.[1,3] Temperatures less than 32°C lead to severe platelet dysfunction despite normal platelet counts.[1,3] Cold platelets are known to undergo morphologic changes that affect adherence, including loss of shape, cytoplasmic swelling, and dissolution of cytoplasmic microtubules necessary for normal motility. Cold-induced slowing of the enzymatic reaction rate of thromboxane synthetase results in decreased production of thromboxane A2, a potent vasoconstrictor necessary for normal platelet aggregation.[12,13] These derangements are reversible with rewarming. Clotting factor dysfunction is another factor contributing to the coagulopathy in the hypothermic patient. This has been shown to be due to the direct effect of hypothermia on the clotting factors physiochemical activity.[14] It is important to remember that clinical tests of coagulation are temperature standardized to 37°C. Fibrometers contain a thermal block that heats the plasma and reagents to 37°C before initiating the assay. Thus, tests of coagulation reflect clotting factor deficiencies, but are corrected for any potential effect of hypothermia on clotting factor function.

The heat deficit of a hypothermic patient can be calculated using the formula $Q = mc(t_2 - t_1)$, where Q is the heat loss (in kcal), m is the patient's body mass (in kg), c is the specific heat of the body (0.83 kcal/kg/°C), and $(t_2 - t_1)$ is the change in body temperature (°C). Application of this formula will allow the calculation of the amount of heat (in kcal) that must be transferred to a hypothermic patient to regain normothermia, assuming no additional losses. Knowing that the specific heat of water is 1.0 kcal/kg/°C allows one to calculate the expected rate of rewarming given the particular method used.

INDICATIONS

Patients presenting with core body temperatures in the ranges of hypothermia must be identified and treated. **Hypothermia should be easily identified, since a temperature evaluation is a vital sign checked in every patient that comes to the Emergency Department.** Treat all patients who present to an Emergency Department with an awareness of the potential that they can develop hypothermia, especially if they are trauma patients or have an altered mental status. **Cover all patients with warm sheets or blankets as soon as their initial evaluation and any necessary procedures are completed.**

CONTRAINDICATIONS

There are no contraindications to the treatment of accidental hypothermia. There are, however, circumstances in which medically induced therapeutic hypothermia may be of benefit.[15–18] Refer to Chapter 188 regarding the details of inducing therapeutic hypothermia. These situations are beyond the scope of this chapter.

SPECIAL RESUSCITATION CONSIDERATIONS

Certain components of the initial resuscitation of the hypothermic patient deserve mention. **All patients with hypothermia are identified by measurement of core body temperature on admission. Close subsequent monitoring is necessary and required.** The following challenges to routine temperature monitoring, and suggested remedies, were noted in a review article.[9] Poor peripheral perfusion may result in difficulty assessing the pulse and blood pressure, making the use of Doppler ultrasound necessary. Cutaneous probes for temperature and pulse oximetry have difficulty picking up signals in hypothermic patients. Oral and auricular temperature

probes are often inaccurate in the hypothermic patient. Consider using a bladder, esophageal, or rectal temperature probe.

Airway management is often required in patients with moderate and severe hypothermia due to a decreased mental status. Standard orotracheal intubation may be difficult due to jaw muscle rigidity. Neuromuscular blocking agents are not recommended for patients with core body temperatures less than 30°C. The use of topical vasoconstricting agents, smaller endotracheal tubes, and blind orotracheal intubation has been suggested. Fiberoptic guided orotracheal intubation can be utilized if available. Management of ventilated patients must include close monitoring of the endotracheal cuff pressure, as the volume and pressure may increase with patient rewarming. Ventilate patients at rates no greater than 8 to 12 breaths per minute to avoid respiratory alkalosis.[9]

Management of the circulatory system in those with moderate to severe hypothermia often requires fluid resuscitation, as these patients are volume depleted. Dextrose in the initial resuscitation fluid is not contraindicated. **Ringer's lactate solution is not recommended due to concerns about decreased hepatic metabolism of lactate in the hypothermic patient.** Dehydration results in hemoconcentration. Therefore, a low hematocrit suggests an underlying anemia and/or blood loss. **The heart is susceptible to arrhythmias. Avoid transthoracic central venous catheters and pulmonary artery catheters until rewarming has been achieved.** Use intravenous catheters in any of the extremities or the external jugular vein. An alternative is a femoral central line as the catheter and guidewire are not long enough to reach the heart and trigger an arrhythmia.

Treat nonperfusing cardiac rhythms (i.e., ventricular fibrillation, asystole, and junctional ventricular rhythms) using Advanced Cardiac Life Support (ACLS) guidelines. The presence of bradycardia, atrial fibrillation, and other dysrhythmias that do not reduce perfusion do not require pharmacologic support, as these will reverse with rewarming. **Defibrillation at core body temperatures less than 30 to 32°C may not be effective. Continue resuscitative efforts in conjunction with rewarming.**[8,9]

Resuscitation drugs are often ineffective at core body temperatures below 30°C. Lidocaine has decreased efficacy at these temperatures.[8,9] Procainamide has been suggested to increase ventricular fibrillation.[8,9] Bretylium has been demonstrated to be effective in animal studies, though information regarding optimal clinical dosage is not known in this patient group.[8,9] **Use caution when administering and dosing all resuscitation drugs, due to their decreased metabolism in hypothermic patients, which can lead to toxicity.** It is recommended that medications be administered at one-half the normal dose during the resuscitation of a moderately or severely hypothermic patient.[9] Avoid vasopressors due to their potential to cause arrhythmias.[9] Repeat the resuscitation cycle with every increase in core body temperature of 1 to 2°C until a core temperature of 32°C is achieved.[8] **Patients should not be pronounced dead until they are warm (>32°C) and dead.[9]**

FLUID MANAGEMENT

The administration of fluids or blood products can result in hypothermia or worsen it. Infusion of 1 L of crystalloid solution kept at room temperature (21°C) results in a decrease in core body temperature of 0.3°C.[1] **When patients are receiving large volumes of resuscitation fluid, active measures to prevent hypothermia must be taken.** This is even more important in patients receiving blood products, which are kept at 4.0°C. Transfusion of 1 L of blood products leads to a decrease in core body temperature of 0.54°C.[1] **A normothermic patient can be rendered hypothermic quickly when subjected to an aggressive fluid resuscitation.**

One of the mainstays in the prevention of hypothermia during resuscitation is to use fluid warmers to infuse intravenous fluids. Unfortunately, conventional fluid warmers use a coil/sleeve system in a water bath and pose problems at both slow and rapid infusion rates.[19] With a slow infusion rate, there is time for the fluid to reach room temperature in the tubing between the warmer and the patient. With a fast infusion rate, the length of time the fluid is exposed to the water bath is too short to effectively warm the fluid.

These problems have been addressed with two devices, both of which are useful in the Emergency Department. They both warm infused fluid to a temperature of 40°C. The first uses a jacket in which circulating warmed fluid covers the entire length of the intravenous tubing, from the warming device to the patient (Hotline, Sims Level 1, Rockland, MA). This device is more effective than conventional fluid warmers at flow rates between 50 and 6000 mL/h.[19] The second device uses an inline heating unit that warms the fluid rapidly and allows for substantially higher infusion rates (Systems 250/500/1000, Sims Level 1, Rockland, MA). This device can infuse crystalloid solutions or blood products at rates up to 2200 mL/min and is extremely useful in the resuscitation of patients in severe hemorrhagic shock.[19] Similar devices are available from a variety of manufacturers. **Use these devices to administer intravenous fluid to hypothermic patients or to those at risk for developing hypothermia.** These devices may be used as components in some of the techniques described below.

PASSIVE EXTERNAL REWARMING

Perform passive external warming on all patients who are mildly hypothermic or who have normal body temperatures and are undressed. Cover the patient with sheets and blankets as soon as they have been examined and any necessary procedures have been performed. If available, the use of warm blankets and sheets is preferred over those at room temperature.

TECHNIQUES

Remove any wet and/or cold clothing. Dry the patient before applying blankets (Figure 189-2). Blankets and sheets may be kept in a blanket warmer as insulating material cooler than the patient will extract heat. **Prevent secondary injury to the patient from**



FIGURE 189-2. Passive external rewarming. Remove any wet and/or cold clothes. Cover the patient with blankets.



FIGURE 189-3. Active external rewarming with a heating blanket.

blankets and sheets that are too hot. There is no reason for the blankets to be any warmer than normal body temperature for passive external rewarming.

ASSESSMENT

An otherwise healthy and normal patient will increase their core body temperature by 0.5 to 2.0°C/h with passive external rewarming. The body attempts to regain normothermia by increasing its metabolic rate. The patient may manifest evidence of increased cardiopulmonary stress and lactic acidosis during this time.[1]

COMPLICATIONS

Complications occur if attempts are made to place inappropriately heated objects directly on the patient. **Under no circumstances should heated intravenous fluid bags be placed in the axilla or groin, or in any other prolonged contact with the skin.** This may result in thermal injuries ranging from superficial blistering to full-thickness burns. Blankets and sheets that are too warm will also cause damage to the skin.

SUMMARY

Use passive external rewarming as a sole agent in otherwise healthy patients with normothermia who are undressed, patients with mild hypothermia, and as an adjunct to more aggressive rewarming techniques. Always be aware of the possibility of a patient developing hypothermia during their Emergency Department stay.

ACTIVE EXTERNAL REWARMING

INDICATIONS

Perform these maneuvers as sole therapy for patients with mild hypothermia, on awake and otherwise stable patients with moderate hypothermia, and in conjunction with more aggressive rewarming techniques.

CONTRAINDICATIONS

Do not use active external rewarming as the sole therapy for patients with moderate hypothermia who have altered mental status or hemodynamic instability. Active external rewarming is contraindicated as the sole therapy for patients with severe hypothermia (core temperature < 28°C). **There is no significant difference in the rates of rewarming between the different devices used for external rewarming. The use of radiant heaters and heating packs is not currently recommended due to the risk of potential complications and limited efficacy.**[20,21]

EQUIPMENT

- Warm blankets
- Forced air rewarming blankets
- Fluid circulating rewarming blankets
- Water bath and associated supplies

TECHNIQUE

Examine the patient. Determine if the patient is a candidate for active external rewarming. Place a forced air rewarming blanket or a fluid circulating rewarming blanket on the patient (**Figure 189-3**). **Do not place these blankets, particularly the fluid circulating ones, underneath the patient.** Placing the blanket under the patient may lead to excessive thermal transfer to areas with decreased blood flow due to pressure and prolonged time of contact. A thin sheet may be placed between a fluid circulating blanket and the skin. This is not necessary with forced air blankets. Warmed blankets and sheets may be placed over the warming blankets.

Active external rewarming can be accomplished by immersion of the patient in a warm water bath (**Figure 189-4**). This technique is easy, effective, and simple. Immersion therapy of the hypothermic patient is not performed in the Emergency Department for several reasons. The equipment is bulky, not portable, and occupies a fixed space. It is difficult to monitor the patient when immersed. Monitoring leads (e.g., electrocardiography and pulse oximetry) will not adhere to wet skin. The use of electrical monitoring equipment in a water bath should be avoided.

ASSESSMENT

Care must be taken to reassess any wounds for recurrent bleeding, any catheters or monitors for placement, and any pressure areas

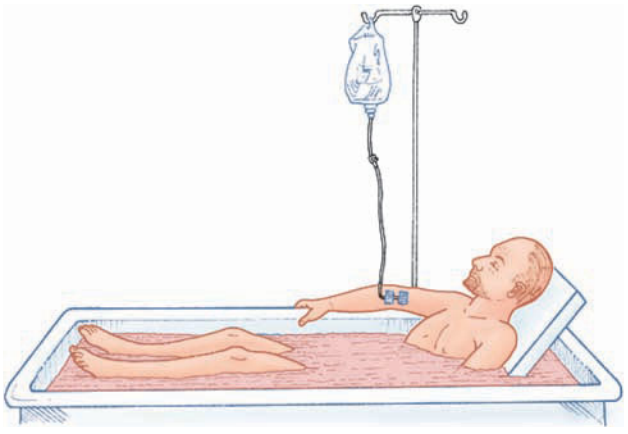


FIGURE 189-4. Active external rewarming with a water bath.

that might be in prolonged contact with the heating elements as the patient is covered with the warming device. With respect to the forced air blankets, check the air source connection to the blanket to make sure that the hot air is not blowing directly onto the patient. A directed flow of hot air onto the patient under the blanket may lead to thermal injury.

COMPLICATIONS

Thermal injuries are associated with active external rewarming. They result from improper use of the devices. Maintain vigilance regarding prevention of a focused delivery of heat to a region of skin, particularly one poorly perfused, to essentially eliminate these burns.

Afterdrop refers to a decrease in core temperature that occurs 15 to 20 minutes after active external rewarming begins.[8] This is thought to be due to vasodilatation of the peripheral tissues as they rewarm and a subsequent washout of cooler peripheral blood back to the central areas. Peripheral vasodilatation can lead to hypotension if fluid resuscitation is inadequate or the patient has cardiovascular compromise. Afterdrop can be attenuated by the concomitant use of core rewarming techniques.

SUMMARY

Active external rewarming is useful in treating moderately hypothermic patients who are awake and alert. Warming rates of 1.0 to 2.5°C/h have been reported.[9] When these devices are being used, frequent monitoring for potential thermal injuries is required in order to prevent secondary injury. This monitoring is easier when the patient is a cooperative partner who can participate in the process. Active external rewarming, like passive external rewarming, is often used in conjunction with more aggressive techniques or core rewarming. The problem of afterdrop is lessened when active external rewarming is used in conjunction with core warming techniques.

AIRWAY REWARMING

Airway rewarming with warmed and humidified oxygen is safe and easily achieved. It can be applied to any hypothermic patient. **However, airway rewarming is never used as a sole means of rewarming.**

INDICATIONS

The technique of airway rewarming may be used in any patient with hypothermia and in conjunction with other techniques. Any patient receiving supplementary oxygen can receive warmed and humidified oxygen. Its efficacy via endotracheal tube is greater than via mask or nasal prongs.

CONTRAINDICATIONS

There are no contraindications to airway rewarming. The more severely hypothermic patient will often need their airway controlled by orotracheal intubation due to a depressed level of consciousness. **Intubation for the sole purpose of airway rewarming is contraindicated.**

EQUIPMENT

- Nasal cannula
- Face mask
- Endotracheal tubes
- Humidifier tank
- Heating circuit
- Oxygen source

TECHNIQUES

Consult the Emergency Department Respiratory Therapist. They will gather, set up, administer, and monitor the required equipment. Connect the humidifier tank and heating circuit in line with the oxygen source. Humidify and warm the inhaled oxygen to 40 to 45°C. A rewarming rate of 1.0 to 2.5°C/h has been reported.[9]

SUMMARY

Airway rewarming can be applied to any hypothermic patient. The oxygen must be humidified to prevent fluid loss from evaporation.

GASTRIC AND BLADDER LAVAGE

These techniques, based on techniques familiar to most Emergency Physicians, are minimally invasive and can be readily performed with minimal interruption of continued resuscitative efforts.

INDICATIONS

These techniques are usually reserved for patients with severe hypothermia. They are rarely used in stable patients and generally reserved for situations where extracorporeal warming is not available.

CONTRAINDICATIONS

The only contraindications to these techniques are the contraindications to the placement of a urethral catheter (Chapter 142) and a nasogastric tube (Chapter 58). Do not perform gastric lavage concurrently with cardiac compressions. Gastric and bladder lavage are of limited value in the management of the hypothermic patient. They are generally bypassed in favor of peritoneal lavage, pleural lavage, and extracorporeal warming.

EQUIPMENT

- Warmed (40°C) intravenous fluid, normal saline or Ringer's lactate
- 60 mL catheter-tip syringe
- See Chapter 142 for urethral catheterization supplies
- See Chapter 58 for nasogastric intubation supplies

TECHNIQUES

Place a Foley catheter (Chapter 142) and/or nasogastric tube (Chapter 58). Confirm proper placement. Instill sterile saline or Ringer's lactate warmed to 40°C. Inject 60 mL aliquots into the tube using the catheter-tip syringe. Instill a total of 300 to 400 mL into the stomach and 200 to 250 mL into the bladder. **Do not overdistend the respective organ.** Gastric overdistention can result in rupture or aspiration. Bladder overdistention can result in rupture and extravasation of fluid. Clamp the Foley catheter or nasogastric tube. Allow the fluid to dwell within the organ for 5 to 10 minutes. Remove the fluid by gravity drainage from the bladder or suction from the stomach. Repeat the process as necessary until the core body temperature increases.

COMPLICATIONS

Gastric lavage may be complicated by perforation of the stomach by either the nasogastric tube or overdistention. Aspiration is a potential complication with gastric lavage. Refer to Chapters 58 and 60 for a more complete discussion of the complications associated with nasogastric intubation and gastric lavage, respectively. Bladder irrigation is safe as long as the bladder is not overdistended. The small surface area of the bladder makes it an inefficient means of rewarming. Refer to Chapter 142 for a more complete discussion of the complications associated with urethral catheterization. Use only normal saline or Ringer's lactate. Do not use sterile water, as it can result in significant volume and electrolyte shifts.

SUMMARY

Perform gastric or bladder irrigation only if other types of body cavity rewarming are contraindicated. These techniques are easily initiated using standard equipment in an Emergency Department. These organs have relatively small surface areas, making these techniques inefficient. Overdistention can result in serious complications.

PERITONEAL LAVAGE

This technique is invasive, based on techniques familiar to most Emergency Physicians, and can be readily performed with minimal interruption of resuscitative efforts.

INDICATIONS

This technique is usually reserved for patients with severe hypothermia. It is rarely used in stable patients and generally reserved for situations where extracorporeal warming is not available.

CONTRAINDICATIONS

Suspicion of injury to a hollow viscus is a contraindication to this technique. The presence of a previous laparotomy scar is a strong relative contraindication. The use of an open peritoneal lavage technique does not mesh well with the continuous infusion of fluid required for this procedure. Other contraindications are those associated with performing a diagnostic peritoneal lavage (Chapter 66).

EQUIPMENT

- Warm (40°C) intravenous fluid, normal saline or Ringer's lactate
- Warm (40°C) peritoneal dialysis fluid
- Fluid infuser device, optional
- Peritoneal lavage kits
- See Chapter 66 for peritoneal lavage supplies
- See Chapter 58 for nasogastric tube supplies
- See Chapter 142 for Foley catheter supplies

A commercially available, disposable, single-patient use peritoneal lavage kit is available from numerous manufacturers. The kit includes all the material required to perform a closed or semi-open diagnostic peritoneal lavage except lavage fluid. An example is the Arrow kit (Arrow International, Reading, PA). It contains 10% povidone iodine or chlorhexidine swabs, gauze squares, fenestrated drape, tubing for the administration of intravenous fluid, 1% lidocaine, 5 mL syringes, 22 and 25 gauge needles, an 18 gauge × 2.5 inch introducer needle, an 0.89 mm × 45 cm J-tipped guidewire, an 8 French lavage catheter, and a #11 scalpel blade on a handle. Refer to Chapter 66 for a more complete list of equipment.

TECHNIQUE

Prepare the patient by placing a nasogastric tube (Chapter 58) and a Foley catheter (Chapter 142). Place two peritoneal lavage catheters, one supraumbilical and one infraumbilical (**Figure 189-5**). Refer to Chapter 66 for complete details regarding placement of the peritoneal lavage catheters. Confirm the position of the catheters. Clamp the infraumbilical catheter. Infuse warm (40°C) intravenous fluid or peritoneal dialysis fluid through the supraumbilical catheter using the Level 1 infuser or a Hotline fluid warmer. The use of dialysate has the added benefit of potentially correcting some electrolyte abnormalities.[8,9] The fluid may be infused manually, but this technique is much less efficient. Infuse 1 to 2 L of fluid. Allow the fluid to bathe the peritoneal cavity for 10 minutes. Remove the clamp on the infraumbilical catheter and allow the fluid to drain from the peritoneal cavity. Repeat the procedure. Up to 10 L/h of

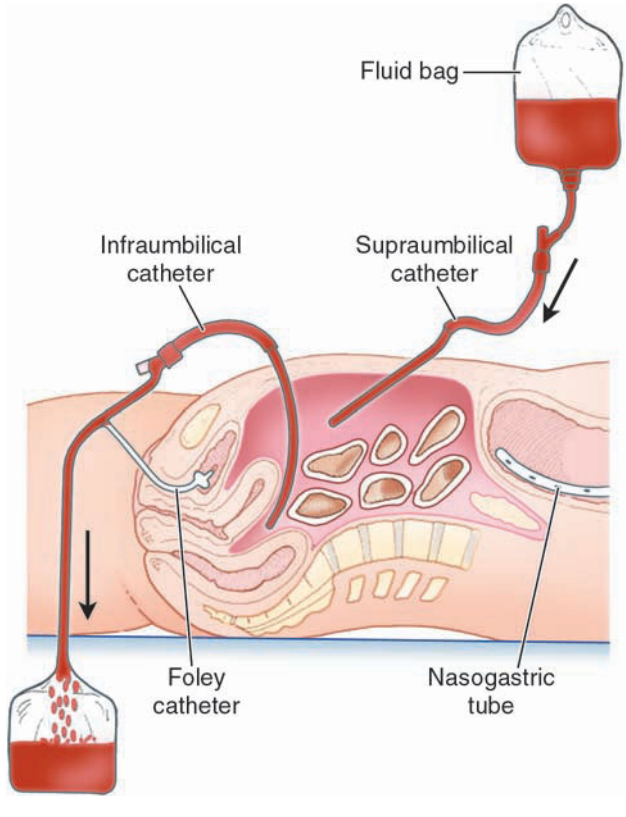


FIGURE 189-5. Active core rewarming with peritoneal lavage.

fluid may be infused in this fashion.[9] An alternative technique is to allow the fluid to flow at a moderate rate and continuously through the supraumbilical catheter, into the peritoneal cavity, and out the infraumbilical catheter. This can be performed manually or with a commercial device developed for this purpose (Veratherm Portable Hyperthermic Perfusion System, Thermal Therapeutic Systems Inc., Pittsburgh, PA).

COMPLICATIONS

The potential complications are primarily associated with the placement of the peritoneal lavage catheter. Refer to Chapter 66 for the details regarding these complications. The infusion and removal of the fluid are safe. Avoid using highly hyperosmolar peritoneal dialysates in patients with persistent hypovolemia or with a questionable perfusion status as this may worsen existing hypovolemia. Do not use sterile water, as it can result in significant volume and electrolyte shifts.

SUMMARY

Peritoneal lavage is the most widely recognized means of body cavity lavage. This is due in part to the familiarity of many Emergency Physicians with the diagnostic peritoneal lavage procedure. It has the advantage of being able to be performed concurrently with chest compressions and other resuscitative efforts. This technique can raise the core body temperature by 1 to 3°C/h.

PLEURAL LAVAGE

This technique is invasive, based on techniques familiar to most Emergency Physicians, and can be readily performed with minimal interruption of resuscitative efforts. Pleural lavage can be performed closed (via a tube thoracostomy) or open (via a thoracotomy incision).

INDICATIONS

This technique is usually reserved for patients with severe hypothermia. It is rarely used in stable patients and generally reserved for situations where extracorporeal warming is not available.

CONTRAINDICATIONS

The presence of a pneumothorax and/or hemothorax is the only contraindication to pleural lavage.

EQUIPMENT

- See Chapter 39 for tube thoracostomy supplies
- Warm (40°C) intravenous fluid, normal saline or Ringer's lactate
- Warm (40°C) peritoneal dialysate
- Fluid infuser device, optional

TECHNIQUE

Place two chest tubes into the same pleural space, either the left or the right side, to perform closed pleural lavage (**Figure 189-6**). The left side is preferred by those who believe that the heart, aorta, and blood within the aorta will be warmed quicker than with right-sided chest tubes. Refer to Chapter 39 for the full details regarding chest tube placement. Place one tube anteriorly in the second or third intercostal space at the midclavicular line (**Figure 189-6**). Place the other tube posteriorly in the fifth or sixth intercostal space at the posterior axillary line (**Figure 189-6**). Secure the tubes

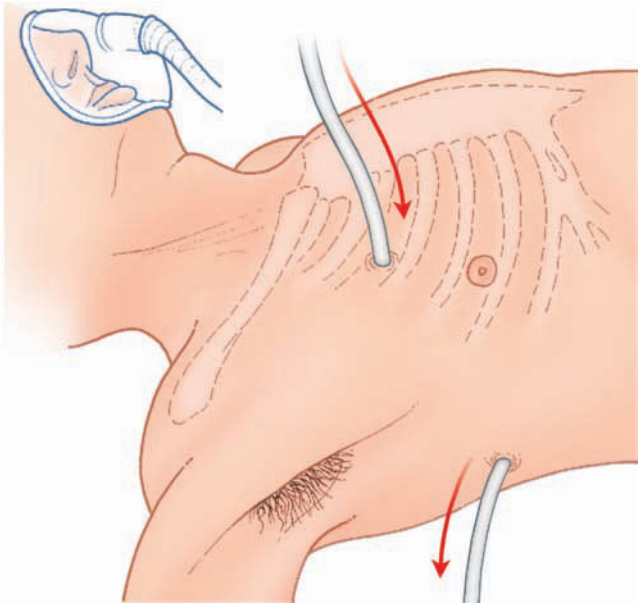


FIGURE 189-6. Active core rewarming with closed pleural lavage.

to the chest wall with suture and tape. Attach the fluid infuser to the anterior chest tube using a Christmas tree adapter. Apply a pleural drainage device to the posterior chest tube in the usual fashion. Infuse warm (40°C) fluid via the fluid infuser device at a rate of 180 to 550 mL/min.[8] Allow the fluid to exit into the pleural drainage device. The fluid will flow into the anterior chest tube, bathe the structures in the hemithorax (i.e., great vessels, heart, lung, and mediastinum), and exit via the posterior chest tube. This can be performed manually or with a commercial device developed for this purpose (Veratherm Portable Hyperthermic Perfusion System, Thermal Therapeutic Systems Inc., Pittsburgh, PA).

Pleural lavage may be performed using an open technique (**Figure 189-7**). This technique is used when a thoracotomy is indicated for other purposes, such as penetrating trauma or to perform open cardiac massage. Refer to Chapter 42 for full details regarding a thoracotomy. **Do not use this technique for the sole purpose of rewarming if other, less invasive or extracorporeal techniques**

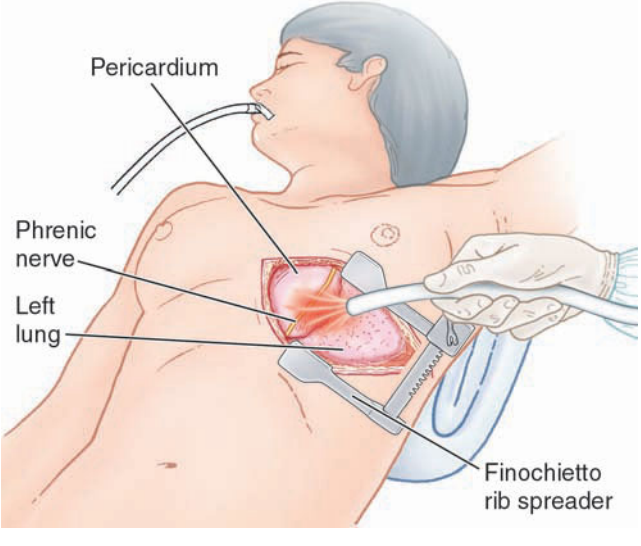


FIGURE 189-7. Active core rewarming with open pleural lavage.

are available. The advantage of open pleural lavage is that it allows direct cardiac rewarming and open cardiac massage.

COMPLICATIONS

The complications are primarily associated with the placement of the chest tube. Refer to Chapter 39 for the full details regarding these complications. Maintain free drainage of the irrigation fluid to avoid increasing the intrathoracic pressure.

SUMMARY

Closed pleural lavage is an effective means of rewarming. It can increase the core body temperature by 1 to 5°C/h. It is very similar in efficacy to peritoneal lavage. Chest tube placement is slightly more challenging than placement of a peritoneal lavage catheter. Free drainage is usually easier to achieve and maintain with a chest tube than with a peritoneal lavage catheter. The two techniques may be employed simultaneously and carried out in conjunction with other resuscitative measures.

EXTRACORPOREAL REWARMING

Extracorporeal rewarming is the most aggressive, effective, and efficient technique to correct severe hypothermia. It includes the use of hemodialysis, arteriovenous rewarming, venovenous rewarming, continuous venovenous hemofiltration, cardiopulmonary bypass, and extracorporeal membrane oxygenation. The choice between the techniques is made on the basis of available resources and the Emergency Physician's familiarity with each technique. Cardiopulmonary bypass is discussed but should not be performed by anyone who is not a Surgeon familiar with the procedure.

HEMODIALYSIS

Hemodialysis is readily available in most institutions. It requires the placement of a central venous line. The only contraindications to hemodialysis are those associated with central venous line placement (Chapter 49) and hemodialysis. An advantage of hemodialysis is that associated drug toxicity or significant electrolyte abnormalities can be simultaneously managed as the patient is being rewarmed.

EQUIPMENT

- See Chapter 49 for central line equipment
- Dual-lumen percutaneous hemodialysis (Quinton or Mahurkar) catheter
- Dialysis machine
- Dialysis nurse or technician
- Warmed (40°C) dialysis fluid

TECHNIQUE

Place a hemodialysis catheter into a femoral vein. Refer to Chapter 49 for the full details regarding the placement of a double-lumen central venous line. The catheter may be placed into a subclavian vein if femoral vein access is contraindicated. Femoral vein placement decreases the risk of inducing an arrhythmia with the guidewire.[9] There is a tendency to have fewer problems related to the positioning of the catheter and achieving appropriate flow rates with femoral catheters. Instruct the hemodialysis technician to set the temperature control on the dialysis machine to deliver a blood temperature of 40°C. Attach the dialysis machine tubing to the lumens of the catheter. Begin hemodialysis.

COMPLICATIONS

The potential complications are primarily associated with the placement of the central venous line. Refer to Chapter 49 for the details regarding these complications. The hemodynamic status of hypotensive patients may become worse upon initiation of hemodialysis, but this technique has been successfully used on such patients.[9]

SUMMARY

Hemodialysis is available at most institutions and is effective in rewarming a patient. The limitations of this technique include the need to have a dialysis technician or nurse available, the time required to obtain on-call personnel, and the time required to set up the equipment. Hemodialysis is a viable option for the rewarming of a hypothermic patient when other forms of extracorporeal warming are not available.

ARTERIOVENOUS REWARMING

This technique was initially described in 1992.[22,23] The authors described placing one large-bore catheter in the femoral artery and another in a central vein (i.e., femoral, internal jugular, or subclavian). This method allows for rewarming in the Emergency Department without the need for specialized equipment (dialysis or bypass machine) and personnel.

CONTRAINDICATIONS

Hypotension or the lack of a blood pressure makes this method moot. Known occlusive arterial disease, particularly in the iliofemoral region, is a relative contraindication.

EQUIPMENT

- See Chapter 49 for central line equipment
- Two 8.5 French introducer catheters
- Two 10 French single-lumen arteriovenous hemofiltration catheters
- Sims Level 1 System 250/500/1000 Fluid Rewarmer
- Luer-lock adapter, male-to-male
- Warmed (40°C) saline

TECHNIQUE

Place two catheters, one in the femoral artery and one in a central vein. Refer to Chapter 49 regarding the placement of a central venous catheter. The placement of the arterial catheter is similar to that of the venous catheter.

The tubing for the Level 1 rapid infuser consists of two intravenous spike-tipped lengths that come together in a Y. The Y then runs to a countercurrent warming chamber and then to the patient. Cut off the spike tip from one of the limbs of the Y and attach the male-to-male Luer-lock adapter. Note that if the rapid fluid infuser is a Sims Level 1 System 500, an additional length of wide-bore intravenous tubing may be needed to bridge the distance between the arterial catheter and the fluid-warmer tubing. This version of the Level 1 may be too tall to allow direct connection of one of the limbs to the arterial catheter. Connect this limb to the arterial catheter. Connect the other arm of the Y to a bag of intravenous fluid with the roller clamp closed.

Allow the system to prime with blood under the patient's arterial pressure. Connect the primed distal end of the tubing to the central venous catheter. The blood will travel via the arterial catheter

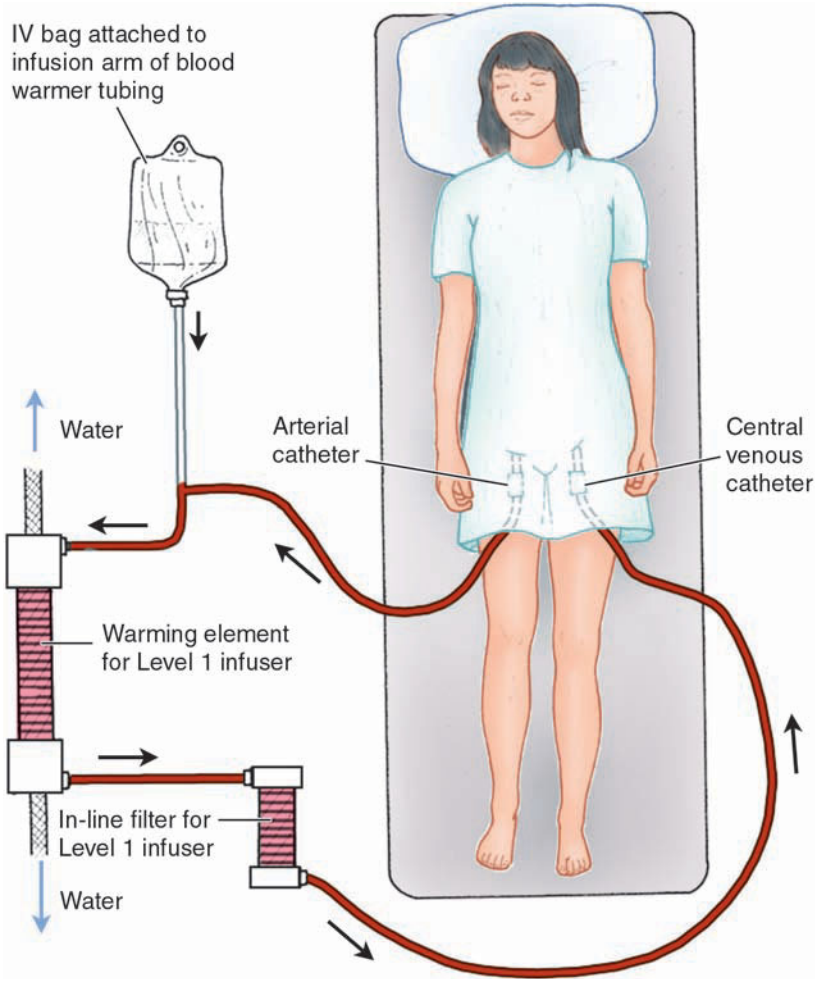


FIGURE 189-8. Arteriovenous rewarming.

to the extracorporeal circuit and through the proximal limb of the tubing to the warming chamber of the Level 1 infuser, through the heating elements to the distal tubing, and back to the patient via the venous catheter (**Figure 189-8**).

The driving force in this circuit is the patient's systemic blood pressure. Low-flow states will limit the efficacy of the system. However, you may use a pressure infusion of intravenous fluid via the other limb of the Y to augment flow. This fluid will be warmed as it reaches the patient, since this other limb of the Y is proximal to the warming element. Systemic anticoagulation is not required, as the tubing for the Level 1 infuser is heparin-bonded. Arteriovenous rewarming is faster and more efficient than venovenous rewarming.[33]

COMPLICATIONS

The complications outlined in the initial description of the procedure include the inability to achieve vascular access, a small hematoma at the arterial puncture site, and ischemia of the limb distal to the arterial catheter.[22] Refer to Chapters 49 and 57 for a full description of the complications that may arise in placing a central venous catheter and arterial catheter, respectively.

SUMMARY

Arteriovenous rewarming is an innovative means by which severely hypothermic patients may be rapidly rewarmed without the resources of a dialysis or bypass pump technician. Flow rates of 225 to 375 mL/min are achieved when the patient's systolic blood pressure is greater than 90 mmHg.[22] This technique transfers 94 to 157 kcal/h back to a patient with core temperature of 32°C.[22]

VENOVENOUS REWARMING

This technique is rarely utilized by Emergency Physicians due to the lack of a venous roller pump and inexperience with this piece of equipment. The technique is briefly described for the sake of completeness. The venovenous technique has two main advantages over arteriovenous rewarming. First is the lack of arterial cannulation, with its potential for limb ischemia. The second is nonreliance on systemic blood pressure/perfusion to drive the system. Flow may be independently determined and delivered by the roller pump. This may be particularly important in the severely hypothermic patient who presents in full cardiorespiratory arrest. The primary disadvantage of this technique is the requirement of expertise in using the roller pump, though advances in design may obviate this in the future.

CONTRAINDICATIONS

Persons not familiar with the function and operation of a venous roller pump should not attempt this technique.

EQUIPMENT

- See Chapter 37 for central line equipment
- Two 8.5 French introducer catheters

- Two 10 French single-lumen arteriovenous hemofiltration catheters
- Sims Level 1 System 250/500/1000 Fluid Rewarmer
- Luer-lock adapter, male-to-male
- Venous roller pump
- Warmed (40°C) saline

TECHNIQUE

The setup for this technique is similar to that for arteriovenous rewarming. Place two catheters, one in the femoral vein and one in another central vein. Refer to Chapter 49 for the details regarding the placement of a central venous catheter. Alternatively, place a dual-lumen hemodialysis catheter.[24] However, if the latter course is to be followed, make sure that the "outflow" port of the catheter is upstream and that the "inflow" port is downstream. This helps to reduce the amount of warmed fluid returning from the circuit that is immediately withdrawn by the roller pump. Place the venous roller pump in line with this circuit, usually between the patient and the warming elements. Adjust the flow rate within the tolerances of the particular device being used.

COMPLICATIONS

The primary complication associated with use of venous roller pumps is an air embolus. This usually happens when the roller pump is operated by a person unfamiliar with it. Recent advancements in roller-pump technology have made their operation simpler and safer. Refer to Chapter 49 for a complete description of the complications that may arise due to the placement of a central venous catheter.

SUMMARY

Venovenous rewarming is one step away from cardiopulmonary bypass. Its use in the Emergency Department is limited due to lack of equipment availability and familiarity. It is a viable option if a roller pump is available as well as a Physician familiar with this procedure.

CONTINUOUS VENOVENOUS HEMOFILTRATION

Continuous venovenous hemofiltration (CVVH) machines have become more widely available, making this an attractive means of rewarming. The use of CVVH machines has largely replaced the previously described venovenous rewarming technique. This technique has two main advantages over arteriovenous rewarming. First is the lack of arterial cannulation, with its potential for limb ischemia. The second is nonreliance on systemic blood pressure/perfusion to drive the system. The use of CVVH in the management of moderate-to-severe accidental hypothermia has been shown to be rapid, safe, and effective.[23,25]

CONTRAINDICATIONS

Persons not familiar with the function and operation of a CVVH machine should not attempt this technique.

EQUIPMENT

- See Chapter 49 for central line equipment
- Dual-lumen percutaneous hemodialysis (Quinton or Mahurkar) catheter
- CVVH Dialysis machine
- Dialysis nurse or technician, trained ICU nurse
- Warmed (40°C) dialysis fluid

TECHNIQUE

As with standard hemodialysis techniques, rewarming with CVVH utilizes a single intravenously inserted, dual-lumen catheter placed in a central vein and connected to the CVVH dialysis machine. Some CVVH dialysis machines have a built-in thermostat allowing for temperature control while others depend on circulating already warmed dialysis fluid bags. Passive and/or active external rewarming maneuvers should be used in conjunction to the CVVH technique. Continuous cardiopulmonary monitoring and frequent monitoring of core body temperature should be undertaken.

COMPLICATIONS

Recent advancements in CVVH technology have made their operation simpler and safer, particularly in terms of the prior concern over an air embolism. However, their use should be restricted to individuals familiar with the operation of these devices. Refer to Chapter 49 for a complete description of the complications that may arise due to the placement of a central venous catheter.

SUMMARY

CVVH is one step away from cardiopulmonary bypass. Its use in the Emergency Department is limited due to lack of equipment availability and familiarity. It is a viable option if the equipment is available as well as a Physician familiar with this procedure.

CARDIOPULMONARY BYPASS

Discussion of this technique is limited to some basic properties of rewarming with cardiopulmonary bypass. This technique should not be attempted by anyone who does not regularly use bypass modalities and without the support of an experienced pump technician. This technique represents the last resort of rewarming techniques. Bypass is usually achieved using femoral-femoral bypass. The cardiopulmonary bypass pump can provide complete hemodynamic and respiratory support during the resuscitation.[26–28] Core body temperatures can be raised 1 to 2°C every 3 to 5 minutes with flow rates of 2 to 3 L/min. If available, use heparin-bonded tubing to avoid systemic anticoagulation, which can worsen existing coagulopathies. The limitations of this technique are that it is extremely resource-intensive, not readily available in many institutions, and requires specific expertise with respect to surgical and mechanical techniques.

EXTRACORPORIAL MEMBRANE OXYGENATION

Although extracorporeal membrane oxygenation (ECMO) technology is a staple in most major Pediatric Intensive Care Units across the world, it continues to be rarely utilized in the adult population. The experience in utilizing ECMO for the management of accidental hypothermia in the adult population is limited to several case reports in the literature.[29,30] Similar to cardiopulmonary bypass, ECMO can be utilized in those patients with complete cardiac arrest and hypoxemia. Hypoxemia and asphyxia are recognized as major predictive adverse factor for survival and/or poor neurological outcome in the hypothermic patient.[31,32] ECMO provides appropriate support for both cardiac as well as pulmonary

functions with the added benefit of allowing for hemodialysis for restoration of electrolyte abnormalities and acid–base imbalances. Further description and discussion of this technique is beyond the scope of this textbook.

ALTERNATIVE TECHNIQUES

There has been much research in the last decade regarding the induction of therapeutic hypothermia. This research has primarily focused on those with brain injury, postcardiac arrest, and stroke. This has resulted in the development of a variety of externally applied and internally applied cooling devices. While not specifically designed to treat hypothermia, they can easily be used to manage the hypothermic patient.[34] Refer to Chapter 188 for a discussion of these methods and devices.

SUMMARY

The management and prevention of hypothermia in the Emergency Department is a challenging and perpetual task. The resuscitation of a severely hypothermic patient in full cardiorespiratory arrest can push the Emergency Physician and the Emergency Department to the limit of their abilities and resources. The real challenge in dealing with hypothermia lies in recognizing and managing the risk of hypothermia in the "routine" patient who presents every day. It is not possible to overstate the importance of continuity of care and the necessity of good communication as the patient is moved from the Emergency Department to either the Operating Room or the Intensive Care Unit, so that rewarming efforts may continue.

190 Hyperthermic Patient Management

Eileen F. Couture

INTRODUCTION

The heatstroke victim can be difficult and challenging, even after a successful resuscitation and stabilization in the Emergency Department. Heatstroke is a multisystem insult. More than 300 people die of heat-related illness in the United States each year.[1] This number was surpassed in a single week in 1995 during a heat wave in Chicago.[2–6] This heat wave resulted in more than 400 deaths and 3300 Emergency Department visits. Although heatstroke is an uncommon medical emergency, it is considered one of the most important of all the environmental heat illnesses because of its potential for high morbidity and mortality in large numbers.[7] Major complications of heatstroke include seizures, adult respiratory distress syndrome (ARDS), acute renal failure, liver disease, rhabdomyolysis, disseminated intravascular coagulation, and death.[8] Survival is possible for the great majority of patients with rapid recognition and aggressive management.

The most effective means of cooling remains controversial. The techniques rely upon prompt recognition of symptoms, immediate intervention in the field, and immediate intervention in the Emergency Department. Begin cooling the patient in the prehospital setting by removing the patient from the heat stress, keeping their skin wet, and fanning the patient in transport. **The patient must be exposed adequately and cooling must be initiated in the quickest and most efficient manner possible as stabilization is occurring.**

Cooling measures must be modified to avoid hypothermia once the core temperature reaches 39°C or 102°F. Decreasing the core body temperature to less than 39°C or 102°F within 30 minutes of presentation improves survival.[4] **Cooling must precede the investigation for the cause. Evaporation and convection are the simplest and most efficient means of cooling victims of heatstroke or heat exhaustion.** Evaporation of 1 g of water dissipates approximately seven times more heat than melting the same quantity of ice.[4] Skin blood flow is preserved as compared with the use of ice, because evaporation and convection are much more efficient modes of heat exchange.[9]

The information in this chapter primarily pertains to hyperthermia from heat-related illness. Despite this, some of these techniques may be used for other causes of hyperthermia. These include endocrine disorders, head injury, infection, intracranial hemorrhage, malignant hyperthermia, neuroleptic malignant syndrome, sepsis, serotonin syndrome, stroke, toxins, or other causes. Consider discussing the use of these techniques to treat hyperthermia with the appropriate consultant if the etiology is not heat-related.

ANATOMY AND PATHOPHYSIOLOGY

Heat-related illness comprises a spectrum of symptoms ranging from mild heat edema to heatstroke. Heat edema is self-limited. The patient presents with edema of the hands, feet, and ankles. This usually occurs in the first few days of heat acclimatization. Heat cramps occur most often in individuals who sweat profusely and are exercising or walking. The patient consumes water without salt, resulting in hyponatremia and muscle cramps. Heat syncope is dizziness or syncope after exposure to high temperatures. It is caused by vasodilatation and consequent postural hypotension. Heat exhaustion results from the excessive loss of body water, electrolytes, or both. The patient may complain of headache, nausea, vomiting, malaise, and myalgias. Heat exhaustion is distinguished from heatstroke by a normal mental status and, generally, a temperature below 39°C or 102°F.[2,8]

Heatstroke must be suspected in any patient who has acute mental status changes or other signs of central nervous system dysfunction in the setting of a high temperature and a history of heat exposure. The initial temperature is usually at least 40 to 42°C or 104 to 108°F. Central nervous system dysfunction may manifest as varying degrees of confusion, obtundation, seizures, delirium, or focal deficits.

Core body temperature is maintained within close limits by a balance between heat production and heat dissipation. Muscular and metabolic activity generates heat. Most fevers encountered are a response to microbial invasion. Some fevers are due to exposure to high temperatures or abnormalities in the thermoregulatory apparatus.[10] Heatstroke may occur in previously healthy individuals who are subjected to severe environmental thermal stress, usually during extreme physical exertion. It may occur in patients with compromised homeostatic mechanisms who are subjected to lesser degrees of exposure (classic heatstroke). Factors that may compromise protective thermoregulatory mechanisms include chronic illness, psychiatric disorders, cardiovascular disease, endocrine disorders, nutritional deficiencies, metabolic disorders, infection disorders, medications, substance abuse, poor judgment, or extremes of age (**Table 190-1**).[8]

It has been speculated that oxidative phosphorylation becomes uncoupled and enzyme systems cease to function when temperature regulation is lost and the core body temperature exceeds 42°C or 108°F. Energy stores become depleted as maximum metabolic demands escalate. This causes the cell membranes to become increasingly permeable, thus increasing sodium influxes. These phenomena have been postulated to be part of a positive feedback loop involving progressive depletion of ATP, increased ion flux,

TABLE 190-1 Factors Related to Heat Illness

Illness	Medications	Behaviors	Groups	Toxins
Autonomic neuropathies	Anticholinergics	Confining garments	Athletes	Alcohol
Cardiovascular disease	Antihistamines	Hot environments	Elderly	Amphetamines
CNS tumors	Diuretics	Inability to care for self	Infants	Cocaine
Dehydration	Lithium	Injudicious exertion	Military recruits	Hallucinogens
Delirium tremens	MAO inhibitors	Poor fluid intake	Neonates	
Diabetes	Phenothiazines	Social isolation	Prior heatstroke	
Hyperthyroidism	Sympathomimetics		Psychiatric	
Major burn scarring	Tricyclic antidepressants			
Parkinson's disease				
Pheochromocytoma				
Psychosis				
Thyroid storm				

CNS, Central nervous system; MAO, monoamine oxidase.

increased rates of membrane depolarization and neurotransmitter activity, and a subsequent increase in heat production. Cell membranes eventually lose their integrity. Heat production accelerates, proteins denature, and widespread necrosis occurs as temperature-control mechanisms fail, leading to organ failure. Cellular damage occurs as a result of the elevated temperatures and the length of exposure to heat.[8,11,12] Tissues at greatest risk for heat-related damage include the vascular endothelium, neural tissue, hepatocytes, and the kidneys.

Heat is dissipated by a combination of radiation, convection, conduction, and evaporation.[10] Radiation is the transfer of heat to objects not in direct contact with the subject. Radiation accounts for approximately 65% of heat loss in cool environments. It is a major source of heat gain in hot climates. Convection is the transfer of heat to circulating fluid or gas. The amount of heat dissipated by convection becomes minimal as ambient temperature rises. Convective heat loss varies directly with wind velocity. Conduction is the direct transfer of heat to another object by direct contact. Evaporation is the conversion of a liquid to the gaseous phase. Evaporation becomes the dominant mechanism of heat loss as ambient temperatures rise.[4,11]

INDICATIONS

Cooling will not harm patients who are hyperthermic, regardless of the etiology. Cooling can be lifesaving in those with true heatstroke. Heatstroke may be difficult to identify if cooling was initiated in the field and the patient's mental functioning is intact. **Initiate cooling immediately if there is any doubt.**[8]

CONTRAINDICATIONS

Patient stabilization always remains the top priority. Assess the patient's airway, breathing, and circulation first, despite the need for immediate cooling. Any life-threatening or limb-threatening conditions must be addressed simultaneously or before proceeding to cooling measures.

Do not initially waste time with typical fever treatments. The use of antipyretics such as acetaminophen and nonsteroidal anti-inflammatory drugs are not effective in treating hyperthermia due to heat-related illness. Do not administer medications used to treat malignant hyperthermia, neuroleptic malignant syndrome, or serotonin syndrome.[13] These treatments do not work for heat-related hyperthermia.

There are specific contraindications to the individual cooling techniques. Iced gastric lavage is contraindicated in patients with altered mental status or depressed airway reflexes unless the patient is endotracheally intubated. It is also contraindicated if nasogastric intubation (Chapter 58) is contraindicated. Iced peritoneal lavage is contraindicated if the placement of a peritoneal lavage catheter (Chapter 66) is contraindicated. Refer to Chapters 58 and 66 for the complete details of placing these devices.

EQUIPMENT

- Core thermometer (e.g., esophageal, rectal, or urinary)
- Large fans
- Spray bottles with a misting nozzle
- Water
- Ice
- Immersion tub
- Ice packs
- Wet sheets and towels
- Cooling blanket
- Peritoneal lavage kits
- Nasogastric tubes
- Iced saline

PATIENT PREPARATION

Immediately remove the patient from the heat-stress environment. Explain the cooling techniques to be employed to the patient and/or their representative. Remove the patient's clothes. Stabilize the patient's airway, breathing, and circulation as necessary. **Patient outcome is directly related to the length of time the tissues are exposed to the thermal challenge.** Cooling rates should not exceed 0.1 to 0.2°C per minute. Apply cardiac rhythm monitoring, a noninvasive blood pressure cuff, and pulse oximetry. Place an esophageal (if the patient is intubated), rectal, or urinary temperature probe to monitor the patient's core body temperature.

TECHNIQUES

EVAPORATION

This technique is simple and causes very little to no discomfort to the conscious patient. An additional benefit is access to the patient should other interventions be necessary.[4] Wet the exposed patient with tepid water. Place large and powerful fans to strategically direct high-flow air currents toward the patient's head, feet, and

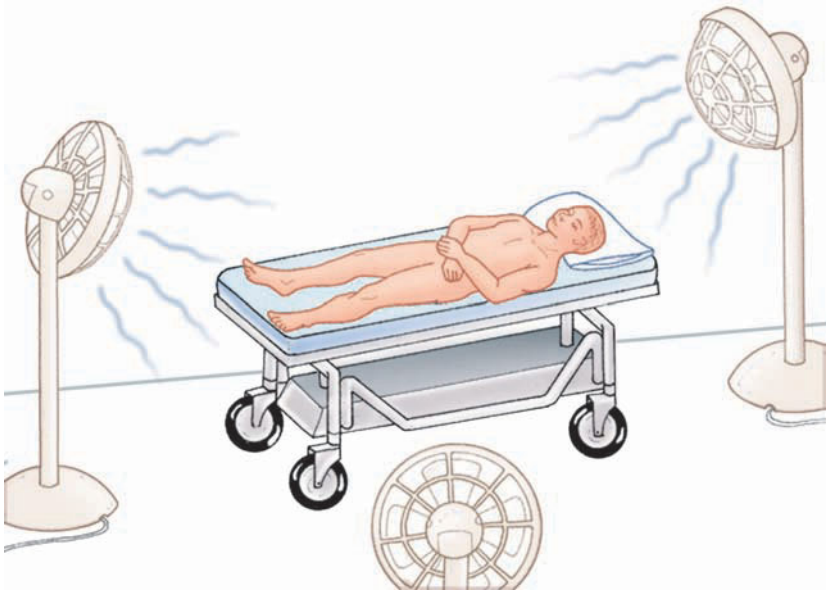


FIGURE 190-1. Evaporation using large fans at the head, foot, and side of the bed to direct high-flow air currents.

torso (**Figure 190-1**). Spray the patient with a mist of water from the spray bottles. Keeping the patient "wet and windy" provides a state-of-the-art cooling method for even the smallest Emergency Department without the need to purchase new or specialized equipment. Place ice packs wrapped in wet towels on the patient's groin, axilla, and neck.

Discontinue evaporative cooling when the core body temperature reaches 39°C or 102°F. Continued cooling can result in hypothermia as the core temperature continues to decrease after evaporative cooling is discontinued. Monitor the patient to ensure that their core body temperature does not increase.

The concept of evaporative cooling gained popularity with the Makkah Body Cooling Unit (BCU). The BCU is used today to provide field treatment for people participating in the annual pilgrimage to Mecca who may develop heatstroke. The BCU has been found to provide the fastest core temperature cooling rates of 0.31°C/min.[11]

ICE WATER IMMERSION

Immersion in an ice water bath is a common method of cooling heatstroke patients. Place the patient in a tub of ice water for 10 to 40 minutes (**Figure 190-2**). Briskly massage the patient's extremities to maintain peripheral circulation and promote heat loss.



FIGURE 190-2. Ice water immersion to cool a hyperthermic patient.

Monitor the patient's core temperature carefully. Rectal temperatures will decrease approximately 0.16 to 0.21°C/min.[8,11]

Ice water immersion is recommended by some authors as the initial technique for hyperthermia management.[6,13,14] Unfortunately, it has limited use in the Emergency Department.[4,11] Preparing an ice bath can result in a delay in cooling the patient. Contact with the ice water results in intense vasoconstriction, which blocks heat exchange, paradoxically increases core body temperature, induces shivering, and is uncomfortable for the patient. Heat transfer from the core to the surface is reduced. The practical issues of impairing access to the patient, monitoring the airway, and initiating resuscitative measures are challenging when the patient is in an ice water bath.[4,11,15] The tub and patient lift device are large, bulky, and not often available in the Emergency Department. Multiple caregivers are required to prevent the patient from drowning and to maintain their head above water.

A simpler and easier method is immersion of just the patient's hands and forearms.[16] This method requires less patient cooperation than full body immersion. It also allows for full patient monitoring during the cooling process.

ICE PACKING

Packing the heatstroke patient in ice is an alternative to ice water immersion. It can result in conductive heat loss that is as effective as evaporative cooling. Patients who are awake and alert do not often tolerate ice packing. Its use may require parenteral sedation. The complications and practical limitations are similar to those of ice water immersion.

Place the undressed patient in the center of the gurney. Completely cover the patient with ice. This technique requires a large quantity of ice, which may be unavailable in the Emergency Department. Consider placing plastic sheets or trash bags, with the edges curved upward, under the patient to prevent the ice and water from spilling onto the floor, as healthcare personnel may otherwise slip on the wet floor, fall, and sustain injuries. An easier alternative is to place the patient in a body bag and fill this with ice. Discontinue cooling when the core temperature reaches 39°C or 102°F.

ICE PACKS

The placement of ice packs over select body areas is a more reasonable option than ice water immersion or ice packing. It may be

used as the sole cooling method or in conjunction with evaporative cooling. Place plastic bags filled with ice or ice water in the patient's axilla and groin. Remove the ice packs when the core temperature reaches 39 °C or 102 °F.

ICED PERITONEAL LAVAGE

Peritoneal lavage in hyperthermia has been investigated in canine models but used infrequently in humans. The advantages of this technique include the large surface area exposed to iced saline and direct cooling of the core. This technique is invasive, time-consuming, requires significant equipment and expertise, and is associated with significant complications. A case report indicated that iced peritoneal lavage with 2 L of normal saline was successful in decreasing the rectal temperature to 39.5°C or 103°F.[9] The patient had responded only partially to external evaporative cooling and iced gastric lavage. Place 1 L bags of saline or Ringer's lactate solution into an ice water bath to cool down. The technique is similar to that used for warming the hypothermic patient. Refer to Chapter 189 for the complete details of this technique. Iced peritoneal lavage should be reserved for the patient who is not responding to other methods of cooling.

ICED GASTRIC LAVAGE

Central cooling techniques have not been studied extensively. An alternative core cooling technique is iced gastric lavage. This method has been compared to room-air cooling in an anesthetized canine heatstroke model.[10] Gastric lavage with iced tap water cooled the canine models rapidly and safely. The technique yielded cooling rates five to six times faster than in controls. Significant differences in hemodynamic parameters were noted to return to baseline more quickly in the iced gastric lavage group than in the control group. The technique is similar to that used for warming the hypothermic patient. Refer to Chapter 189 for the complete details of this technique. Instill 10 mL/kg of iced sterile saline, allow it to dwell for 30 to 60 seconds, and suction out the fluid. Repeat the procedure as necessary. Potential hazards using this technique include aspiration, gastric mucosal injury, electrolyte imbalances with water lavage, and dysrhythmias.[10]

ALTERNATIVE TECHNIQUES

There has been much research in the last decade regarding the induction of therapeutic hypothermia. This research has primarily focused on those with brain injury, postcardiac arrest, and stroke. This has resulted in the development of a variety of externally applied and internally applied cooling devices. While not specifically designed to treat hyperthermia, they can easily be used to manage the hyperthermic patient. Refer to Chapter 188 for a discussion of these cooling methods and devices.

ASSESSMENT

Monitor core body temperature closely with an esophageal, rectal, or urinary temperature probe. Monitor the patient's vital signs, neurologic function, urine output, and laboratory measurements (arterial blood gases and serum electrolytes). Consider monitoring central venous pressure and pulmonary artery pressure, especially in patients with heatstroke and limited cardiac reserve. Volume deficits may not be more than 2 to 3 L, especially in patients with classic heatstroke. Hypotension usually responds to intravenous fluids. If required, use an inotrope that produces little vasoconstriction, such as dobutamine. The use of H_2 blockers may decrease the incidence of gastrointestinal bleeding.[12] Treat rhabdomyolysis aggressively with saline diuresis, alkalinization of the urine, and an infusion of 0.5 gm/kg of mannitol with or without furosemide.[12] Treat seizures with benzodiazepines.[12]

AFTERCARE

Patients with minor heat-related illnesses may be safely discharged home after cooling. Instruct the patient to rest, drink plenty of fluids, and avoid the heat. Discuss with the patient the methods to remain cool if they are exposed to heat. This requires adequate rest, hydration before physical exertion, periods of rest during exertion when the individual can cool off, and adequate oral fluid intake during exertion. Arrange follow-up within 24 hours for a reevaluation.

Admission is required in several circumstances. Admit patients with heat exhaustion for 23 hour observation if they have abnormal vital signs, abnormal laboratory investigations, or if they remain symptomatic after fluid therapy. Admit all patients with heatstroke to an intensive care unit. Permanently altered and unstable thermoregulatory mechanisms in the survivors of heatstroke increase their susceptibility to future heat illness. Prevention through education should be a part of every discharge plan.

COMPLICATIONS

Further management of the heatstroke victim can be difficult, even after successful initial resuscitation and stabilization. Heatstroke is a multisystem insult that affects virtually every organ system. Neurologic complications of hyperthermia include seizures, cerebral edema, and localized brain hemorrhages. Irreversible brain damage often occurs above 42°C or 108°F. Cerebellar impairment may persist after recovery. Cardiac complications include tachyarrhythmias, high cardiac output heart failure, and myocardial infarction. Pulmonary edema may be cardiogenic in patients with a limited cardiac reserve or secondary to ARDS. Pulmonary aspiration can be encountered in obtunded patients. Acute renal failure may be due to direct heat damage, renal hypoperfusion, or rhabdomyolysis. Mucosal ulceration of the gastrointestinal tract is common and can lead to gastrointestinal hemorrhage. Liver damage and dysfunction are common. The extent of hepatic necrosis and cholestasis may not be apparent until 48 to 72 hours after the heat injury. Hematologic complications include hemolysis, thrombocytopenia, and disseminated intravascular coagulation. Megakaryocytes are especially sensitive to heat injury. Disseminated intravascular coagulation is triggered by diffuse endothelial and organ damage. Its onset is usually delayed 2 to 3 days and is associated with a high mortality.[17,18]

Complications can occur during the cooling of the hyperthermic patient. **Discontinue all cooling techniques when the core body temperature reaches 39°C or 102°F.** Continued cooling can result in hypothermia as the core temperature continues to decrease after cooling is discontinued. Monitor the patient to ensure that their core body temperature does not increase. The patient may experience muscle fasciculations, shivering, and shaking during the cooling process. These can be managed with intravenous benzodiazepines. Ice water immersion and ice packing make patient monitoring and management difficult if not impossible. Iced peritoneal lavage and iced gastric lavage are invasive procedures associated with significant potential complications. Refer to Chapters 58 and 66 regarding the complications associated with the placement of the peritoneal lavage catheter and the nasogastric tube, respectively.

SUMMARY

The best intervention for heat-related illness is prevention. If caught early, heat illness responds to rest, exposure to shade and a breeze, and the ingestion of cool liquids. External evaporative cooling is

acknowledged to be the safest means of cooling the hyperthermic patient. The tragedy of heatstroke is that it so frequently strikes highly motivated young individuals under the discipline of work, military training, or sporting endeavors. Heat-illness precautions should be implemented even in temperate zones during the hot summer months.

191 Autotransfusion

Carlos J. Roldan and Amit Mehta

INTRODUCTION

Trauma is the leading cause of death in children and adults under 44 years of age.[1] Exsanguination plays a significant role in as many as half of these deaths, most commonly after the patient reaches the hospital and within the first 24 hours after injury.[2] Hemorrhagic shock is a primary indication for the transfusion of homologous blood products. Transfusions with homologous blood products carry the possibility of associated complications including transfusion reactions, transmission of infectious diseases, and sensitization to antigens.[3] Massive transfusions are associated with the additional complications of acidosis, dilutional coagulopathy, and hypothermia. Transfusion of homologous blood products in the trauma patient has been independently associated with an increase in both morbidity and mortality, particularly when transfusing older, stored blood products.[4–6] Blood centers have more than doubled the prices of blood products in recent years due to a decline in blood donors, higher skilled labor costs, and increases in the cost of testing and processing blood.[7]

Alternative transfusion strategies have been developed for elective surgeries. These include autologous (acute) normovolemic hemodilution, autologous preoperative donation, and intraoperative cell salvage with autotransfusion. The first two are not possible in the acute Emergency Department setting. Cell salvage with autotransfusion represents a viable alternative to autologous transfusion in the Emergency Department, but has received limited attention in the trauma patient.

In the trauma setting, an autotransfusion was first performed by Elmendorf during the First World War on a soldier with a traumatic hemothorax.[8] It was subsequently used sporadically as a life-saving procedure.[9] A modified autotransfusion for a traumatic hemothorax was described in 1978.[10] This technique was simple, safe, and easy to practice. It was used in approximately 400 patients with a traumatic hemothorax without any noticeable complications. This technique is still applicable to current practice.

Many of the patients with a life-threatening hemothorax either die before reaching the Emergency Department or experience severe hemodilution that accounts for some deaths in the Emergency Department and the Operating Room. Since hypovolemic shock secondary to trauma is the most frequent indication for a massive blood transfusion in the Emergency Department, it is therefore an indication for an autotransfusion. Much of the controversy surrounding practice paradigms centers on the disagreement as to what constitutes the proverbial perfect procedure.

An autotransfusion may occur in the Emergency Department, Operating Room, and Surgical ICU with increasing frequency. In this procedure, the shed blood is collected, mixed with an anticoagulant, concentrated, washed or filtered, and then returned through an intravenous (IV) line to the patient. Harmful contaminants such as potassium, fat, and free hemoglobin are removed from the salvaged blood. This blood is returned through a 40 micron blood filter to collect particulate matter and microthrombi. An autotransfusion in the Emergency Department is generally limited to an acute traumatic hemothorax associated with clinically significant hypovolemia.

INDICATIONS

An autotransfusion should be considered with the anticipated loss of at least 20% of the patient's estimated total body blood volume. It should also be considered if the Emergency Department cannot obtain or provide cross-matched compatible blood. It can be used for the patient unwilling to accept homologous blood, but willing to accept salvaged blood. The average amount of blood to be autotransfused should be expected to be greater than 1 unit to make this procedure cost effective.[11–13]

There are numerous advantages to an autotransfusion. It is convenient and immediately available as a blood product replacement. The blood is already warmed and at, or just below, body temperature. It addresses any special needs of the patient such as when they have religious preferences or a rare blood type. There is no chance of allergic reactions, alloimmunization, disease transmission, febrile reactions, and transfusion reactions. An autotransfusion requires no work on the part of the blood bank, has no compatibility issues, and ensures that the patient receives compatible blood. It conserves homologous blood products for other patients. An autotransfusion results in the blood having a normal pH, viable platelets, and viable clotting factors when compared to homologous blood supplies. Higher levels of 2,3-DPG in autologous blood results in the easier release of oxygen from hemoglobin in the tissues. Finally, there is the positive psychological benefit to the patient when they are informed that they received their own blood.

CONTRAINDICATIONS

There are numerous contraindications to the use of an autotransfusion. The presence of a coagulopathy regardless of its etiology or when it occurs (i.e., in the Emergency Department, preoperative, intraoperative, or postoperative) or evidence of disseminated intravascular coagulopathy (DIC) may be more optimally managed with the administration of specific blood component therapy. Evidence or suspicion of serious infectious processes (e.g., mediastinal, pericardial, respiratory, or systemic) precludes the use of an autotransfusion. Do not autotransfuse blood if there is the presence of a malignant neoplasm at collection site (i.e., abdominal or chest cavity) that can lead to possible contamination of the blood with malignant cells. Do not autotransfuse blood which is collected from a potentially contaminated abdominal or thoracic cavity (e.g., esophageal tear). Do not autotransfuse from a cavity that was irrigated with a solution that can cause lysis of red blood cells prior to blood collection and potentially precipitate end-organ damage if the salvaged product is administered. This includes sterile water, hydrogen peroxide, alcohol, hypotonic irrigation solutions, or povidone-iodine antiseptic gels or solutions. Blood collected from body cavities that have had the administration of topical thrombin or microfibrillar hemostatic agents should not be autotransfused. Patients with renal or hepatic failure may not tolerate the increased levels of plasma-free hemoglobin or potassium that occurs with an autotransfusion. Relative contraindications include cesarean delivery and sickle cell disease.

EQUIPMENT

- Sterile gloves and gown
- Face mask with a face shield or goggles
- Cap

- Povidone iodine or chlorhexidine solution
- Chest tube drainage apparatus with either a water seal or a dry one-way valve
- In-line autotransfusion system blood collection bag
- Whole blood in-line microaggregate filter for reinfusion (usually 40 microns, but can vary between 20–170 microns)[14]
- Nonvented blood compatible IV administration set
- 250 mL bag of sterile normal saline for priming of IV tubing and microaggregate filter prior to blood infusion
- Pressure bag for rapid blood infusion
- Blood warming system if it is anticipated that multiple units of blood will need to be infused to help prevent hypothermia[15–17]
- Citrate anticoagulants
- Tube thoracostomy supplies (Chapter 39)

Anticoagulation for an autotransfusion in the ED setting is generally recommended to help prevent the formation of clots in the autotransfusion system. While the administration of anticoagulants can be beneficial, it is not without risk and its use and dosage are at the discretion of the treating Physician. Heparin anticoagulation is one option. However, the local administration of heparin can lead to the formation of platelet microaggregates and potentially lead to systematic heparinization which can result in further hemorrhage in a patient who is already bleeding.[18] **Citrate anticoagulants, which are considered local anticoagulants, are thus preferred over heparin.** Citrate works by binding with calcium ions to inhibit the conversion of fibrinogen into the insoluble protein fibrin, preventing the blood from clotting. Since citrate only binds with calcium, it only anticoagulates the blood it is collected with. The liver rapidly metabolizes the citrate once the anticoagulated blood is reinfused.[16]

Citrate phosphate dextrose (CPD) is a commonly used anticoagulant. It is recommended to use 1 mL of CPD for every 7 mL of blood. Because it is difficult to estimate the amount of blood in a patient's chest cavity, one approach is to instill 60 mL of CPD into the autotransfusion bag, enough to anticoagulate one unit of blood. When 1 unit of blood has been collected (about 500 mL total volume of blood plus CPD), it may be reinfused or additional CPD may be added to continue the collection. If bloody drainage is ongoing, prepare a new collection bag and inject anticoagulant before disconnecting the filled collection bag for reinfusion. The CPD injection may be facilitated by the use of a volume-control IV chamber. Run the desired amount of CPD into the chamber and then infuse it via the IV tubing to the injection port.

Citrate phosphate dextrose adenine (CPDA) may also be used as an anticoagulant at a ratio of 1 mL per 7 mL of blood. Some consider CPDA the anticoagulant of choice for an autotransfusion of a traumatic hemothorax. It provides a reduced pH mixture that is advantageous to the platelets. The CPDA solution maintains the viability of the platelets. It also reduces clot formation in autotransfusion equipment, plugging of the blood filter with microemboli, and clotting of the IV lines.

PATIENT PREPARATION

Assess the patient for the signs and symptoms of hypovolemia, hypoperfusion, and/or a hemothorax. Describe the procedure, its risks, and benefits to the patient and/or their representative. Obtain written or oral consent, if possible. **This procedure requires strict aseptic technique.** Clean any dirt and debris from the patient's chest wall. The Emergency Physician should don full sterile and personal protective equipment at this point. This should include sterile gloves, a sterile gown, a face mask with an eye shield or goggles, and a cap. Apply povidone iodine or chlorhexidine solution to the skin over the chest wall and allow it to dry. Apply sterile drapes to delineate a sterile field.

Much preparation is required before starting an autotransfusion. The autotransfusion system requires prior assembly. Therefore, consider setting up the autotransfusion components for patients who are at high risk for a hemothorax before inserting the chest tube. Otherwise, blood that drains immediately upon chest tube insertion is lost to recovery. **Refer to all manufacturers' directions for use, warnings, and cautions regarding anticoagulant medications, microemboli filters, and IV blood administration sets prior to their use.** Prophylactic broad-spectrum antibiotics may be administered immediately before the chest incision is made for the tube thoracostomy or just prior to the reinfusion. Follow all hospital protocols for blood handling, waste disposal handling, and infection control. Insert a large-bore chest tube. Refer to Chapter 39 for the complete details regarding the tube thoracostomy.

TECHNIQUES

There are several manufacturers of chest drainage and autotransfusion systems. The Pleur-Evac System (Teleflex Medical, Research Triangle Park, NC) is one of the commonly used systems in many Emergency Departments.[30] The Atrium Chest Drain Autotransfusion System (Atrium Medical Corp., Hudson, NH) is the second of the two more commonly used systems (**Figure 191-1**).[31]

Three different techniques for blood collection are in-line, self-filling, and continuous. The in-line autotransfusion blood bag is a standard bag that attaches to the chest drain (**Figure 191-2**). The



FIGURE 191-1. The Oasis 3650 chest drain system with autotransfusion blood recovery. (Photo courtesy of Atrium Medical Corp., Hudson, NH.)



FIGURE 191-2. An in-line autotransfusion bag. (Photo courtesy of Atrium Medical Corp., Hudson, NH.)



FIGURE 191-3. A self-filling autotransfusion bag. (Photo courtesy of Atrium Medical Corp., Hudson, NH.)

self-filling autotransfusion bag incorporates a low vacuum that is activated to improve the flow of fluid from the chest drain into the bag (**Figure 191-3**). The final option is the continuous autotransfusion. It is used to directly reinfuse shed autologous blood via a blood compatible infusion pump, a microemboli blood filter, and a nonvented blood compatible IV administration set. This is a true closed system and reduces the potential for contamination. It does not require the clamping and unclamping of tubes, exchanging autotransfusion bags, and the interruption of chest drainage to change autotransfusion bags. It results in less exposure to the patient's blood with a closed system. It saves time and money by not changing autotransfusion bags, filters, and IV tubing. Unfortunately, this closed system is rarely available in the Emergency Department and requires additional training for its use.

The technique chosen depends upon the chest tube drainage system used in your institution. Some chest tube drainage systems allow for more than one technique to collect blood for an autotransfusion. The specific port locations and connections will vary slightly among the different manufacturers, but the general concepts are relatively universal. The general technique will be described below. The specific steps depend upon the actual equipment available.

Attach the autotransfusion bag to the chest drain. Inject anticoagulant into the collection unit as soon as possible during or before the blood collection if this is required. Collect the blood. When one unit of blood has been collected (about 500 mL of blood plus the volume of anticoagulant), it may be reinfused. Remove the filled autotransfusion bag and replace it with a new one containing anticoagulant. Discontinue blood collection when it is determined that an autotransfusion is no longer required or there is no further bloody drainage from the chest tube.

Reinfuse the blood. Prime the IV blood administration and microemboli blood filter with sterile saline. Invert the autotransfusion bag so that the spike port points upward. Remove the protective cap covering the spike. Insert blood tubing into the spike port by using a constant twisting motion. Attach a microfilter onto the blood tubing. **Remove the air from the autotransfusion bag.** Keep the unit inverted and squeeze all the air from the bag carefully through the filter and the drip-chamber assembly to prevent an air embolus. Close the infusion set clamp. Invert the autotransfusion bag and suspend it from an IV pole with the plastic strap. Open the infusion set and flush the administration line to remove all of the air. Attach the distal end of the infusion set to the IV line. Infuse the blood using gravity or pressure.

Keep in mind some general principles when performing an autotransfusion. Do not hang or hand carry the autotransfusion bag by its tubing. Use the hanger provided. Replace the spike port cap immediately following removal of the blood filters and IV tubing to prevent air entering the system. The air vent must remain closed at all times when not in use. A new microemboli blood filter and IV blood tubing must be used for each autotransfusion bag. When using vacuum suction with the collection apparatus, it is important to use the lowest level possible to reduce the risk of red blood cell hemolysis during collection.[32] The recommended starting vacuum pressure is 20 mmHg.[15,33]

ASSESSMENT

Assess the patient's cardiopulmonary status and vital signs frequently during the autotransfusion and at least until 1 hour after the autotransfusion is complete. Periodically monitor laboratory data to include hematocrit, prothrombin time, partial thromboplastin time, platelet count, serum lactate, and arterial blood gas values. Monitor and mark amount and type of drainage from the collection system hourly for the first 8 hours, then every 2 hours as volume loss can cause hypovolemic shock. Evaluate and maintain drainage tube patency every 2 to 4 hours. Mark the drainage level on the outside of the drainage-collection chamber in hourly or shift increments. Document the assessments and laboratory values in the medical record.

AFTERCARE

Once the infusion of the autologous blood has started, it is important to monitor the patient's clinical status in response to the infusion during the patient's stay in the Emergency Department. This will involve monitoring their vital signs and other hemodynamic parameters, including central venous pressure.[12] Monitor laboratory data to assess the success and possible complications of the autotransfusion process. This generally includes electrolytes, renal function, hemoglobin and hematocrit, platelet count, coagulation profile, and DIC profile to assess for a consumptive coagulopathy.[12]

The Emergency Physician, in conjunction with the nursing staff, must also maintain the integrity of the autotransfusion system during the infusion of autologous blood. It is necessary to ensure the autotransfusion bag is replaced each time it is filled to capacity to prevent overflow of blood into the chest drainage apparatus. Ensure each collection bag has anticoagulant added to it prior to the collection of blood. A new microaggregate filter must be used for each collection bag prior to it being infused. Prior to infusing blood, inspect it through the collection bag for evidence of clotting. Discard the autotransfusion bag and do not reinfuse it if it contains clotted blood or particulate matter. Purge all the air from the collection bag, intravenous tubing, and microaggregate filter to prevent an air embolism. Observe the autotransfusion to ensure that the entire contents of the collection bag are not allowed to infuse through the microaggregate filter and intravenous tubing. The transfusion of shed blood collected under post-traumatic conditions should begin within 6 hours of initiating the collection at the longest so as to reduce the risk of bacterial overgrowth and minimize damage to the blood components during storage.[19]

COMPLICATIONS

In general, the complications from an autotransfusion are clinically insignificant if the proper technique is followed and if less than 3000 mL of blood is reinfused. Overall, the complications are categorized as hematologic and nonhematologic. Refer to Chapter 39 regarding the complications associated with a tube thoracostomy.

HEMATOLOGIC

A coagulopathy may occur in trauma patients following an autotransfusion. However, the autotransfusion itself has not been overwhelmingly proven to be the etiology.[3] These patients are more likely to have other independent risk factors for a coagulopathy such as hypothermia and acidosis.[20] This makes it difficult to determine the contribution of the autotransfusion to the development of a coagulopathy.[20] DIC is a rare complication but should be anticipated and treated accordingly. A dilutional coagulopathy may occur when greater than 3500 mL of autologous blood is transfused. Treatment includes administration of fresh frozen plasma and platelets to compensate for the proportional decrease in platelets and fibrinogen.[21] Hemolysis of red blood cells secondary to mechanical factors during the collection process, the use of hypotonic irrigation fluids, excessive suction pressure, aspiration of clotted blood, or the use of hemolytic solutions (e.g., povidone iodine, hydrogen peroxide, or alcohol) to collect blood.[22,23] Hemolysis can also occur secondary to the prolonged exposure of red blood cells to the serosal linings of traumatized body cavities.[24] Thrombus formation may occur as a result of increased plasma-free hemoglobin that promotes a procoagulant effect and increases the risk of free hemoglobin precipitation in the renal tubules.[25,26]

NONHEMATOLOGIC

Particulate embolism has been reported to occur during and after an autotransfusion. Most components of the equipment are designed for singe use. Resterilization or reuse may compromise the structural integrity and lead to device failure. An air embolism may result from inadequate use of the IV set or the microemboli blood filter. An air embolism has also been associated with the reinfusion of the entire autotransfusion blood bag contents that contain residual air and a pressurized infusion of the autotransfusion bag with the air vents open. Citrate toxicity and myocardial depression may occur after the rapid infusion of citrate-anticoagulated blood. The clinical manifestations of citrate toxicity include a perioral tingling sensation followed by abdominal cramping and cardiac dysrhythmias. Citrate toxicity can be prevented by ensuring that the ratio is not greater than 1:5 of the citrate anticoagulant to blood. Sepsis in patients with an isolated hemothorax is considered only a minimal risk. Sepsis has been associated with the difficulty that exists in maintaining a completely sterile environment in patients receiving an autotransfusion.[27–29]

SUMMARY

An autotransfusion is a basic technique that is possible in the Emergency Department. It is not the standard of care under all settings. The procedure requires familiarity with the equipment, continuing education, and quality control. This may be the reason it is underutilized in many Emergency Departments. Anticipation of which patients would benefit from this technique might be problematic and time consuming, especially when assembling equipment that may not be used frequently. Proper use of the devices can be advantageous to avoid the multiple complications associated to hypovolemic shock in trauma patients. The low risk of complications related to this technique make an autotransfusion a viable option to a homologous transfusion.

192 Helmet Removal

Eric F. Reichman

INTRODUCTION

The helmeted person who becomes injured presents unique challenges to prehospital healthcare providers, athletic trainers, and Emergency Department personnel in providing initial stabilization and management. Greater numbers of people are wearing helmets due to the increasing public awareness for the prevention of head injuries associated with recreational and athletic activities. This practice will limit the most severe outcomes from head trauma. However, the helmeted patient is not immune from life-threatening head and neck injuries. **Secondary injury due to improper helmet removal can adversely affect patient outcome.**[1]

Helmets vary in size, type, and accessories on the basis of the user's activity (**Figure 192-1**). They consist of a hard plastic, polycarbonate, and/or fiberglass shell over either a layer of foam covered by material, inflatable air bladders, or both. Motorcyclists and racers wear full-face helmets with or without retractable or removable visors. Football, lacrosse, and hockey players use open-faced helmets. These may have clear visors and/or face cages whose bases are screwed into the helmets. Bicyclists, kayakers, roller bladers, skateboarders, and skaters wear simple skull helmets. These helmets cover the top of the skull like a hat and have a strap that is snapped or clipped under the chin to maintain the helmet in position.

Athletes playing football and hockey wear protective shoulder padding in addition to protective helmets. Their facial injuries tend to be less severe.[2] With the helmets and shoulder padding, their cervical spines, in comparison to those of helmeted motorcyclists without shoulder padding, are more adequately stabilized.[2,3] Helmet removal with and without shoulder pad removal has been shown to result in head and cervical spine movement.[4,5] This can increase the risk of spinal cord damage in the helmeted patient with a cervical spine injury.[2,3]

Current recommendations for helmet removal are to leave the helmet in place until the patient arrives in the Emergency Department or Trauma Unit.[2–4,6–10] **The only exception permitting the removal of a helmet in the field is when it significantly delays lifesaving measures or if airway access is obstructed.**[2,3,6] This may occur in the unconscious and/or apneic patient. Prehospital healthcare providers should be able to maintain an adequate airway, stabilize a patient's cervical spine, and control associated hemorrhage with removal of only the face plate, guard, and chin strap of the helmet.[6,7]

ANATOMY AND PATHOPHYSIOLOGY

The type and fit of protective equipment, the mechanism of injury, the patient's age, and the patient's physical development all influence cervical spine injury. There is a greater risk of injury when the helmet is too loose. It has been noted that most people wear helmets that are too large for their heads. Inertia is defined as a body's ability to resist change of position and motion. A 4 pound helmet can exert a 200 pound force on the wearer's head and neck when impact occurs at 50 mph. Injury is often more serious when inertial forces cause excessive extension and flexion of the cervical spine without adequate protection for the lower head and neck.[7,11]

The anatomic location of cervical spine injuries tends to differ between children and adults. The immature pediatric spine is more susceptible to flexion and extension injuries in the upper cervical (C2 to C3) segments due to the child's proportionally larger head size, shorter neck with immature development, weak neck muscles, and the neck's higher degree of flexion and extension.[7,11,12] The relative amount of cartilaginous tissue in comparison to bone makes the pediatric patient more prone to spinal cord injury when subjected to high inertial forces. These injuries may be more difficult to detect on plain radiographs, as cartilaginous injuries are radiolucent.[11,12]

Similar conditions of disproportionate head-to-neck size are artificially created in the helmeted patient. The motorcycle helmet will often cause hyperflexion of the neck. Flexion and extension injuries without adequate lower neck protection result in an increased incidence of upper cervical spine (atlantoaxial, C1, and C2) injuries in comparison to lower cervical spine segments.[12,13] There is a greater incidence of lower cervical spine (C5 and C6) injury among football and hockey players.[13] The shoulder padding offers support to the lower head and upper neck. It decreases the amount of flexion and extension at the time of impact.

Flexion and distraction while removing a helmet may cause spinal cord compression, as demonstrated in unstable C1 to C2 injuries with helmet removal in cadaveric models.[13] Similar unfavorable results were demonstrated with neck flexion and extension during helmet and shoulder pad removal.[13] The properly fitting helmet is tight enough that a significant force must be applied to remove it in the field, thus increasing the chance of cervical spine movement. **Apply proper in-line cervical immobilization before helmet removal or medical intervention while avoiding in-line traction. In-line traction increases the risk of subluxation or distraction at the site of injury.**

It is recommended that the helmet and padding not be removed in the field. Overzealous manipulation of the patient or improper helmet and/or padding removal can complicate an underlying injury. The helmet can be secured to a long backboard with supplemental neck stabilization provided by use of neck immobilizers, foam-Velcro fitted supports, or sandbags. If shoulder pads or helmets are removed in the field, the posterior aspect of the neck and shoulders must be adequately supported while in-line immobilization is maintained to avoid further spinal cord injury. Cervical immobilization with and without helmet removal is best accomplished with at least two people to assure that the patient's head and neck remain stable.



FIGURE 192-1. Types of helmets. **A.** Simple skull helmet. **B.** Football helmet. **C.** Partial face covering helmet. **D.** Full face covering helmet. **E.** Full face covering helmet.

INDICATIONS

Under most circumstances, the helmeted patient can be assessed and stabilized in the field without removing their helmet or shoulder pads.[4,8–10] The patient can often be initially managed, radiographed, and the cervical spine radiographically "cleared" prior to removal of the helmet in the Emergency Department.[14] Although there is some information that plain radiographs can be inadequate to visualize the bony structures if the helmet and pads remain on the patient.[15,16] The current common use of CT scans to clear the cervical spine make this not as important as most helmets and pads are nonmetallic.[4,17]

Helmet removal is warranted emergently in patients who are apneic, without an adequately sustainable airway, those at risk for airway compromise from a helmet being left in place, if it interferes with airway management, and those who have uncontrollable hemorrhage.[14] Helmets that are loose fitting or that do not adequately stabilize the head and neck should be removed. Other indications to remove a helmet include if it prevents proper patient immobilization, or if the face mask cannot be removed. **When a helmet is removed, any pads and neck support devices attached to the pads must be removed to maintain the cervical spine in a neutral position and prevent secondary injury.**

CONTRAINDICATIONS

Adhere to strict cervical spinal cord injury precautions throughout the prehospital period. Do not remove the helmet unless absolutely necessary. It is not possible to completely exclude a spinal cord injury or vertebral fractures in the field.

Do not remove the helmet until the cervical spine has been "cleared" of any injury in the Emergency Department. Delay removal if the patient is unconscious, has an abnormal mental status, is under the influence of ethanol or drugs, is intoxicated or potentially intoxicated, has distracting injuries, if there is evidence of a spinal cord injury, if a complete physical examination cannot be performed, if the cervical spine has not been radiographically cleared, or if the patient has neck pain. The only exception is if the patient's airway and breathing cannot be supported with the helmet in place.

EQUIPMENT

- Long backboard
- Head and neck immobilizer
- Adjustable cervical collar
- Scissors or shears suitable to cut the face mask
- Cast saw with spare blades
- Screwdrivers, flat head and Phillips head
- Face mask removal tools
- Towels

PATIENT PREPARATION

The hemodynamically stable and helmeted patient should have radiographs of the cervical spine, be physically assessed, be determined not to be intoxicated, and have a normal mental status prior to removal of their helmet.[14,18] This includes a complete neurologic examination. Explain the removal procedure and its possible complications to the patient and/or their representative. Explain all the potential risks involved in helmet removal, including the possibility of worsening an underlying spinal cord injury. The risk of permanent central nervous system damage should be stated as well as the fact that the precautions to avoid such injury are not foolproof but will be observed as carefully as possible. Answer any questions or concerns of the patient or their representative. **If the patient is awake and alert, instruct them to tell you immediately if they experience numbness, pain, paresthesias, or tingling during the removal procedure.**

Remove any removable parts if they were not detached from the helmet prior to arrival in the Emergency Department. The face mask, face shield, and/or visor can often be removed with a flat or Phillips head screwdriver or an electric screwdriver. If the screws cannot be removed because they spin in place or are rusted, cut the plastic clips holding the face mask onto the helmet. A variety of tools are available to aid in face mask removal.[19] The hospital's maintenance department can provide an anvil pruner, bolt cutters, or PVC pipe cutter. Commercial devices have been designed to remove a face mask. These include the FM extractor (Sports Medicine Concepts, Genesco, NY) and the Trainer's Angel (Trainer's Angel, Riverside, CA). Unfortunately, these commercial devices are not often available in the Emergency Department.

Carefully look for any damage to the patient's helmet. External damage to the helmet may be the only initial indication of the severity of the impact. Inspect the integrity of the helmet shell for fit and structural breaks. The patient may be wearing eyeglasses or sunglasses under the helmet. Remove the glasses before helmet removal begins. Contact lenses may remain in place until the helmet is removed.

The helmet will cause flexion of the cervical spine when a patient is placed supine. This flexion is even more pronounced in a child due to their large occiput. Place rolled towels or sheets under the patient's shoulders to eliminate the excessive flexion of the cervical spine. Such flexion is minimal and requires no towels under the shoulders if the patient is wearing shoulder pads in addition to a helmet.

TECHNIQUES

MANUAL ONE-PERSON TECHNIQUE

Helmet removal can be performed by one or two people. Reserve the one-person technique for extreme interventions (**Figure 192-2**). With only one person present, it is necessary to pad voids behind the patient's neck and shoulders (**Figure 192-2A**). **The goal is to keep the head and neck in the neutral position as much as possible while removing the helmet.**

Stand above the patient's head looking down toward their feet. Place the heels of both hands on the sides of the helmet (**Figure 192-2B**). Insert the index, middle, ring, and little fingers into the space between the patient's head and the helmet. Gently spread open the helmet with both hands to create clearance between the helmet padding and the patient's face and ears (**Figure 192-2B**). Slowly and gently remove the helmet (**Figure 192-2C**). **Stop removing the helmet immediately if the patient experiences pain or neurologic symptoms and use a 2-person or cast saw technique.** If the helmet is of the full-face type, gently tilt it posteriorly and continue to pull the helmet off until the nose is cleared. Return the helmet to a neutral position after the nose is cleared. **Avoid cervical spine hyperextension during this stage of helmet removal.**

Stop removing the helmet when the bottom of the helmet is just above the patient's occiput. Move the fingers of both hands onto the patient's occiput while keeping the heels of both hands on the helmet (**Figure 192-2D**). The fingers will now maintain stabilization and immobilization of the head and neck. Push the helmet off the patient's head using the heels of both hands while maintaining immobilization of the patient's head and neck (**Figures 192-2E & F**).

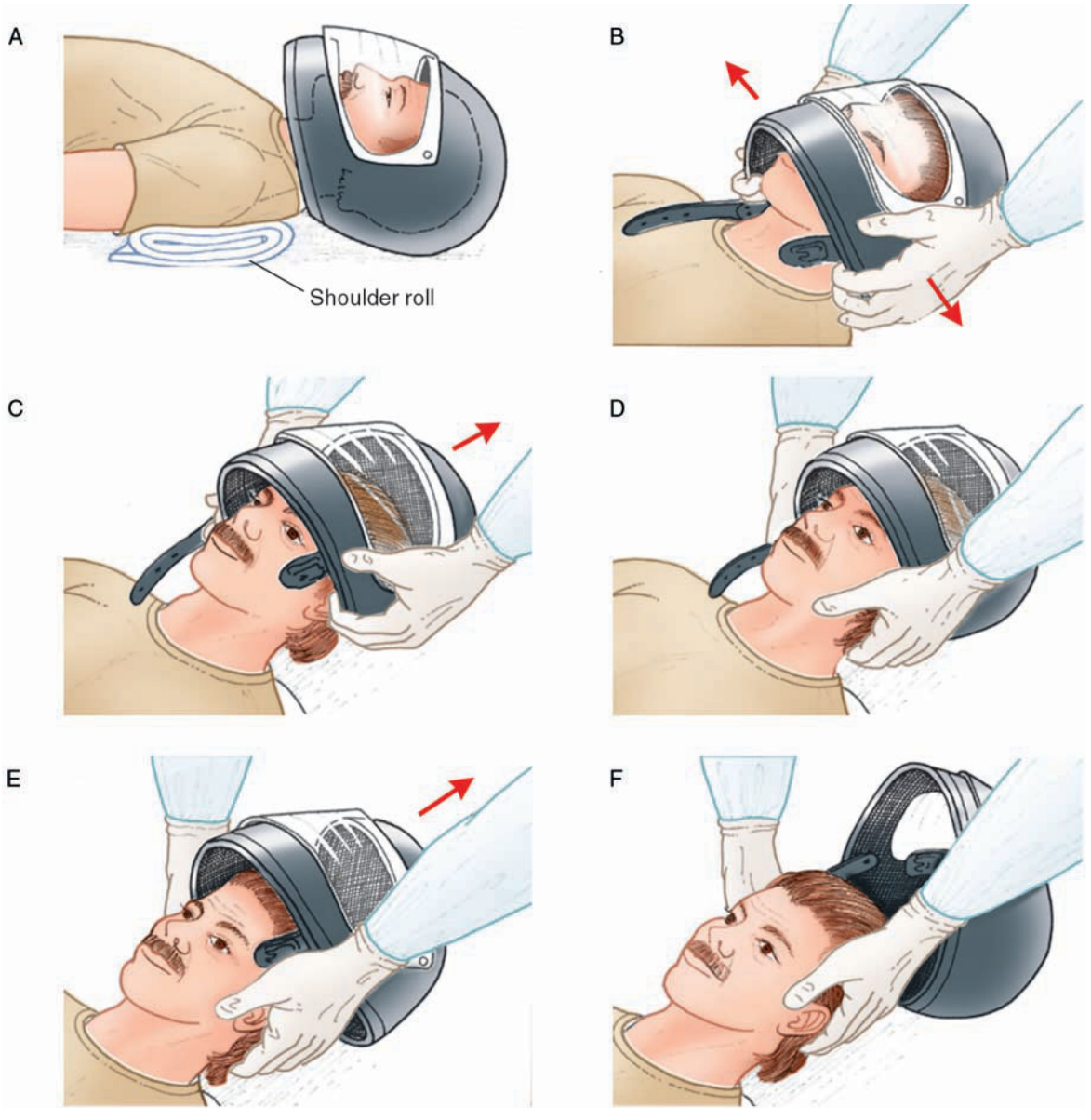


FIGURE 192-2. The one-person helmet removal technique. **A.** Patient positioning. **B.** The base of the helmet is spread open. **C.** The helmet is removed to expose the occiput. **D.** In-line immobilization is applied with the fingers. **E.** The helmet is pushed off with the heels of the hands. **F.** The helmet is removed while in-line immobilization is maintained.

Remove the shoulder pads if present. Maintain the head manually in-line until immobilization can be accomplished with a cervical collar, backboard, sandbags, and tape.[5,14,18]

MANUAL TWO-PERSON TECHNIQUE

The two-person technique has the same goals as the one-person technique (**Figure 192-3**). The assistant provides in-line immobilization while the helmet is removed.[5,14,18] Instruct an assistant to stand at the patient's side, at the level of the patient's neck and shoulders. Place one of the assistant's hands under the patient's occiput and upper neck. Place the assistant's other hand under the patient's mandible so that the mental process (chin) rests in the assistant's first web space (**Figure 192-3B**). Place the tip of the assistant's thumb on the angle of the patient's mandible. Place the index and long finger of the assistant's hand on the contralateral angle of the patient's mandible. Instruct the assistant to hold this position and maintain in-line immobilization of the patient's head and neck.[5,20]

The procedure to remove the helmet is similar to that described for the one-person technique. Stand above the patient's head looking down toward their feet. Place the heels of both hands on the sides of the helmet (**Figure 192-3B**). Insert the index, middle, ring, and little fingers into the space between the patient's head and the helmet. Gently spread open the helmet with both hands to create clearance between the helmet padding and the patient's face and ears (**Figure 192-3B**). Slowly and gently remove the helmet (**Figure 192-3C**). **Stop removing the helmet immediately if the patient experiences pain or neurologic symptoms and use the cast saw technique.** If the helmet is of the full-face type, gently tilt it posteriorly and continue to pull it off until the nose is cleared. Return the helmet to a neutral position after the nose is cleared. **Avoid cervical spine hyperextension during this stage of helmet removal.** Completely remove the helmet (**Figure 192-3D**).

Maintain the head manually in-line until immobilization can be accomplished with a cervical collar, backboard, sandbags, and tape.[5,14,18] The Emergency Physician's hands should be applied

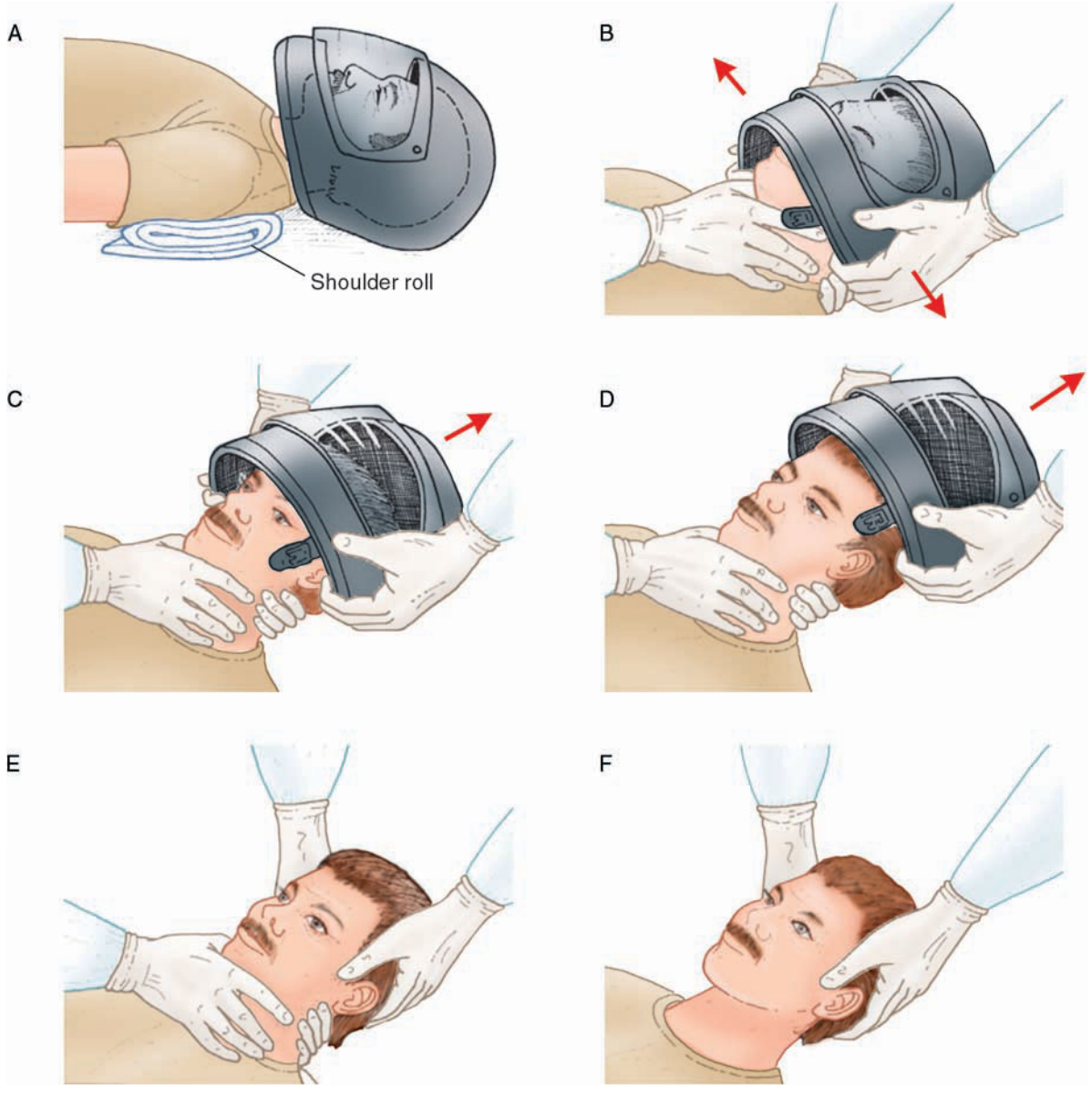


FIGURE 192-3. The two-person helmet removal technique. **A.** Patient positioning. **B.** An assistant provides in-line immobilization. The base of the helmet is spread open. **C.** Remove the helmet to clear the nose. **D.** The helmet is removed while the assistant continues in-line immobilization. **E.** The Emergency Physician provides in-line immobilization, in addition to the assistant. **F.** The assistant has removed their hands and the Emergency Physician maintains the in-line immobilization.

to the patient's head and neck to maintain in-line immobilization (**Figure 192-3E**). Instruct the assistant to remove their hands (**Figure 192-3F**). Remove the shoulder pads if present. Instruct the assistant to apply a cervical collar and secure the patient's head. The Emergency Physician can now release hold of the patient.

CAST SAW (BIVALVE) TECHNIQUE

A cast saw (**Figure 192-4**) can effectively be used to cut through the shells of most helmets (**Figure 192-5**). This technique allows for removal of the helmet without cervical spine movement.[14,18,21] **Cut the helmet off any patient with a neurologic injury, abnormal cervical spine radiographs, if there is a concern for head and neck trauma, or if the helmet is extremely snug-fitting to prevent cervical spine movement.** This technique requires the presence of two providers.[14,18,21]

Protect the patient from secondary injury from the cast saw, the helmet cutting process, and the sharp edges of the helmet.



FIGURE 192-4. The cast saw.



FIGURE 192-5. The cast saw (bivalve) technique. **A.** Patient positioning. **B.** An assistant provides in-line immobilization. **C.** The helmet has been cut with a cast saw. **D.** The anterior portion of the helmet is removed. **E.** The posterior portion of the helmet is removed. **F.** The Emergency Physician provides in-line immobilization, in addition to the assistant. **G.** The assistant has removed their hands and the Emergency Physician maintains the in-line immobilization.

Instruct the responsive patient to keep their eyes closed throughout the cutting and removal process to prevent corneal foreign bodies, corneal abrasions, and globe penetration. Place a moist towel over the patient's face for protection. Explain that there may be sounds of material or Velcro being torn or pulled with the helmet and not to be alarmed. Warn the patient about the noise associated with cutting the helmet with the cast saw. Protect the patient's eyes from exposure to foreign body penetration or abrasions if they are unresponsive. This includes taping the eyelids closed and placing a moist towel over their face.

Instruct the assistant, as described above for the two-person technique, to stabilize and immobilize the patient's head and neck (**Figure 192-5B**). Cut the helmet from ear to ear in a coronal plane with the cast saw (**Figure 192-5C**). **Carefully cut the padding and straps with a heavy scissors. Use care to not cut the patient's ears as well not force the tips of the scissors into their ears or scalp.** Remove the anterior portion of the helmet (**Figure 192-5D**). Gently slide out the posterior portion of the helmet while the assistant maintains in-line immobilization of the head and neck (**Figure 192-5E**). The Emergency Physician should then support the

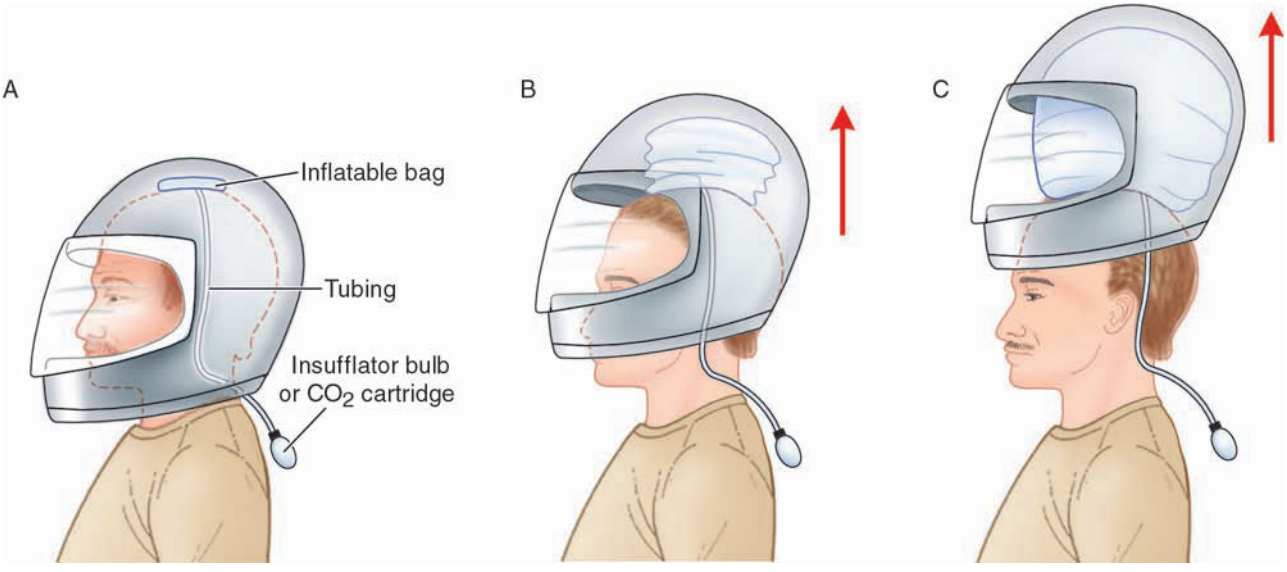


FIGURE 192-6. The Eject Helmet Removal System. **A.** The system in place between the helmet and the patient's head. **B.** Inflation of the airbag releases the helmet and begins to elevate it off the head. **C.** The airbag is further inflated until the helmet is removed from the head.

patient's head and maintain in-line immobilization (**Figure 192-5F**). Instruct the assistant to slowly and carefully remove their hands (**Figure 192-5G**). Remove the shoulder pads if present. Instruct the assistant to apply a cervical collar and secure the patient's head. The Emergency Physician can now release hold of the patient.

ALTERNATIVE TECHNIQUES

A novel device is the Eject Helmet Removal System (Shock Doctor Inc., Minneapolis, MN). This device was formerly produced by another company under the name of HATS OFF Emergency Helmet Removal System. This simple, easy to install, and low cost device has been recommended or required for use my many professional athletic, car racing, and motorcycle racing associations and organizations. The device consists of an accordion-folded airbag, tubing that exits the airbag and clips onto the edge of the helmet for easy access, and an insufflation bulb (**Figure 192-6**).

It is available in two forms. The first is the individual unit that can be purchased and installed in the helmet by the person wearing the helmet. The second is the EMS Kit for EMS and healthcare personnel to use if the device is not preinstalled by the helmet wearer. The EMS Kit contains several of the devices, insufflation bulbs, an insertion tool, and CO_2 cartridges that can be used instead of the insufflation bulb.

The device can be preinstalled by the helmet wearer. The folded airbag is placed inside the top of the helmet, either over or under the lining depending on the helmet design. The tubing is run from the airbag, either under or between the padding. The distal end of the tubing attaches to the edge of the helmet with a clip.

The device is simple to use. One person is required to provide in-line immobilization to the cervical spine. A second person is required to activate the device and remove the helmet. If the device is preinstalled in the helmet, locate the tubing insufflation port. Attach the insufflator bulb (**Figure 192-6A**). Squeeze the insufflator bulb to inflate the airbag. Alternatively, attach the CO_2 cartridge to inflate the airbag. As the airbag inflates, it will elevate and lift the helmet off the patient's head (**Figures 192-6B & C**).While one person maintains cervical spine immobilization, the other person should remove the helmet followed by removal of the pads if present. Apply a cervical collar and secure the patient's head.

If the device is not preinstalled, it can be easily placed inside the helmet. One person is required to provide in-line immobilization to the cervical spine. A second person is required to insert the device, activate it, and remove the helmet. Use the insertion tool to slip the airbag into the helmet and position it near the top of the patient's head. The remainder of the procedure is exactly as described above.

ASSESSMENT

Reassess the patient after removing the helmet and securing their head and neck.[22] Examine the patient for secondary injury due to the helmet removal procedure. These include lacerations and avulsions to the ear and nose, corneal abrasions, and corneal foreign bodies. Perform a complete head, eyes, ears, nose, and throat examination looking for injury. Perform and document a complete neurologic examination to ensure there is no change from the initial examination and that the helmet removal did not result in an iatrogenic injury.

AFTERCARE

Clean and vacuum any helmet debris if the helmet was cut with the cast saw. This will prevent any of this material from getting into the patient's eyes or nose as well as preventing them from inhaling the debris.

COMPLICATIONS

The most concerning aspect of helmet removal is adequate immobilization of the patient's head and neck during the procedure. Gross movement of the head and neck can result in displacement of fractures, spinal cord injury, or exacerbation of a partial spinal cord injury. **Avoid any movement of the head and neck when there is a strong suspicion of a spinal cord injury or severe head trauma.** Some movement of the patient's head or neck is likely to occur during helmet removal. **Minimizing the amount of motion is paramount.**

Secondary injury to the ears, eyes, and nose can be avoided by using careful technique. Spreading open the sides of the helmet before removal in the one-person or two-person techniques will

eliminate traction injuries to the scalp and ears. Tilting the helmet posteriorly will allow the chin portion of the helmet to clear the nose and avoid traction injuries to the nose.

A separate set of complications is applicable to the cast saw (bivalve) technique. Proper education of the patient is required to prevent them from moving because of the noise and vibration associated with this technique. Covering the patient's eyes and face with a moist towel (or gauze squares) will prevent corneal abrasions, corneal foreign bodies, globe penetration from foreign bodies, oral and nasal foreign bodies, and the inhalation of any debris. Use caution to prevent cutting the patient's ears or scalp when cutting the helmet padding. The cut edges of the helmet are extremely sharp. Careful removal will prevent cutting the patient's ears or scalp.

SUMMARY

The Emergency Physician who cares for trauma victims must be aware of the different types of helmets available and the means to safely remove them. Proper assessment of the helmeted patient will determine the need for emergent helmet removal. A thorough physical assessment and radiographic studies may take place prior to removing the helmet if the patient is stable upon initial assessment. By using proper techniques, helmets may safely be removed without causing secondary injury.

193 Hazmat Patient Management

Atilla B. Üner

INTRODUCTION

Hazardous materials (hazmat) incidents occur most often during the transport of chemicals or at industrial site accidents. Hazmat incidents may strike any community at any time.[1] Every Emergency Department must be prepared to respond to victims of a hazmat exposure.

Decontamination is the procedure of eliminating or reducing to a safe level any harmful substances on persons and equipment.[2] **Decontamination of victims in the field should always be performed by Emergency Medical Service (EMS) providers or before the patient enters the Emergency Department.** However, this does not always occur. Patients may be too ill for lengthy decontamination procedures prior to transport. Exposed patients may leave the scene and present to the Emergency Department on their own.[3–5] Basic decontamination by Emergency Department personnel can be safely performed outdoors in a designated decontamination area.[6,7]

Exposure to a hazmat contaminated patient who has been inadequately decontaminated or not decontaminated at all is a real possibility. This can result in exposure and secondary injury to healthcare personnel, other patients, and visitors.[5] The Emergency Department may be closed in part or in whole until the facility can be decontaminated. The panic and fear induced by rumors or odors can lead to unnecessary facility closure, delayed or inadequate patient treatment, and psychogenic illness in both healthcare personnel and bystanders.[3,4]

The three primary goals for the Emergency Department are to isolate and contain the contamination; decontaminate and treat exposed patients while protecting staff, other patients, and visitors; and maintain normal services, or reestablish them, as soon as possible.[3]

Early recognition of potentially hazmat contaminated patients will aid in preventing secondary contamination and Emergency Department closures. Numerous clues may identify a patient for hazmat contamination at triage.[3,4] These include accidents at agricultural or industrial sites, accidents involving chemical transports, suspected mass casualty incidents, a cholinergic toxidrome, mucous membrane irritation, chemical burns, soiling with unidentified liquids or powders, intentional overdose with chemicals, unexplained unconsciousness or cardiac arrest, and symptoms occurring in Paramedics or Emergency Medical Technicians (EMTs) after patient transport.

Information management is critical to the response.[4] Designate a person to obtain as much information as possible on the involved substance. Even preliminary and general information is useful and should be immediately conveyed to the treating Emergency Physician.[1] The maintenance of material safety data sheets (MSDS) is mandatory for each chemical used or stored at an industrial site or during transport. Request information on the MSDS from fire or EMS services at the scene. Further information resources are listed after the "References" section of this chapter. Verify all information for accuracy by cross-referencing several sources.[4]

This chapter describes a general approach to the management of the hazmat contaminated patient. The Emergency Department response and patient management will have to be tailored to the specific agent(s) and circumstances, such as number of patients and facility resources. All Emergency Departments are strongly encouraged to conduct regular inservice training sessions and drills on hazmat decontamination procedures. Information on hospital-based decontamination best practices is available from the United States Department of Labor, Occupational Safety & Health Administration.[7]

ANATOMY AND PATHOPHYSIOLOGY

Hazardous materials can enter the body through inhalation, absorption, and ingestion.[8] The total dose is a function of the concentration and properties of the substance, the exposure time, and the exposure route. There is a dose–response relationship between the absorbed dose and toxic effects for most toxic chemicals.[8] The effects can be local, systemic, and quite variable for different agents.

Inhalation is the most common route of exposure. It may lead to local irritation, airway obstruction, and/or pulmonary systemic absorption. Absorption through intact skin is facilitated by fat solubility, open wounds, burns, exposure of the eyes and mucous membranes, and by dermal contamination underneath soiled clothing leading to an occlusive dressing effect.[2,4] The axillae, groin, and skin folds have a thin epidermal layer that facilitates the absorption of a contaminant. Children have a larger surface area to body weight ratio and more permeable skin, making them more vulnerable to absorption of toxins.[9] Ingestions can be accidental or intentional.

Patients exposed to hazardous materials may show any or all of the following: local effects such as chemical burns, respiratory tract effects of inhaled toxins, systemic effects of absorbed toxins, associated trauma, psychiatric reactions (e.g., agitation and anxiety), or contamination without apparent injury.[4]

The hazard to personnel, or risk of secondary contamination, is determined by the dose of the hazardous material that is carried by the victim and absorbed by the caregiver.[10] Toxic liquids and solids can pose a dermal contact hazard.[3] Solids or volatile liquids can pose an inhalational hazard.[3] Most gases or vapors dissipate quickly and are unlikely to pose a secondary contamination hazard.[7,10] However, the risk to emergency personnel is real.[4,5,11] Contamination with corrosives or pesticides may indeed cause illness in personnel.[4,10,11] Toxins can rarely be emitted from vomitus

(e.g., hydrogen cyanide after cyanide salt ingestion) or exhaled breath (e.g., after ethylene oxide exposure).[2]

INDICATIONS

Decontaminate any potentially contaminated patient prior to their entry into the Emergency Department.[11] The more toxic the substance, the more rapidly the decontamination should be performed. Pesticides and corrosives are common and worrisome contaminants.[10] Asymptomatic contaminated patients can be triaged for decontamination before those with symptoms to prevent toxicity if the risk of toxicity is high. Decontaminate symptomatic patients before asymptomatic patients if the risk of toxicity is low.[4] Initiate any life support measures simultaneously with decontamination.[4] Patients who have been decontaminated or exposed to gases or vapors without signs of skin or eye irritation do not require further decontamination.[2,4,6]

Patients should never be made to wait in their contaminated clothing. They need to be given the means to undress in privacy, change into clean clothing, and await decontamination by hospital personnel.

The absence of a system to isolate wastewater is not a contraindication to water decontamination. **When in doubt, decontaminate the patient.** Dilution will suffice to reduce the hazardous substance to a safe level.

CONTRAINDICATIONS

Contraindications to water decontamination include contamination with metallic sodium, lithium, calcium, potassium, cesium, and rubidium.[1,12] Other contraindications to water decontamination include exposure to dusts of pure magnesium, sulfur, strontium, titanium, uranium, yttrium, zinc, and zirconium.[1,12] These substances react violently with water and can cause secondary injury.[1,12] Cover the patient and/or substance with mineral oil, remove the substance with forceps, and store it in a container with mineral oil.[4,12] However, many of these substances may already have reacted with moisture on the patient's skin.[1,12,13] Rapid removal of the chemical agent is better than allowing continuing injury to occur.[6,13] Adding large amounts of water to the small amount of residual chemical on the patient's body poses little risk of creating a serious reaction hazard.[13,14]

Patients soaked in flammable liquids pose special problems. Water decontamination may be inadequate to completely remove the substance from the patient's skin. Do not cardiovert or defibrillate the patient until the material is completely removed from the skin, so as to prevent an explosion or a fire.[6]

The use of chemical agents for neutralization is contraindicated. These substances may cause secondary injury, toxicity, or react with another substance in an adverse manner. Use large quantities of water for decontamination (e.g., a shower) rather than a neutralization agent.[6]

EQUIPMENT

Personal Protective Equipment (per Person)

- Scrub suit and closed shoes
- Plastic shoe covers
- Protective goggles
- Water resistant face mask
- Latex gloves
- Chemical resistant (i.e., nitrile) gloves
- Chemical resistant coverall suit with booties and hood
- Duct tape
- Rubber apron
- Butyl rubber gloves
- Chemical resistant rubber boots or shoe covers
- Respiratory protection (i.e., PAPR with assigned protection factor 1000)[7]

Patient Decontamination

- Decontamination unit located outside of the hospital
- Designated decontamination facility inside the hospital
- Decontamination stretchers, if applicable
- Portable wading pools for ambulatory patients
- Warm running water source with a hose and soft-stream nozzle
- Portable barriers to assure privacy and protect from wind
- Liquid hand or dishwashing soap
- Liquid shampoo
- Soft-bristled brushes
- Devices to decontaminate hands and nails (e.g., surgical scrub sets)
- Eye irrigation equipment

Miscellaneous Supplies

- Polyethylene plastic bags
- Name tags
- Yellow tape and signs to mark decontamination zones
- Scissors to cut clothing
- Scrub suits, towels, and blankets for patients before and after decontamination

The Occupational Safety and Health Administration (OSHA) requires level B protection for responders to an unknown chemical hazard, with a positive-pressure self-contained breathing apparatus and chemical resistant clothing.[3,8,11] The high cost of such equipment and constant skills retraining required to use it may prohibit some hospitals from purchasing it and has made compliance difficult.[8] The OSHA has published best practice guidelines for hospital-based chemical decontamination procedures, including detailed recommendations for personal protective equipment (PPE).[7]

Hospital gowns, standard Tyvek suits, surgical masks, and latex gloves are not considered adequate protection.[4,10,12] Personal protective equipment is available through specialized dealers and requires training to provide reliable protection.[4,8,11,12] The minimum protection recommended for hospital decontamination personnel includes a scrub suit, a chemical resistant suit with booties and hood, plastic shoe covers, at least two layers of gloves (surgical and nitrile) taped at the sleeve, protective eyewear, and respiratory protection.[4,7,8]

There is little consensus on how to provide respiratory protection. The required level of respiratory protection, if any, will depend upon the agent, the dose, prior training, and decontamination circumstances.[4,8,11] The OSHA has published guidelines under which the use of powered air-purifying respirators (PAPR) is sufficient.[7] The use of PAPRs requires regular training. Respiratory protection is rarely necessary if decontamination is performed outdoors.[10] Information obtained about the contaminant will aid in determining the level of protection required.

PATIENT PREPARATION

Patients should be initially received in a secured area outside of the Emergency Department. Clearly mark the area with yellow tape or other similar device. This is considered a contaminated

"hot zone." Triage, a primary survey, and any required immediate lifesaving interventions (e.g., Basic Life Support and CPR) may be performed here by appropriately protected personnel.[4,8,15] Rapid removal of clothing is essential as absorption is time dependent, and contaminated clothing can act as an occlusive dressing or continue to off-gas contaminant.[13] **Patients should not wait for decontamination in their contaminated clothing**. Instead, patients who are able should remove their own clothing and be given clean clothing or blankets for warmth and modesty. Children should not be separated from their caregivers if at all possible.[9]

Patients who present to the Emergency Department with real or imagined contamination are under high stress and are likely to act out if left unattended. Early self-removal of clothing will help alleviate fears and provide real early decontamination benefit.

The decontamination area is also considered a contaminated "hot zone."[4] **Perform basic life support and immediate life-saving measures only in the decontamination area.**[12] However, the extent of medical treatment in the decontamination area will need to be decided on a case-to-case basis. Treatment of cardiac dysrhythmias and wounds or administration of toxin-specific antidotes may have to be initiated prior to complete decontamination.[12,15] **Keep in mind that invasive procedures prior to decontamination may provide a percutaneous route of contamination with the hazardous substance.** Devices, such as monitors, used in the decontamination area will have to be decontaminated after use.[12] Use long leads, if available, that extend into the clean support area to prevent having to decontaminate monitoring devices.[12] **Patients are considered safe to move into the contamination reduction area ("warm zone") and then the Emergency Department (support area, "cold zone") only when decontamination is completed.** Perform a secondary survey, including a search for any toxidromes, and begin definitive medical treatment after decontamination.[4]

DECONTAMINATION TECHNIQUE FOR CHEMICAL AGENTS

Don personal protective equipment before approaching the contaminated patient.[4] This will prevent the healthcare worker from becoming contaminated, now making them a patient, and requiring the healthcare worker to be removed from duty. Suggested minimum personal protective equipment and its application is described here. Wear standard work attire, such as a scrub suit, and closed shoes (no clogs or slippers). Place plastic shoe covers over shoes. Don goggles and a water resistant face mask if no PAPR is worn. This is for splash protection only. Don latex gloves followed by nitrile or other chemical resistant gloves. Don a chemical resistant coverall suit with booties and a hood. Tape the sleeves to the gloves with duct tape. Don a butyl rubber apron and butyl rubber gloves for protection against water and chemicals. This protocol provides no respiratory protection. Don a PAPR if respiratory protection is desired or required.

Perform a primary survey and treat any life-threatening conditions with basic life support interventions.[4] Remove all of the patient's clothing. This includes shoes and jewelry. Cut off the clothing if necessary. Place the clothing in a plastic bag and seal it with duct tape. Place this bag into another bag and seal it to "double bag" the clothing. Double bag any jewelry and watches separately if time and circumstances permit. This allows for possible later decontamination and salvage. Label the bags with the patient's name or medical record number. Patients may assist with their own decontamination. **Do not irrigate the patient prior to complete clothing removal.** Chemicals on clothing will soak through wet clothing and onto the skin, resulting in additional injury or absorption.[2,6]

Remove any visible chemicals on the patient's body by gently washing off liquids or brushing off solids. Avoid skin irritation or injury, as both will lead to increased absorption of any remaining chemicals. Avoid aerosolization of the contaminant. Blot any heavy liquids with absorbent towels.[2,6]

Patients with open wounds require the area surrounding the wound to be gently washed with water. Irrigate the wound with clean water. Cover large wounds with plastic wrap to prevent runoff into the wound during the remaining decontamination procedure.[2] **Do not delay copious water irrigation if this wound care cannot be accomplished rapidly.**

Begin copious water irrigation with warm water using low water pressure (normal shower pressure) for 3 to 5 minutes. Use liquid soap, shampoo, and soft brushes to gently cleanse the skin and any body hair.[5] Thoroughly rinse the patient after soaping and shampooing. Repeat the procedure until all visible contamination is removed. **Do not forget to thoroughly clean any mucous membranes, the nails, the external auditory canals, the axillae, the groin, and any other skin folds.** Use cleaning devices such as surgical scrub sets for nail folds or syringes to flush the external auditory canals.

Irrigate the eyes, if contaminated, for 5 minutes. Remove any contact lenses and place them in a double bag. A Morgan lens may be used if the globe is intact. Irrigation with running water is also an option but may be less thorough than with a Morgan lens. A nasal oxygen cannula may be placed on the bridge of the nose if both eyes are affected.[2] Allow water to flow through the cannula and direct it from the medial canthus outward. Refer to Chapter 155 for the details regarding eye irrigation.

Do not let caregivers carry children in a wet decontamination environment as they may fall and injure themselves and the child. Instead, have decontamination personnel carry the child. It may take two providers to safely carry a struggling wet child while wearing personal protective equipment.[9] An alternative is to use a gurney or wheelchair.

The nonambulatory contaminated trauma patient or a patient with altered mental status may need to be decontaminated on a specialized stretcher that is equipped to catch wastewater. Autopsy tables from the morgue may be used after covering the surface with plastic. Enough decontamination personnel must be available to maintain cervical spine immobilization while log-rolling the patient as the decontamination process is performed.

DECONTAMINATION TECHNIQUE FOR BIOLOGICAL WEAPONS AGENTS

Biological weapons agents include bacteria, spores, viruses, and toxins. Chemical decontamination renders biological weapons agents harmless by the use of disinfectants.[14] **Most biological warfare agents are transmitted by inhalation; therefore, respiratory protection is highly recommended.** Treat dermal exposures immediately with soap-and-water decontamination using a soft brush followed by rinsing with copious amounts of water. This alone is often sufficient to avert contact infection. Wash with a dilute bleach (hypochlorite) solution to eradicate any remaining biological agent.

Mix one part Clorox bleach and nine parts water, as standard stock Clorox is a 5% solution, to make a 0.5% sodium hypochlorite solution. The diluted bleach solution must be made fresh daily with a pH in the alkaline range. Diluted and undiluted bleach solutions evaporate quickly. Store the bleach solution in closed and distinctly marked containers to avoid confusing the 5% and 0.5% solutions. Wash the contaminated areas with a soaked cloth or swab for 10 to 15 minutes with the 0.5% sodium hypochlorite solution. **A contact time of 10 to 15 minutes is required.**[14] Rinse thoroughly with water.

The dilute bleach solution is contraindicated for application into the eyes, into open brain and spinal cord injuries, or for surgical irrigation of the abdomen. However, it may be used for lavage of

other noncavity wounds and removed by suction to an appropriate disposal container. Within 5 minutes, the now contaminated bleach solution will be neutralized and is considered nonhazardous.

Use a 5% hypochlorite solution (undiluted Clorox) to decontaminate fabric, clothing, and equipment. **A contact time of 30 minutes prior to normal cleaning is required for the decontamination of equipment.** The 5% bleach solution is corrosive to most metals and injurious to most fabrics. Thoroughly rinse and oil metal surfaces after completion.

Physical methods to render biological weapons agents harmless include heat and radiation. Dry heat requires 2 hours of treatment at 160 °C to render biological agents completely harmless. Autoclaving is effective. Steam at 121°C and 1 atmosphere of overpressure (15 psi) will reduce the required time to approximately 20 minutes, depending upon volume.

Rooms in fixed spaces that become contaminated are best decontaminated with gases or liquids in aerosol form (e.g., formaldehyde). This is combined with surface disinfectants, in most cases, to ensure complete decontamination. Solar ultraviolet radiation that reaches the earth's surface has a certain disinfectant effect, often in combination with drying, and will aid in the decontamination of outdoor decontamination facilities. Chlorine-calcium or lye may be used if it is necessary to decontaminate terrain.

ASSESSMENT

Move the patient after decontamination to the contamination reduction zone ("warm zone"). Assess the patient and initiate any required advanced life support measures. **There are no objective criteria to assess whether decontamination was sufficient.** There is, however, evidence that copious water irrigation and soap cleansing are highly effective in removing many chemical contaminants.[4] Measure the tear film pH if the eyes were exposed to corrosive agents. Continue eye irrigation until the pH is neutral. This may take up to 15 minutes. Assess all wounds. Thoroughly irrigate any wounds. **Transfer the patient into the support zone (Emergency Department or "cold zone") when they are deemed decontaminated.**

HEALTHCARE PERSONNEL DECONTAMINATION TECHNIQUE

Healthcare personnel must remove their personal protective equipment in an organized fashion to prevent self-contamination after decontamination of the patient.[8] This is a suggested protocol for the minimum personal protective equipment, which may need to be altered if more sophisticated equipment is to be decontaminated and recycled.

Remove the tape securing the gloves to the suit. Place the tape in a plastic bag. Remove the outer gloves, turning them inside out as they are removed. Place the gloves in the plastic bag. Remove the suit, turning it inside out as it is removed. Place the suit in the plastic bag. Seal the bag with duct tape. Remove the plastic shoe cover from one foot and step over the "clean line." Remove the other shoe cover and put that foot over the line. Place both shoe covers in a plastic bag at the line. Remove the goggles and mask. Place them in the plastic bag. Seal the plastic bag. If a PAPR if worn, an assistant is required to prevent contamination of reusable equipment. The assistant dons gloves and supports the battery pack while the belt is loosened and the hood is removed. Hold the hood away from the body to avoid contamination. Detach the hose. The assistant places the pack and hose in a bag for reprocessing. Place the hood in a separate bag for reprocessing or disposal and seal the bag with duct tape.[16] Remove the inner gloves. Place them in a plastic bag and seal it. Close off the dirty area until the level of contamination is established and the area is properly decontaminated. Move to a shower area. Remove the scrub suit and seal it in a plastic bag. Shower thoroughly with soap and water. Dress in normal work attire.

AFTERCARE

Further patient management will depend on the type of exposure and other circumstances. Perform a thorough secondary survey to detect occult trauma or medical illness. Monitoring for cardiac dysrhythmias or for noncardiogenic pulmonary edema may be necessary after exposure to certain chemicals.[2,6] Some toxins necessitate treatment with specific antidotes, which should be initiated as soon as possible.

Dilute ingested chemicals with 4 to 8 ounces of water. Activated charcoal (1 g/kg) may be given to prevent further absorption.[6] Ingestion of corrosive agents may necessitate early endoscopy, in which case charcoal should be withheld.[6] Induction of emesis is rarely indicated and may pose a hazard to the patient (if they ingested corrosives or hydrocarbons) and to healthcare personnel (if the patient ingested cyanide).[2,6] Refer to Chapters 59, 60, and 61 for the details of gastrointestinal contamination.

COMPLICATIONS

Hypothermia may be caused or worsened by the decontamination procedures.[2,6] This must be anticipated and treated accordingly. Children are especially vulnerable to hypothermia.[9] Residues of highly toxic chemicals remaining in skin folds or under nails may pose a risk to the patient and caregivers.[6] This should be searched for and removed. Toxic vomitus may pose a risk to healthcare personnel, even after adequate decontamination.[2,6] Emesis must be contained and discarded appropriately.

SUMMARY

Emergency Departments must be prepared to decontaminate and treat victims of hazardous materials exposures at any time. Procedures must be developed, practiced, and incorporated into the hospital's mass casualty incident plan. Lack of preparation and practice will expose medical personnel to greater risks and lead to less than optimal patient care. This chapter presents a general approach to decontamination procedures, which must be adapted to the individual circumstances and type of exposure.

194 Physical Restraints

Cheryl Person, Dean Sagun, and Mark Fanning

INTRODUCTION

In recent years, psychiatric emergency services have become a major point of entry into the mental health system and a principal treatment site for many patients with chronic and severe mental illness.[1] Emergency Department (ED) patients with altered mental status, emotional and psychological disturbances, head trauma, psychiatric illness, or other medical conditions may be aggressive, physically injurious, or violent.[2,3] The aggression may be exhibited toward themselves or toward the healthcare personnel who are caring for them.[4] **Given the volatile nature of some presenting conditions, physical restraints might be necessary to ensure the safety of the patient and the healthcare personnel.** One prospective study found that 0.07% of ED patients were restrained

during the 1-year study period.[5] Consistent with clinical practice, most patients in this study were restrained for agitation, disruptive behavior, or violent behavior.

Physical restraints are the direct application of physical force to a patient without patient consent to restrict their freedom of movement. The use of restraints for managing behavioral emergencies is allowed only when all other less restrictive measures have failed and severely aggressive or destructive behaviors place the patient or others in imminent danger. The Centers for Medicare and Medicaid Services (CMS) defines physical restraint as "any manual method, physical or mechanical device, material or equipment attached or adjacent to the patient's body that they cannot remove and that restricts freedom of movement or normal access to one's body."[6] The use of restraints in the ED may help to prevent patients from physically harming themselves or others. Imminent safety concerns are the only justification for the application of physical restraints.[6] Once applied, physical restraints must be used for the shortest time possible and with the least restriction possible.[6,7] If used properly and in the appropriate patient, physical restraints are humane and effective in the management and treatment of the patient while ensuring the safety of the patient and the healthcare personnel.

This chapter will present the rationale and technique for using both locked-door seclusion and physical restraints in the ED. This chapter focuses on the aggressive, dangerous, and/or violent patient. It does not review the techniques for physically restraining the young child during brief diagnostic or therapeutic procedures.

LEGAL CONSIDERATIONS

Informed consent is required before Emergency Physicians can lawfully treat competent adult patients, all of whom have the right to refuse medical treatment. Refer to Chapter 1 for a complete discussion of the informed consent process. United States courts have consistently upheld the idea that a competent adult would consent to treatment to maintain health or life and also that a patient could be restrained to protect others or self as long as the reasons for interventions are clearly documented.[8] Even in an emergency setting, the competent adult retains their right to refuse treatment. **Coercive measures, including restraints and threat of restraints, cannot be used solely because a patient refuses treatment.** It is never appropriate to restrain a competent patient against their will solely because they are refusing recommended treatment.[9] The Joint Commission (TJC), which governs hospitals, have required specific training elements for personnel who will be applying physical restraints. They also require hospitals to have clearly delineated policies as to who is certified as capable of applying restraints. The elements of training include the use of nonphysical interventions and the demonstration of these skills.

INITIAL APPROACH TO THE PATIENT

It is important to attempt to use verbal de-escalation techniques prior to initiating physical restraints. All of these techniques should be carried out in a calm voice that is clear, slow, and low in volume. This approach can assist the Emergency Physician in engaging the patient and calming the situation. Gently question the patient as to why they are distressed. Allow the patient time to think about the question prior to offering an array of potential choices. Common reasons why ED patients get agitated include being made to undress and put in hospital attire, being hungry, being frightened in a medical facility, being frustrated at the perceived lack of concern on the part of healthcare providers, being in pain which they do not feel is being promptly addressed, and not understanding why things are happening. **Addressing the patient's specific concern can often de-escalate the agitated patient.**

If the patient is still unable to communicate their needs or is too agitated to tolerate questioning, begin to orient them to their environment. Explain in clear language what needs to occur. For example, "Mr. Smith, you are in the ED because you are having a fever, and we now need to get you dressed in a hospital gown. Can you do that for me? May I help you?" **Allow the patient some control to make decisions about the sequence of events as much as safety permits.** For example, if the patient first wants to use the restroom or drink water, allow the patient to do these things first. Patients who are frightened or confused often de-escalate with these techniques.

It is often possible to encourage the patient to take oral or intramuscular medication prior to the use of physical restraint. The ability to begin a patient on needed medical treatment (i.e., benzodiazepines for alcohol withdrawal or antipsychotic agents for paranoia) may allow the patient to de-escalate and eliminate the need to initiate physical restraint. These patients must be carefully monitored including constant observation, pulse oximetry, and vital signs at regular intervals and telemetry if appropriate.

CONTRAINDICATIONS

Physical restraints should not be used for the sake of convenience or if a competent adult refuses treatment. It should not be used for patients who are currently not demonstrating behaviors that would put them, staff, or others in imminent danger. Patients with a history of violence but exhibiting no active imminent aggression also cannot be restrained. It is an urgent intervention that should be used only when less restrictive interventions have failed.

Because of the potential severity of the complications associated with the use of physical restraints, they must be immediately released when the patient is no longer demonstrating dangerous behavior. Hospitals must ensure appropriate staffing levels to meet this dynamic need. Every acute care hospital has developed policies and procedures for the monitoring and documentation associated with the use of physical restraints. A sample of the required documentation can be found in **Table 194-1**. The Emergency Physician

TABLE 194-1 Typical Documentation Requirements for the Physical Restraint of a Patient

Physician orders
- Date and time of order
- Description of specific behavior which placed patient, staff, or others in imminent danger
- Alternatives to restraint employed (e.g., verbal de-escalation)
- Patient response to alternatives

Ongoing assessment
- Family notification of restraint as appropriate
- Documentation of personnel involved in the application of restraint, including security and other trained staff
- Patient's reaction to restraint
- Patient's pre-existing medical or psychiatric condition that may increase the risk of harm
- Description of behaviors that patient needs to demonstrate to release restraints

Conclusion of restraint
- Documentation of the expected behavior demonstrated by the patient that led to release of restraints
- Debriefing of the patient regarding the episode of restraints including their reaction to the application of restraints
- Debriefing of the staff as appropriate
- Discontinuation of the restraint order

must be cognizant of these requirements and be able to follow these policies and procedures. Asphyxiation and strangulation are the two most serious complications of physical restraint. Personnel must be available to continuously monitor the patients' respiratory status through the application of restraint.

The use of leather restraints significantly increases the risk of rhabdomyolysis, skin breakdown, and neurovascular complications, even when used correctly. Patients should demonstrate the ability to break free from soft restraints or require the additional security of leather restraints prior to the application of leather restraints. Leather restraints are thus to be considered a restraint of last resort.

Seclusion should not be used if the patient is unstable, must be medically monitored, or if they overdosed on medications and/or poisons. Seclusion is also contraindicated if the room cannot be constantly monitored visually, either electronically with close-circuit video or by direct observation through a window.

EQUIPMENT

- Gloves
- Additional personal protective equipment, if indicated
  - Gown
  - Face mask with an eye shield or goggles
  - Cap
- Standard ED bed
- Hospital approved restraint devices, 2- and 4-point
- Philadelphia collar, various sizes
- Additional personnel

The following equipment may be necessary for putting a patient in physical restraints. First, utilize personal protective equipment (PPE) if contact with the patient's body fluids may occur. Second, only devices manufactured for the express purpose of restraining a patient should be used. Restraints are available in a variety of styles (Humane Restraint, Waunakee, WI, www.humanerestraint.com). They are made of a number of materials (e.g., polyurethane, polypropylene, leather) with Velcro or buckles to secure them. Use a standard ED bed for 2-point and 4-point restraints. Padding material must be utilized to protect the patient's bony prominences. Soft restraint manufacturers usually include this already attached to the restraint. Leather restraints are physically stronger and less constricting than soft restraints. These are more effective in the truly violent patient than soft restraints. Makeshift restraints (i.e., gauze rolls) are difficult to apply and must be tied extremely tight to hold the patient. These makeshift restraints must be avoided in the ED because of the increased risk for injury to the skin, peripheral nerves, extremity vasculature, and respiratory difficulties (if placed around the chest).

The restraints, personnel, and a plan should be assembled and ready prior to initiating physical contact with the patient. This will reduce the risk of asphyxiation due to a prolonged physical contact time with the patient. A sufficient number of personnel must be available. They should all be approved for applying restraints to protect both the patient and the staff. At least one of the staff members should be a female if the patient is female. It is best to have security standing ready to assist if needed. Their mere presence and visibility to the patient as a "show of force" is often enough to calm the patient. Emerging practices may include a scribe to document the initiation of restraint, to ensure the safety of the patient during the application of restraints by keeping time, monitoring the patient's status, and confirming respirations. An Emergency Physician order for physical restraint is required (**Table 194-1**). It must be documented within 1 hour of the application of the restraints. Thus, it can be documented after the restraints are initiated.

PREPARATION

Appropriate use of restraints requires prior planning and education of physicians, nurses, and security staff. Without sufficient training and safeguards, physical restraints may pose a danger to the patient as well as the staff.[2,10] To ensure the safety of a patient and the staff, the Emergency Physician must provide a timely diagnosis and an appropriate acute management plan. **The "ABCs" of the emergency evaluation of aggressive and impulsive behavior include safety, diagnosis, and management. Safety is the first priority when confronted by a potentially violent patient.** Adequate evaluation, diagnosis, and management is impossible without proper safety mechanisms.

The application of physical restraints requires the understanding that physical/mechanical restraints are devices that can be used to prevent patient interference with medical treatment, reduce risk for falls and subsequent injury, and/or keep the patient from harming themselves or others. **Physical restraint should only be used as a last resort for maintaining patient safety. The alternatives to physical restraint should be continually evaluated.** It is important to be familiar with hospital procedures for ordering physical restraints, including documentation requirements (**Table 194-1**). It is also advantageous to have personnel on hand who are trained in the application of physical restraints and have demonstrated competencies in the area (usually nursing staff).

The Emergency Physician must understand the indications and purposes for use of the different types of restraints and their respective functions (e.g., wrist restraints to prevent arm movement). The Emergency Physician should observe and document the type of behavior that has led to the need for physical restraint (e.g., attempting to harm oneself or others, removing IV catheters or other equipment) and the type of restraint prescribed (**Table 194-1**). The treatment team (i.e., Emergency Physician and nursing) should each document the situation, the alternatives to physical restraint that were attempted along with their lack of success. Review the manufacturer's directions for assembling and placing the physical restraint. Lower the bed as low to the floor as possible. Visually inspect the bed to ensure it is free of objects that may be trapped under a physically restrained patient.

Gather all the supplies required for the physical restraint procedure. Assemble the personnel required for safety during the physical restraint procedure. One or two people will usually be physically applying the restraints. It is common to need up to four additional personnel to hold the patient during the application of the restraints. Understanding the nature of the aggressive behavior and the physicality of the person who will need to be restrained may help determine how many additional personnel are required. **It is always better to have more people than needed than not having enough. It is dangerous for the patient and the staff to have fewer people available to help than is needed. It is often better to have a "show of force" with multiple staff members and security present and visible to the patient. The mere presence of multiple people convey the message you are serious, often makes the patient more compliant, and gives the patient an excuse to cooperate with the application of physical restraint.** Although the application of physical restraints is time limited, it is a personnel intensive process. In a busy ED, be aware that other agitated patients may take this opportunity to elope from the facility.

Communicate with the patient and family. Evaluate whether the patient or family members require special considerations regarding communication (e.g., due to illiteracy, language barriers, or deafness). Make arrangements to meet these special needs

if necessary. Briefly assess the patient and family for knowledge deficits and anxiety regarding the physical restraint procedure. Assign a staff member to provide information and emotional support as needed.

Family members should not be present for the physical restraint procedure. They may become agitated themselves during the procedure and make it an unsafe environment for staff. They may also serve as an agitating influence on the patient. All family should be politely asked to wait in the lobby or family room until the patient is secure. Inform the family that they may return once the patient is restrained and any procedures have been completed. They should also be informed that under no circumstances should they attempt to loosen or remove the physical restraints, as this should be done solely by hospital staff. Assign a staff member to escort the patient to the lobby or the family room.

All staff involved must have a knowledge of proper patient positioning. **Do not restrain a patient with one or both arms positioned above their shoulders. These "arm-elevated" positions can result in respiratory compromise. Patients must be restrained in the supine position with their arms by their sides. The restraints must always be tied to the bed frame and not the side rails.**[11] The patient can experience significant pain and injuries if the bed rails are lowered while the restraints are tied to them.

TECHNIQUES

LOCKED-DOOR SECLUSION

One form of physical restraint within the ED is locked-door seclusion (LDS). LDS provides a low stimulus environment that is free of dangerous objects. It is a less restrictive form of physical restraint that is an appropriate and viable alternative if the patient is more likely to be an escape risk, dangerous to others, or dangerous to themselves. Patients who are violent or self-destructive may be placed in LDS. Agitated patients can be placed in LDS by security that are authorized and trained to physically escort patients. A "show of force" often makes the patient more cooperative. ED staff can assist a patient who is not physically threatening, but for whom the regular ED environment provides too much stimulation to allow effective treatment to occur. In all cases, security should be present to prevent injury to the patient or the staff. Agitated patients may require that all treatment, including changing into hospital attire, commence in the LDS setting.

Hospitals who have LDS capability should have built the room according to TJC parameters to provide safety, reduced stimulation, and less risk of patient self-injury. These rooms should have very limited equipment and supplies other than a bed so that the patient does not injure themselves. A patient can inflict significant self-injury with simple things such as blood collection tubes, needles, and tongue depressors to name a few. **Once occupied, the LDS room must be continuously monitored via video or direct 1:1 monitoring through a window or portal.** State law varies on what type of monitoring and documentation is required. **It is important to recognize that a patient is not absolutely safe in LDS.** Highly agitated patients can injure themselves in such a context. The most likely cause of death in LDS is a cardiac event. It is especially important that a physical examination proceed as rapidly as possible after the patient is placed in LDS in order to address and correct any underlying causes of aggression and/or agitation (e.g., head trauma, diabetic ketoacidosis, hypoxia, etc.).

PHYSICAL RESTRAINTS

Perform hand hygiene and apply personal protective equipment as needed. Introduce yourself and your plan to the patient in a calm manner. Assemble all the required personnel in the room. Provide privacy by closing the door to the room and/or pulling the curtain around the patient's bed if in a shared patient room.



FIGURE 194-1. Soft wrist restraints should have a gap of one to two fingers breadths between the patient's wrist and the restraint.

The Emergency Physician should not physically participate in holding the patient or the application of physical restraints. This allows the Emergency Physician to maintain the physician–patient relationship required to subsequently evaluate, manage, and treat the patient. With the help of trained assistants, physically assist the patient into a comfortable supine position that allows easy access to the area of the body to which the restraint will be applied. Apply the soft restraints to the patient's wrists, leaving approximately 1 to 2 cm distance between their wrist and the restraint. It should fit snugly but not constrict (**Figure 194-1**).

Apply and tie the two long ends or strapping to the bed frame as a unit (**Figure 194-2**). They should be attached to the portion of the frame that moves when the head of the bed is raised and lowered. **They should not be attached to the side rails.** Attaching the restraints to the side rails increases the patient's risk for injury when they are lowered. Make a slip knot with the strapping (**Figure 194-2**). This allows for easy removal in case of an emergency. Secure the restraints to the bed frame in such a manner that both wrists remain at the patient's sides to reduce shoulder injury risk. **Never restrain the patient with one or both arms above their shoulders to ensure that the patient does not experience respiratory compromise.** The slip knot is easily released by pulling on the free ends of the strapping (**Figure 194-3**).

The 2-point soft restraint of the wrists is less restrictive than the 4-point restraint of all limbs. Apply the 4-point restraints to both wrists and ankles. Apply the soft restraints to the patient's ankles similar to that of the wrists. Leave approximately 1 to 2 cm distance between the ankle and the restraint (**Figure 194-4**). They should also be attached to the bed frame.

Soft restraints are less restrictive than leather restraints. The method for determining which type of restraint is required must be determined by clinical experience and the current situation involving the specific patient and their behavior. Patients who are physically frail and nonviolent may benefit from 2-point soft restraints. However, if they are able to move too freely and are agitated, 4-point restraints may be necessary for patient safety. Severely agitated, aggressive, and dangerous patients may require leather restraints. **The goal is to utilize the least restrictive restraint method while ensuring the safety of the patient and the staff.**

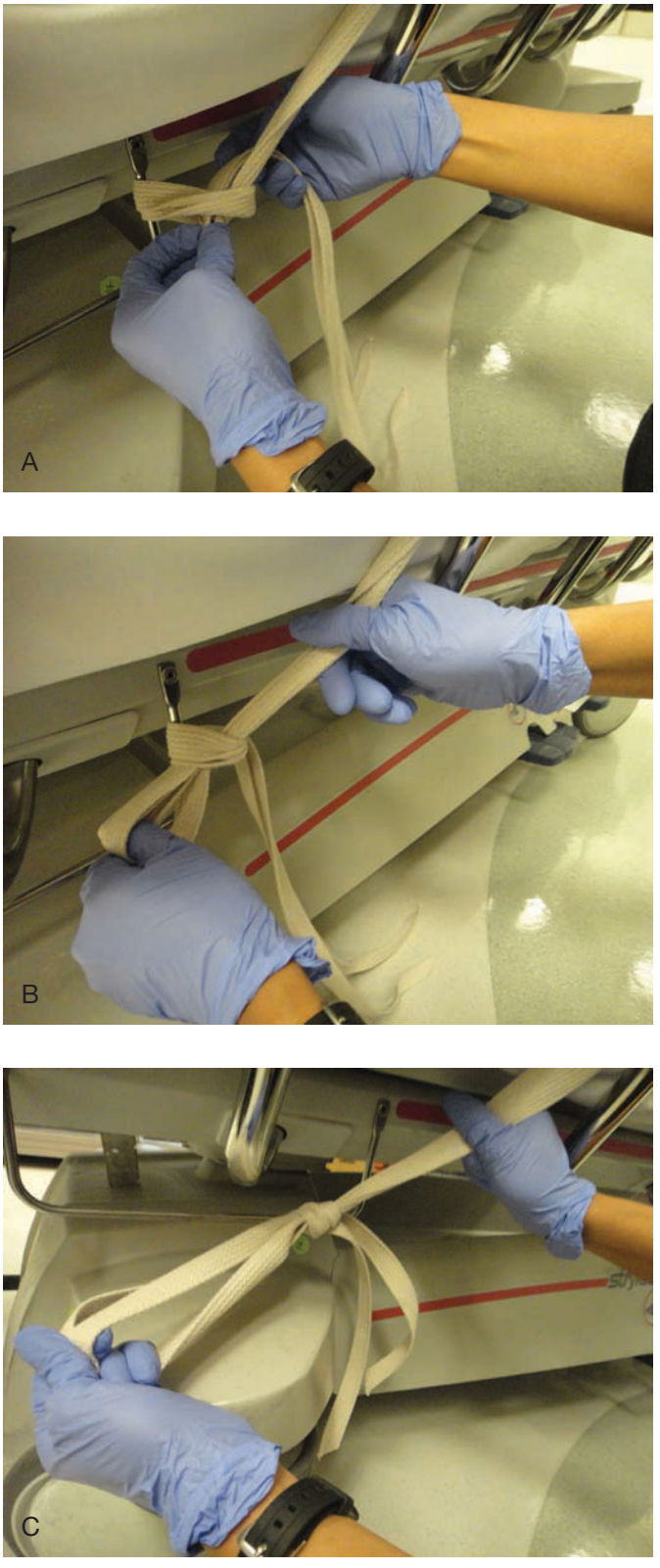


FIGURE 194-2. Soft restraints are attached to the bed frame using a slip-knot. **A.** Starting the slip knot. **B.** Making the slip knot. **C.** Tightening the slip knot.

Other restraint devices have been used in conjunction with extremity restraints. Apply a Philadelphia collar to minimize the potential for biting and head banging. An alternative, and more readily available in the ED, is to apply a standard cervical collar that is used for the trauma victim. This standard cervical

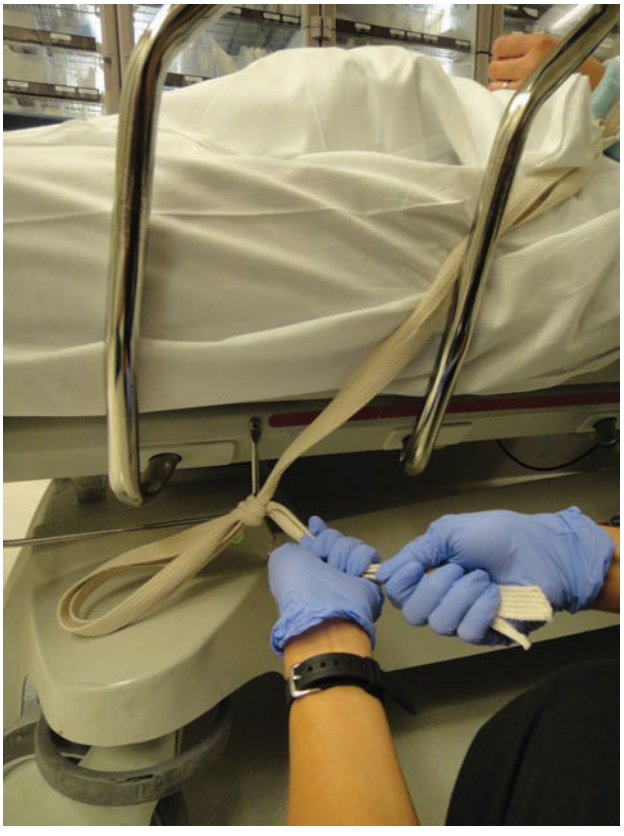


FIGURE 194-3. Pulling the loose end of the soft restraint will immediately release the knot.



FIGURE 194-4. Soft ankle restraints should have a gap of one to two fingers breadths between the patient's ankle and the restraint.

collar should be exchanged as soon as possible with the softer Philadelphia collar to prevent the standard collar from injuring the patient. **Never use a torso restraint or sheet around the torso.** Limiting chest movement and respirations can result in respiratory compromise and death. Use a device specifically designed to be wrapped around the patient's hips and that attaches to the bed frame. Chemical restraint can be safely administered once the patient is physically restrained.

PEDIATRIC PATIENTS

Pediatric patients are rarely restrained for aggressive and violent behavior. The very young are commonly restrained for diagnostic and therapeutic procedures.[25] These are brief episodes of discrete restraint for specific indications. The same general indications, contraindications, and concerns should be used with children as in an adult. Young children should not be placed in LSD by themselves. This can result in them becoming more frightened and agitated. Allow the parent or guardian to remain in the LDS room if it is safe for them to do so.

Technically, the procedure is the same for pediatric patients that require physical restraint for aggressive and violent behavior. However, the restraint time requirements are different. Limit the time an adult is physically restrained or in seclusion to 4 hours. Physical restraints and seclusion must be limited by decreased time intervals in pediatric patients: 2 hours for children and adolescents ages 9 to 17 and 1 hour for patients under 9 years old. After this time period, document an assessment and a new order for the continued use of physical restraints or seclusion. As appropriate in older children, release the restraints every 1 to 2 hours and assist the patient to the bathroom, and/or offer food and fluids.[11] It is wise to document patient assessments at more frequent intervals than that with an adult. Follow your hospital's policies regarding documentation and assessments.

Frightened young children who are not able to respond rationally to their circumstances may be soothed when held by an adult, termed therapeutic holding. This helps the pediatric patient regain control of their emotions and is used as an alternative to mechanical restraint or seclusion.[2,12–16] If it is used in the ED for other procedures, it is considered part of ongoing care. This requires specific training beyond the scope of this chapter. Adolescents may need to be separated from friends or family members who are causing their behaviors to escalate.

ASSESSMENT

Patients who are restrained require constant observation by specifically trained personnel. The complication rate for a patient in physical restraints has been estimated at 5.4% to 7%, although none were life threatening.[5,15] Evaluate the patient every 15 minutes for signs of injury according to hospital protocol for the type of restraint. Documentation of monitoring includes confirming airway patency, breathing, and circulation. At regular intervals monitor IV catheters, urinary catheters, drainage tubes, and other equipment to verify correct positioning and the absence of occlusion by the restraints. Assess the needs of the patient and/or family members. Offer additional information and emotional support as needed. Continually assess whether restraint of the patient is necessary. Evaluate the appropriateness of restraint use, including the level and characteristics of the patient's activity at least once every 4 hours. Note whether the patient continues to exhibit the behaviors (e.g., agitation, combativeness) that have made restraint necessary. The treating Emergency Physician must perform and document a face-to-face evaluation of the patient within 1 hour of the application of physical restraints.[11] Provide written information as appropriate to reinforce patient/family teaching. Document the procedure in the patient's medical record, including all patient/family teaching and the need for follow-up education, if any.

Patients will need to be continuously monitored if they are restrained secondary to violent and self-destructive behaviors. State laws vary on monitoring if the patient is placed in restraints for nonviolent and non-self-destructive behavior, but they may be monitored less frequently. Hospital policies determine these parameters such that they meet legal, TJC, and CMS requirements.

AFTERCARE

Once the restrained patient has calmed down, an organized approach should be taken to remove the restraints. Talk with the patient about removing the restraints and review the patient's ability to stay calm and follow instructions. This process is known as debriefing.[11] Some Emergency Physicians release all restraints at once. **However, releasing the patient's restraints in a stepwise approach may prove safer.** First, release one of the patient's arms. Inform the patient that if they remain calm, other restraints will be removed. **The patient must be observed to ensure that they do not release their other restraints once an arm is free.** Wait a short period of time before releasing the patient's opposite arm if in 2-point restraints or their opposite leg if they are in 4-point restraints. If the patient was in 4-point restraints, wait a short period of time then release the remaining two restraints at the same time. An alternative in the 4-point restrained patient is to initially remove both leg restraints followed by one arm then the other. **The patient should never be left with only one arm restrained without a staff member at the bedside because this allows too much mobility and may cause harm to both the patient and the staff members if the patient becomes combative or falls from the bed.[2] Never leave a patient restrained only by their legs as they can become injured if they fall off the bed.**

Discuss with the patient the reason restraints were required. Include in the discussion the alternatives that were first tried and that failed, thus requiring physical restraint. Review the behaviors that should be avoided in the future that will prevent the application of physical restraints.

COMPLICATIONS

The use of physical restraints can result in asphyxia, strangulation, and sudden death if they are incorrectly applied or if the patient is not appropriately monitored.[17–21] Patients restrained in the prone position or who are under the influence of stimulants are at an increased risk of complications.[22–24] Never restrain a patient in the prone position as this can compromise their respiratory function. Tightly applied restraints or the patient fighting against the restraints can result in abrasions, skin breakdown, contusions, extremity fractures, joint dislocations, neurovascular damage, or rhabdomyolysis leading to acute renal failure.[2] Consider the use of chemical restraint (Chapter 195) to minimize these potential complications and to be able to release the physical restraints.

DOCUMENTATION

Thorough documentation of the incidents involving the use of restrictive physical intervention is essential (**Table 194-1**). No single set of documentation guidelines has been drawn up to define what exactly should be recorded after such incidents have occurred.[15] The documentation standards for restraint and seclusion episodes include the circumstances leading to their use monitoring requirements, and staff debriefing.

SUMMARY

Patients come or are brought to the ED seeking relief from a variety of maladies. However, on occasion, they display behavioral disturbances which create imminent danger for themselves and others. Alternatives to physical restraint must be attempted and documented before the initiation of physical restraints. At times, it is necessary to physically restrain a person. This chapter provides the rationale, medicolegal justification, and commonly used techniques for physical restraint in the ED.

195 Chemical Restraint

David K. Duong and Hemal Kanzaria

INTRODUCTION

Acute agitation, psychosis, and violent behavior are common presentations in the Emergency Department (ED). It has been estimated that 32% of EDs in teaching hospitals report daily verbal threats and that 25% restrain at least one patient per day.[1,2] Management of the agitated patient presents a complex challenge of minimizing the risk of potential violence while enabling appropriate clinical evaluation of the agitated state. The underlying diagnosis is often unknown and treatment must often be rendered urgently with limited time for decision making. Such presentations can interfere with the ED evaluation and treatment as well as compromise both patient and staff safety. These behavioral emergencies may require pharmacologic intervention to reduce agitation, resume a more normal physician–patient relation, and facilitate safety.

The use of chemical restraint implies that medications are used to control behavior and confine a patient's bodily movement, but without an assessment and treatment plan.[3] However, this is rarely the case in the ED, as medications to manage behavioral emergencies are administered as part of an evaluation and plan of care. For the purposes of this chapter, chemical restraint will refer to the emergent use of medications to control dangerous behavior in a patient.

GENERAL CONSIDERATIONS

Behavioral emergencies provide complicated medical and ethical considerations. The benefits of chemical restraint should be seriously considered against the potential side effects of the medication. Emergency Physicians must be aware of alternatives to chemical restraint as well as the careful assessment, reevaluation, and treatment of the acutely agitated patient. Ideally, chemical restraint provides a calming, rather than sedating, effect with a continued emphasis on doing no harm to the patient while simultaneously reducing the risk of violence.[4,5] An objectively good response to chemical restraint may still leave the patient feeling traumatized and angered. **To the extent possible, allow the patient to participate in treatment decisions.** This can be achieved through simple tasks such as asking the patient if they have a medication preference or offering a choice between potential medications.[5] If this approach fails, attempt further verbal de-escalation or a "show of force" before any physical or chemical restraint.[6]

EDs should have written policies regarding restraint use and monitoring as mandated by the Centers for Medicare and Medicaid Services (CMS) and The Joint Commission (TJC).[3,7] Both CMS and TJC have protocols for the use of restraints. The CMS defines chemical restraint as use of a medication to restrict a patient's behavior or freedom of movement but is not the standard treatment or dosage for the patient's underlying condition. Both CMS and TJC recognize the legitimate use of restraint for the acute medical or surgical patient to prevent patient injury and alleviate violent behavior that places the patient, staff, or others in immediate danger. Both organizations identify restrictions, including that restraints must only be used when less invasive interventions have failed; must be ordered by a licensed clinician (can be a nonphysician); require the patient to be evaluated by a Physician within 1 hour after restraint initiation; and cannot be written as a standing or as needed order.[3,8–10]

A brief consideration of the legal and ethical implications of chemical restraint deserves mention. In general, consent for evaluation and care is implied during an emergency. The courts assume a competent lucid adult would consent to treatment necessary to maintain health or life.[11] Emergency Physicians must also consider whether the patient has the decisional capacity to refuse offered care. The more life threatening the emergency, the greater should be the Emergency Physician's comfort in treatment. If there is doubt as to the competency of the nonconsenting patient, it is best to err in favor of treatment.[11] If the patient is competent, then some leeway must be given to patient preference for treatment. **The Emergency Physician must document their thought process and justification for administering chemical restraint.** The covert administration of chemical restraint may be problematic and no universal ethical standard has been established in an ED setting.[12,13] It is also always advisable to review the ED and hospital restraint protocols that have been vetted through the hospital administration and legal review.

INDICATIONS

There is no precise definition of clinical agitation or violent behavior in the ED that necessitates chemical restraint.[14] Experts have agreed that explosive and/or unpredictable anger, intimidating behavior, restlessness, pacing, excessive movement, physical and/or verbal self-abusiveness, demeaning or hostile verbal behavior, and impulsive or impatient behavior are components of clinically significant agitation.[5] A history of violence (regardless of diagnosis), male sex, drug abuse, and alcohol abuse are associated with violent behavior.[11,14–16] However, there is no reliable way to clinically predict which patients will be imminently violent. The history and physical examination will usually determine which patients are agitated, violent, or have imminently violent potential. Verbally engage the patient to the extent possible to obtain preliminary information and assess their potential for verbal de-escalation. The patient should ideally be asked about their intent to harm themselves or others, if they possess a weapon (on their person or at home), a history of recent violence, current alcohol or illicit drug use, medical conditions, and psychiatric conditions. **The possibility of violence should be taken seriously and acted upon quickly.**

Chemical restraint may, however, be necessary if verbal interaction is not adequate to alleviate violent behavior. For most agitated patients, de-escalation through verbal communication should be attempted before initiating chemical restraint. However, the Emergency Physician must gauge the potential to manage agitation and violence through verbal and behavioral interaction given the clinical situation and available resources. Not every violent patient can be managed in a stepwise fashion. Do not delay appropriate intervention for violent behavior. The ultimate decision to use chemical restraint, either alone or after less restrictive alternatives, is a clinical decision that must be made at the time the behavior is occurring.

TABLE 195-1 Contraindication to Specific Medications used for Chemical Restraint[22]

Agent	Contraindications
Lorazepam	Hypersensitivity to lorazepam or any component of formulation Acute narrow angle glaucoma Significant sleep apnea Severe respiratory insufficiency
Midazolam	Hypersensitivity to midazolam or any component of formulation, including benzyl alcohol Acute narrow angle glaucoma Concurrent use of CYP3A4 inhibitors (i.e., amprenavir, atazanavir, ritonavir)
Haloperidol	Hypersensitivity to haloperidol or any component of formulation Significant Parkinson's disease Severe CNS depression Bone marrow suppression Severe cardiac or hepatic disease
Droperidol	Hypersensitivity to droperidol or any component of formulation Known or suspected QT prolongation
Risperidone	Hypersensitivity to risperidone or any component of formulation
Olanzapine	Hypersensitivity to olanzapine or any component of formulation
Ziprasidone	Hypersensitivity to ziprasidone or any component of formulation History of (or current) prolonged QT interval Concurrent use of other QTc prolonging agents Recent MI or history of arrhythmia, uncompensated heart failure

CONTRAINDICATIONS

Attempts should be made to determine if the patient has any known allergies through a review of the medical record, through collateral history from the patient's family, and any known medical or psychiatric providers. A known allergy to a specific medicine is a contraindication to its use and to use of other medications within the same class. Dosing adjustment and caution should be used when administering medication in patients who are elderly, debilitated, have comorbid medical conditions, or a history of side effects with the use of such medications. Contraindications to the specific medications (classes) described in this chapter are listed in **Table 195-1**. **Chemical restraint is not indicated for a patient who refuses to cooperate or intensely stares. It is also not appropriate to use chemical restraint for punishment or for the convenience of staff.**

EQUIPMENT

- Personal protective equipment (gloves, mask, goggles or face shield, and gown)
- Alcohol pads
- Syringes, various sizes
- Needles, various gauges
- Pharmaceutical agents
- Resuscitation equipment
- Defibrillator
- Oxygen source
- Oxygen masks
- Nasal oxygen cannulas
- Oral airway
- Nasal airway
- Bag-valve mask device
- Continuous pulse oximetry
- Capnography, if available
- Continuous cardiac monitoring
- Intravenous access supplies
- Equipment for physical restraint

PATIENT PREPARATION

Do not attempt to chemically restrain a patient until they are searched for dangerous objects and disarmed by hospital security or police. Identify a single team leader for the chemical restraint process. This is generally the Emergency Physician, who should assign roles and instruct other involved providers.[15,17] If the patent is voluntarily willing to take oral medications, less preparation is required compared to that for an agitated patient that is unwilling to take medications. Safely make attempts to decrease external stimuli, such as offering to place the patient in a more quiet area in the ED. **Consider how many staff members may be needed to intervene and formulate this team prior to any intervention.** It may be prudent to have more staff members readily available if needed. For instance, a patient may be so physically combative as to require five people, one person to restrain each limb by immobilizing at the major joint and a fifth person to hold the head. If possible, brief the team on what is expected and of possible dangers. Universal precautions should always be used to protect the healthcare provider.

Always approach the patient face-to-face and not from behind or without warning. Staff must appear calm and in control, speaking in a nonprovocative, nonconfrontational, and noncondescending manner. **Within a room, the patient should not obstruct a staff member's ability to exit the room.** Thus, staff should initially not have the patient between them and a door until the situation is under reasonable control.

Always leave the door to the room open to facilitate escape if the staff feel they are not safe. The open door also allows additional staff to enter and assist. It may be necessary to have security nearby and aware of the situation.

CHEMICAL RESTRAINT AGENTS

Improvements in pharmacologic treatment of the acutely agitated or psychotic patient have been recently made, resulting in more medication choices. The medication selected should be based on diagnostic or etiologic considerations, onset and duration of action, efficacy, route of administration available, patient's history of response to the medication, patient preference, ease of administration, and potential for adverse effects (**Table 195-2**).[4,5] **The ideal agent for sedation of the acutely agitated patient in the ED is one that is rapidly effective without causing excess sedation, easily administered, available via multiple routes of administration, and safe.**[18,19] Here, we present a summary of the pharmacologic options available for chemical restraint based upon the currently available evidence.

BENZODIAZEPINES

Benzodiazepines have achieved popularity because of their tolerability and safety. These medications bind to the alpha subunit of the $GABA_A$ receptor to enable inhibitory neurotransmission.

TABLE 195-2 General Choices for Chemical Restraint Based Upon Consensus Guidelines[5,29,30]

Provisional diagnosis	First-line medication	Second-line medication	Comments
No data available, patient willing to take oral medications	Lorazepam PO (first choice) Risperidone PO	Olanzapine PO Haloperidol PO Quetiapine PO	
No data available, patient unwilling to take oral medications	Lorazepam IM (first choice) Ziprasidone IM Olanzapine IM Haloperidol IM		
Psychotic disorder, unwilling to take oral medications	Haloperidol IM + Benzodiazepine IM or Olanzapine IM	Ziprasidone IM Ziprasidone IM + Benzodiazepine IM Haloperidol IM Benzodiazepine IM	
Schizophrenia	Olanzapine PO Risperidone PO Risperidone PO + Benzodiazepine PO Haloperidol PO + Benzodiazepine PO	Quetiapine IM Ziprasidone IM	If IM meds required, use Olanzapine, Haloperidol + Benzodiazepine, Ziprasidone, or Ziprasidone + Benzodiazepine
Mania	Olanzapine PO Risperidone PO	Quetiapine PO Ziprasidone PO Haloperidol PO	If IM meds required, use Olanzapine or Haloperidol + Benzodiazepine
Alcohol withdrawal or stimulant toxicity	Benzodiazepine PO or IM		
Conduct disorder (pediatric)	Nonpharmacologic means	Benzodiazepine PO or IM	

Note this table is adapted from information based on expert consensus panel recommendations. These recommendations should not replace clinical judgment for the needs of a given patient and clinical scenario.

Lorazepam and midazolam are the most often used benzodiazepines in the ED. They are an effective monotherapy for the initial treatment of the undifferentiated acutely agitated ED patient.[20] Multiple studies have shown that benzodiazepines reduce agitation and are as effective as haloperidol alone.[5,21] They should be used when no past medical history is available, no specific treatment is indicated (i.e., personality disorder), or when benzodiazepines have specific benefits (e.g., EtOH intoxication). Benzodiazepines have fewer significant side effects than conventional antipsychotics. They have been associated with excessive sedation and rarely paradoxical disinhibition. **Combination therapy with a typical antipsychotic may be more effective than either benzodiazepine agent alone.**

Clonazepam, diazepam, and flunitrazepam are benzodiazepines which have been shown to be potentially effective in reducing agitation. However, this information is based upon extremely small studies in hospitalized patients with known psychiatric diagnoses. Moreover, there have been inconsistent results and flunitrazepam is not available in the United States.[20] Diazepam has erratic absorption after intramuscular (IM) administration and its active metabolite make this medication less useful in the ED. Therefore, these benzodiazepines will not be discussed.

Benzodiazepines are contraindicated if the patient has a known allergy to a benzodiazepine (**Table 195-1**). Administer benzodiazepines cautiously and adjust the dose in patients who are elderly, debilitated, have respiratory insufficiency or sleep apnea, hepatic disease, or renal disease. The most common side effects of benzodiazepines include excessive sedation and respiratory depression, which can be found in over 10% of patients receiving these medications.

Emergency Physicians should be careful not to overdose benzodiazepines, especially with the possible adverse effects of excessive sedation and respiratory depression. Use flumazenil to reverse benzodiazepine-related sedation. The initial dose is 0.2 mg IV over 30 seconds. This can be redosed at 0.3 mg IV over 30 seconds if the desired level of consciousness is not obtained.[22] **Extreme caution should be exercised if flumazenil is administered. Its use may result in withdrawal seizures if the patient is chronically taking benzodiazepines.**

LORAZEPAM

Lorazepam has excellent absorption after IM administration with a rapid onset of action and a short duration of action (**Table 195-3**). The medication has minimal risks when used as a single dose or short-term administration.[19] The onset of action varies slightly depending upon the formulation administered. Sedative effects are achieved within 15 to 30 minutes of IM administration. Peak plasma concentration is achieved within 60 to 90 minutes with a duration of action of approximately 8 hours.[22,23]

TABLE 195-3 Profiles of Benzodiazepines Used for Chemical Restraint[4,5,20,22]

Agent	Dose (mg)	Route	Onset of action	Elimination half-life (h)	Metabolism	Excretion	Dosing limit	Side effects
Lorazepam	2 or 4	IV IM PO	5–10 min IV 15–30 min IM 20–30 min PO	10–14	Hepatic	Urine	12 mg/d	Respiratory depression, excess sedation
Midazolam	5	IV IM PO	3–6 min IV 10–20 min IM 10–30 min PO	1–4	Hepatic	Urine	30 mg/d	Respiratory depression, excess sedation

Lorazepam PO or IM is recommended as first-line therapy for undifferentiated agitation, alcohol-related agitation, and substance-induced agitation.[5] Expert consensus guidelines suggest optimal lorazepam dosing as 1 to 3 mg PO or 0.5 to 3 mg IM. Studies in the acutely agitated patient show that 2 or 4 mg lorazepam IM is as effective in reducing agitation and violent behavior with significantly fewer side effects compared to 5 mg haloperidol IM.[5,20,21]

MIDAZOLAM

Midazolam is a water-soluble benzodiazepine with good IM absorption, rapid time to onset, rapid time to recovery, and with minimal side effects (**Table 195-3**). Traditionally this medication has been used more for conscious sedation than rapid tranquilization. Sedation is achieved within approximately 15 minutes, while peak effect occurs at 30 to 60 minutes. The mean duration of action of IM midazolam is 2 hours. This medication is metabolized by the liver and excreted in the urine.[22]

Midazolam has a shorter time to onset of sedation and more rapid time to arousal compared to lorazepam and haloperidol.[24] One potential limitation includes the short half-life, which may require frequent re-dosing to maintain tranquilization.[19,25] As with all the benzodiazepines, midazolam can cause significant respiratory depression. Midazolam appears to be safest at a dose of 5 mg and without the concomitant use of narcotics.[4,25–27]

COMBINATION THERAPY

Medications can often be combined to achieve synergistic therapeutic effects while reducing potential adverse outcomes. For example, previous studies have focused on combining benzodiazepines with typical antipsychotic agents. **Combination treatment allows for lower doses of antipsychotic medication to achieve adequate sedation. Moreover, a lower incidence of extrapyramidal symptoms (EPS) may be due to benzodiazepine prophylaxis or treatment of antipsychotic-induced side effects.[23]**

The combination of lorazepam and haloperidol is the most commonly studied and utilized combination therapy in clinical practice. **A combination of 2 mg lorazepam with 5 mg haloperidol has been shown to more rapidly reduce agitation than either agent alone, and with fewer side effects relative to haloperidol alone.** The combination can be mixed together in the same syringe and administered IM if used immediately.[21,28] It is important to note that studies supporting these data do not control for re-dosing. Nevertheless, current ACEP guidelines recommend that the combination of a benzodiazepine and haloperidol may produce more rapid sedation than monotherapy in the acutely agitated psychiatric patient in the ED.[20]

ANTIPSYCHOTICS

Typical, also known as first-generation or conventional, antipsychotics and benzodiazepines have historically been the mainstay of treatment for acute agitation and psychosis. These medications have been available in parenteral formulations for years. However, conventional antipsychotics and benzodiazepines can cause serious adverse effects. The utility of atypical, also known as second-generation, antipsychotics is expanding as rapid-acting preparations become available. Atypical antipsychotics have differing mechanisms of action, a broader spectrum of response, and a lower side effect profile.[29]

Choosing the initial antipsychotic medication depends upon the patient's mental health and medical history, the need for concurrent sedation, and the side effect profile (**Table 195-4**). A typical or atypical antipsychotic drug can be used as monotherapy in the acutely agitated patient with known psychiatric illness. Use an oral preparation of either an antipsychotic or benzodiazepine in the cooperative but agitated patient. Options for the oral treatment of agitation related to schizophrenia or mania include olanzapine, risperidone, risperidone in combination with a benzodiazepine, or haloperidol in combination with a benzodiazepine. Use IM preparations for uncooperative schizophrenic patients. Options include olanzapine, ziprasidone, haloperidol in combination with a benzodiazepine, or ziprasidone in combination with a benzodiazepine. IM benzodiazepines are preferred over newer atypical antipsychotics in patients where no history is available or the underlying illness is undifferentiated.[5,29,30]

TYPICAL ANTIPSYCHOTICS

HALOPERIDOL AND DROPERIDOL

Haloperidol is a butyrophenone antipsychotic. It blocks dopaminergic D_1 and D_2 receptors in the brain. It is the best studied of all the typical antipsychotics, though the majority of studies have been conducted in psychiatric patients with unclear applicability to the undifferentiated acutely agitated ED patient.[20] The peak serum concentration is achieved in approximately 20 minutes after IM

TABLE 195-4 Profiles of Antipsychotics Used for Chemical Restraint[5,22,23,29]

Class	Drug	Dose	Route	Onset of action (min)	Elimination half-life (h)	Metabolism	Elimination	Dosing limits	Side effects
Typical antipsychotic	Haloperidol	2.5–10 mg	PO IM IV	30–60	18	Hepatic	Urine + feces	30 mg	EPS, NMS
	Droperidol	5 mg	IV IM	10–30 IV 10–20 IM	1–4	Hepatic	Urine + feces	30 mg/d	Prolonged QTc
Atypical antipsychotic	Ziprasidone	10 mg q 2 h or 20 mg q 4 h	PO IM	15–20	7 PO 2–5 IM	Hepatic	Urine + feces	40 mg/d	Prolonged QTc
	Risperidone	2 mg q 2 h	PO	<90	20	Hepatic	Urine + feces	12 mg/d	Orthostatic hypotension, prolonged QTc at max dose
	Olanzapine	5–10 mg q 2–4 h	PO IM	180–360 PO 15–45 IM	21–54	Glucuronidation and cytochrome P450 mediated oxidation	Urine + feces	20–40 mg/d PO 30 mg/d IM	Orthostatic hypotension, prolonged QTc at max dose

administration (2 to 6 hours after PO administration), while adequate sedative effects can be expected within 30 to 60 minutes for both IM and IV administration. The duration of effect is approximately 24 hours.[6,22,23]

Dose–response studies have demonstrated that a single dose of 7.5 to 10 mg of haloperidol may produce the best outcome with the fewest side effects. Higher doses yield lesser degrees of improvement while increasing the risk of adverse effects.[4,5,31] **While the utility of haloperidol as monotherapy is limited, the traditional combination therapy of haloperidol with a benzodiazepine is a first-line option for schizophrenia, mania, and psychosis.**

Droperidol is another butyrophenone neuroleptic that inhibits dopaminergic transmission. It is closely related to haloperidol but only available in a parenteral formulation. Compared to haloperidol, it has rapid absorption with a quicker onset of action (15 to 30 minutes) and a much shorter half-life (2.2 hours).[22,23] The peak effect is achieved within 30 minutes of IM administration and the duration of effect is 6 to 8 hours. Consequently, compared to haloperidol, it has been shown to be more effective at acutely reducing agitation while requiring fewer repeat doses and causing fewer side effects.[23] This medication has also been compared to benzodiazepines. Droperidol produces better sedation, requires fewer repeat doses, and results in a shorter ED length of stay compared to lorazepam alone.[19,20,32–34] Despite these promising results, continued use of droperidol became controversial after the FDA issued a black box warning in 2001 secondary to the drug's potential for QTc prolongation.[35]

Emergency Physicians should be aware of relevant side effects associated with typical antipsychotics. This includes EPS, cardiac arrhythmias, and neuroleptic malignant syndrome. Haloperidol has been associated with acute dystonias, parkinsonism, and akathisia. The frequency of EPS associated with haloperidol use varies significantly across studies, but has been cited to affect between 0% and 50% of patients.[21,34] These side effects are of particular concern given that they may lead to increased patient agitation and medication refusal. Anticholinergic medications such as benztropine (0.5 to 2 mg IM or IV) or diphenhydramine (50 mg IM or IV) may be used to prevent or treat EPS. Droperidol has a lower incidence of EPS in the acute setting.[33,34,36] Caution should be used when administering typical antipsychotics in patients with Parkinson disease, anticholinergic toxicity, PCP intoxication, or movement disorders. There was concern that antipsychotic agents lowered the seizure threshold in mice, but this has not been found in humans.[11]

Typical antipsychotics cause QT interval prolongation, most likely due to their quinidine-like cardiac affects.[6,19] While there have been reports of sudden death occurring with chemical restraint using typical antipsychotics, haloperidol is considered to have a low risk of causing QTc prolongation. Droperidol is recognized for its potential for causing dose-dependent prolongation of the QTc and subsequent dysrhythmias. However, multiple reviews of large series of patients receiving droperidol have concluded that while this medication can be associated with prolonged QT interval, there is not conclusive evidence that it can cause life-threatening cardiac events. ACEP guidelines recommend that if rapid sedation is needed, and after consideration of the possible adverse affects, droperidol may still be preferable to haloperidol.[20] Despite this, droperidol use has dramatically decreased since the FDA black box warning. **When using antipsychotic medications, it is important to understand the potential effects on the QTc interval. The likelihood of QTc interval change is increased when patients are already taking other medications that prolong the QTc, or when they have certain comorbidities.** Caution should be used, especially in patients with cardiac disease or those taking antipsychotics chronically. **If possible, obtain an ECG prior to the administration of a typical antipsychotic.** Withhold typical antipsychotic medication if the QTc is above 500 ms or if the patient has risk factors associated with QT prolongation. If administered, do not give additional doses if the QTc increased by >25% after administration.[19]

There has been additional concern that typical antipsychotics may be affiliated with neuroleptic malignant syndrome (NMS), which is characterized by mental status changes, muscular rigidity, fever, and autonomic instability. The risk of this complication may increase in patients receiving large amounts of typical antipsychotics over a short period of time, and may be further exacerbated in those who are poorly hydrated and restrained in a poorly ventilated holding room. It has been estimated that NMS is a rare complication seen in approximately 0.2% to 1% of patients using typical antipsychotics, thus these patients should be monitored for such physiologic changes.[4,6,23]

ATYPICAL ANTIPSYCHOTICS

With the advent of newer neuroleptic medications available in IM formulations, atypical antipsychotics are considered a breakthrough for the treatment of agitation and psychosis (**Table 195-4**). Currently olanzapine, ziprasidone, and risperidone are available in rapid-acting forms that can be used to treat acute agitation. These medications are generally well tolerated and do not cause excessive sedation compared to typical antipsychotics. This can lead to shorter ED stays and increased patient participation in care. These medications show promise to be as effective as the typical antipsychotics with a better side effect profile.[29] Caution regarding QTc prolongation should still follow the general considerations as with typical antipsychotics discussed above.

The use of atypical antipsychotics for treatment of acute agitation holds great promise. There is currently limited data on the use of these medications in the undifferentiated agitated patient. Most studies have been conducted in selected, consented, and less agitated individuals compared to the typical unselected, involuntary use in ED patients.[20]

ZIPRASIDONE

Ziprasidone is a benzylisothiazolylpiperazine antipsychotic with serotonin-dopamine antagonist effects. It was the first available atypical antipsychotic in the IM formulation. The IM preparation achieves peak concentration in 30 to 45 minutes and has a duration of effect of at least 4 hours.[19,22,23]

Multiple randomized controlled trials demonstrate that 20 mg IM ziprasidone is effective at rapid tranquilization of the agitated patient with a psychiatric history. There seems to be a dose–response effect, as studies have shown increased efficacy when comparing 2, 10, and 20 mg doses. The 20 mg dose is well tolerated without evidence of increased EPS, dystonia, akathisia, respiratory depression, excessive sedation, tachycardia, or clinically significant QTc prolongation.[37,38] Ziprasidone appears to be comparable in efficacy to droperidol, midazolam, and haloperidol in combination with a benzodiazepine.[25,39] It may be more effective and better tolerated than IM haloperidol at treating acute psychosis.

Ziprasidone's high serotonin-2A/dopamine-2 ratio neurotransmitter affinity results in a low incidence of EPS compared to conventional antipsychotics. Ziprasidone appears to cause greater prolongation of the QTc interval compared to haloperidol, olanzapine, and risperidone.[40] However, this medication has not been associated with torsade de pointes, sudden cardiac death, and only rarely increases the QTc interval over 500 ms.[19,40] In summary, ziprasidone seems to be a safe and well-tolerated medication for the treatment of acute agitation, but should not be used in patients who are at risk for QTc prolongation.

RISPERIDONE

Risperidone is a benzisoxazole antipsychotic medication with serotonin-dopamine antagonist effects. Due to its serotonin ($5\text{-}HT_2$) and dopamine (D_2) antagonism, risperidone has a low risk of EPS. This medication comes as an orally disintegrating tablet, and thus should be placed on a patient's tongue using dry hands. The tablet will dissolve within seconds. It achieves peak plasma concentration within 1.5 hours.[22,23]

The combination of 2 mg PO risperidone plus 2 mg PO lorazepam has been shown to be equivalent to 5 mg IM haloperidol in combination with 2 mg lorazepam in reducing agitated psychosis in the emergency setting. Patients receiving the oral combination were also less somnolent and thus could be appropriately examined. Such data suggest that oral risperidone is an acceptable agent for the agitated but cooperative patient.[20,41]

OLANZAPINE

Olanzapine is another atypical antipsychotic with combined serotonin-dopamine antagonist effects. The medication is available in both an orally disintegrating tablet and an IM formulation. The IM preparation achieves peak plasma concentration in 15 to 45 minutes (5 hours for PO form) and has a duration of action of up to 24 hours.[22,23]

IM olanzapine effectively treats acute agitation in patients with schizophrenia, bipolar mania, and dementia. Olanzapine appears effective at reducing agitation with a quicker onset of action, while having a lower incidence of dystonia and EPS when compared to haloperidol for the treatment of agitated schizophrenic inpatients.[42] IM olanzapine was shown to be more effective than IM lorazepam at acutely reducing agitation and required less re-dosing in agitated patients with bipolar mania.[43] IM olanzapine was as effective with quicker onset of action compared to IM lorazepam for the treatment of agitated patients with Alzheimer's disease and vascular dementia.[44] A Cochrane review of olanzapine use for agitation remarked that data for the oral formulation is insufficient and essentially remains untested. While each of the above trials was industry-sponsored, they conclude that IM olanzapine has some value in managing acute aggression.[45]

Pooled analysis of QTc data demonstrated a favorable QTc profile for olanzapine in the treatment of schizophrenia, dementia, and bipolar mania.[46] However, studies have showed significantly higher rates of orthostatic hypotension in patients receiving IM olanzapine and ACEP guidelines recommend orthostatic vital signs to be taken if repeated dosing occurs.[19,20,47,48] Of note, olanzapine has been affiliated with a number of fatalities. Cardiopulmonary depression, bradycardia, and hypotension were noted in these cases.[5,20,23] Review of the fatalities demonstrated that patients tended to have significant comorbidities and often received concomitant benzodiazepines or excessive olanzapine dosing. **The combination of a benzodiazepine and olanzapine should not be given concomitantly as a result of this evidence.**[5,20,23]

ASSESSMENT OF SUCCESS

Consensus guidelines endorse calming without sedation or with mild sedation to the point of drowsiness (without sleep) as the most appropriate goal.[5,15,49] This allows the resumption of a more normal patient–physician relationship, the ability to obtain informed consent, and ensures the safety of both the patient and the staff. Such an approach may be associated with fewer injuries, shorter length of stay in the ED, and a quicker transition to the next appropriate level of care.[4] Sleep has been previously treated as an endpoint of chemical restraint. However, it eliminates the potential for patient participation in decision making and is not a guarantee of safety. **The desired therapeutic objective of reduction in agitation or aggression with minimal sedation to allow for a timely assessment and treatment of any medical condition that requires acute intervention.**

If success is not achieved, further dosing or an alternative medication may be required. Though timing of repeated doses depends upon the pharmacokinetics of the medications employed, most of the agents should exert their effects by 30 to 60 minutes. If there is no improvement in agitation or violent behavior, administer another similar or higher dose of the initial medication. **Consider administering lorazepam unless olanzapine was used.** If a combination of an antipsychotic and benzodiazepine was used, this may be repeated. Switching medications is only advised after three to four doses of the medication were given with insufficient effect or two doses of medication had no effect. Switching from one antipsychotic to another antipsychotic is generally not advised due to the different adverse effect profiles of the separate antipsychotics.[5,50] However, if a conventional antipsychotic was administered that resulted in EPS, an atypical antipsychotic may be used if further dosing is needed.[51]

AFTERCARE

After chemical restraint is employed, the staff must continue to interact with the patient in a calm, nonjudgmental, and noncondescending manner. Patients still require a staff member to observe them throughout their ED stay. As with any other ED patient, the issues of elimination and hydration should be anticipated and addressed. If the patient is calm and alert, the degree and frequency of vital sign and cardiopulmonary monitoring is dictated upon medical concerns and the patient's clinical status. If the patient is sedated, they should have frequent cardiac, neurologic, and pulmonary monitoring, as well as frequent vital sign and respiratory assessments. Additionally, initiate aspiration precautions and the changing of positions to prevent pressure sores. The chemically restrained patient must be evaluated for side effects and adverse reactions, such as orthostasis, dystonic reactions, akathisias, EPS, and NMS.

Document the indication and description of the chemical restraint process, the outcome, and any complications. It is also prudent to document the less restrictive alternatives that were considered or performed prior to chemical restraint. If during the interaction with the patient, it is discovered that a specific person(s) is in danger, they should be warned and the local police notified, especially if there is a situation where it is not possible to prevent a violent patient from leaving the ED (Tarasoff v. The Regents of the University of California, Supreme Court of California, 1976).

Psychiatric consultation should be a part of the evaluation of the violent patient. Standard medical clearance should be documented, including resolution of abnormal vital signs, resolution of mental status and behavioral abnormalities, stability of ambulation and mobility, and ability to understand and follow discharge instructions.

ALTERNATIVES

The management of the patient exhibiting dangerous behavior usually requires several techniques that are used sequentially or in concert with other techniques. Though some of these techniques may be used as alternatives, they are generally used in conjunction with chemical restraint.

As stated above, verbal de-escalation is usually the first approach to the violent patient and may be the only intervention necessary. The overarching principle with verbal de-escalation is that

staff convey their professional concern for the well-being of the patient.[11,14,15] Though a full description of verbal de-escalation techniques is not in the scope of this chapter, there are a few critical points to note. During the interaction with a violent patient, use a nonjudgmental, calm, and neutral approach. Give assurance that they will not be harmed and use empathic statements. Healthcare providers should be clear with limits on dangerous and violent behavior and the actions that will be taken to mitigate such behavior and actions. One should avoid lying to or arguing with the patient as these can represent a challenge to the patient to justify violent behavior and actions.[14]

A "show of force" is intended to deter dangerous behavior by having a daunting number of staff and security present in front of the violent patient. Ideally, personnel in the show of force should remain neutral and not provoke the patient, while a single team leader interacts with the patient to de-escalate the behavior.[11,14]

Physical restraint is another alternative that may be employed in place of, or temporarily in conjunction with chemical restraint. Both CMS and TJC have standards for use of physical restraints. The use of physical restraints is discussed in Chapter 194.

THE PREGNANT PATIENT

The safety, efficacy, and fetal outcome of using isolated doses of an antipsychotic medication and/or a benzodiazepine during pregnancy have not been directly studied and there is no strong evidence of any teratogenic effects from their use.[52,53] Benzodiazepines are considered fairly safe to use during pregnancy, as no definitive association between benzodiazepines and teratogenicity has been shown. Given the lack of evidence proving or disproving teratogenicity, the benefits of administering short-term doses of benzodiazepines generally outweigh the risks in emergent situations.[54,55] Though most benzodiazepines cross into breast milk, this is not usually a concern in the agitated ED patient who typically receives short-term therapy.

A consensus panel of expert Emergency Psychiatrists recommends using haloperidol as a first-line agent in the agitated pregnant patient.[30] Successful use of haloperidol and risperidone, with and without lorazepam, have been described.[56] There is limited experience with the use of ziprasidone, olanzapine, and quetiapine in the medical management of the agitated pregnant patient.[56] Atypical antipsychotic use has thus far not been linked to congenital malformations.[56,57]

Monitor women in their second and third trimester for inferior vena cava obstruction if chemically restrained and placed in the supine position. Place them in the left lateral decubitus position. They may be at an increased risk of aspiration due to lower esophageal sphincter relaxation during pregnancy. The pregnant patient's respiratory status must be carefully monitored. The normal increase in respiratory rate and decrease in tidal volume can be effected if the patient is oversedated or somnolent.

THE PEDIATRIC PATIENT

In general, chemical restraint of the pediatric patient should follow the overarching themes of chemical restraint in the adult. Every reasonable attempt possible should be made to obtain parental consent for the medical management of a violent pediatric patient. If an emergent situation precludes parental consent, further communication attempts and early discussion with the patient's parent(s) must be pursued. The child should be offered the option of taking the medication orally prior to the IM or IV routes of administration. This may help instill trust and help engage a likely frightened child, as even the idea of a needle may increase the agitation of a child and family members.[58–60] If minors are discharged, they should be in the care of a responsible adult who understands and agrees with the discharge plan.

TABLE 195-5 Medications Used for the Chemical Restraint of Pediatric Patients[58,60]

Drug	Formulation	Dose
Lorazepam	PO/IM/IV	0.05–0.1 mg/kg/dose (max 2 mg/dose)
Diazepam	PO/IM/IV	0.04–0.2 mg/kg/dose (max 10 mg/dose)
Haloperidol	PO/IM/IV	0.025–0.075 mg/kg/dose (max 5 mg/dose)
Risperidone	PO	0.25 mg (school age) to 2 mg (late adolescent)
Olanzapine	PO/IM	2.5 mg (school age) to 10 mg (late adolescent)
Diphenhydramine	PO/IM/IV	1 mg/kg/dose (max 50 mg)

The agents most commonly used for the chemical restraint of the pediatric patient are lorazepam, haloperidol, risperidone, and antihistamines.[5,61] Intranasal administration of midazolam has been studied for conscious sedation, but not for chemical restraint. Thus, use of intranasal midazolam cannot be recommended until there is further experience with this route of administration.[62,63] Benzodiazepines may cause paradoxical disinhibition, in which there is increased agitation. This is more common in children with developmental delay and organic brain syndromes.[60] For children with established attention deficit disorder, there is no data to support the use of stimulants to control behavior.[64]

The use of haloperidol and droperidol in pediatric patients should follow the same guidelines as in adults and are viewed as generally safe in children. Atypical antipsychotic use in pediatric patients is becoming more frequent. Olanzapine is approved for pediatric use and available in IM and orally disintegrating tablet form (**Table 195-5**). Risperidone is an effective and safe alternative.[64] Experience with ziprasidone use in the ED for pediatric patients is extremely limited and there is no available pediatric dosing for this medication. Diphenhydramine can be an effective agent due to its sedative effect. Extrapyramidal side effects may be treated with diphenhydramine (1.25 mg/kg/dose IV or IM) or benztropine (0.02 to 0.05 mg/kg/dose IV or IM).

SUMMARY

Acute agitation and violent behavior may be due to a variety of medical and psychiatric etiologies and is not an uncommon finding in ED patients. At times it may be appropriate to use pharmacologic intervention to calm the agitated patient in order to facilitate the appropriate diagnostic and therapeutic workup while ensuring patient and staff safety. Typical antipsychotics and benzodiazepines have been the traditional options, but the use of atypical antipsychotics is expanding with the development of new rapid-acting formulations with less adverse effects. Given the medical, ethical, and legal complexities involved in the treatment of acute agitation, it is advisable to review CMS, TJC, and hospital policies regarding chemical restraint. Emergency Physicians should be aware of the indications, as well as the risks and benefits, of chemical restraint.

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